LANDSLIDES IN JAPAN

The Japan Society of Landslide
National Conference of Landslide Control

1988

Preface

In Japan landslides were begun to study scientifically from about 1948. With gradual progress made in investigation and control technologies, the Japan Landslide Society was established in 1963. Since the Society's firm foundation was formed based on comprehensive studies, consisting of geology, topography, soil mechanics, geophysics, hydrology and sand erosion control, the studies have made remarkable progress and at the same time investigation and control methods as well as prediction methods for landslides have achieved dramatic growth in every field.

In 1972, the Society published "Landslides in Japan" elucidating the behavior of landslides, including investigation and control methods, as well as case studies of well-known landslides in Japan.

In response to favorable criticism, the 2nd edition was published in 1977, and the 3rd and revised edition in 1980 which introduced new technologies. It is our great pleasure that the 4th edition elucidating the latest status on landslides is published in 1988.

We are precisely in the age of internationalization and landslide studies are no exceptional problem. The Working Group for mass movement and landslide of ISEG (International Society of Engineering Geology), ISL (International Symposium on Landslides) in ISME (International Conference on Soil Mechanics and Foundation Engineering), and ICFL (International Conference and Field Workshop) are performing their continuous activities to provide opportunities for exchange of ideas and information among researchers around the world and for cooperation in landslide studies. This morning, we received a newsletter from a new group called ILRG (International Landslide Research Group). Our Society will also publish an international newsletter "Landslide News" in the future.

In this age of internationalization, it is of great significance that "Landslides in Japan" is published in English.

Finally, we wish to express our sincere thanks to the chief editor and his editorial staff who generously gave their time and great efforts for this edition, and to those persons who contributed their cooperation on our behalf and to the Japan Landslide Control Council who willingly agreed to joint publication.

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1. Introduction

The Japanese archipelago consists of narrow arcuate islands extending approximately 3,000 km with a total area of about 378,000 km^2. Almost 75 percent of the national land is covered with steep and complex topographical areas. Further, the four plates of Pacific Plate, Eurasia, the Philippine Sea and North America meet here, resulting in very active tectonic movements. Thus, the islands are always exposed to the risk of large-scale earthquakes and have 77 active volcanos, which account for about 10% of those in the world, with constant volcanic activity.

The majority of the mountainous areas exposed to such tectonic movements is dominated by a very fragile geological structure such as folded mountains, volcanos and fractured zones.

In addition, the Japanese archipelago is located on the border between the Eurasia continent and the Pacific ocean, and air masses in both regions affect the meteorological conditions of the Japanese land mass. The frontal activities become very active in the rainy season from early June to mid-July with resultant frequent heavy rain. During June to October, several typhoons often frequent Japan and its surroundings causing rainstorms and heavy rain by stimulating the front. In winter, very cold air flows into Japan from Siberia, bringing heavy snow along the Sea of Japan. Annual average precipitation reaches almost 1,800 mm. Most of the precipitation concentrates in snow season, rainy season and typhoon season. Thus, natural conditions such as fragile geological structure, steep topography and intensive rainfall initiate the occurrence of landslide-related disasters.

At the same time, the Japanese population of nearly 120 million (1985) and its property are concentrated in narrow alluvial plains accounting for only about one fourth of the national land. The highly congested economic society has been developed on these small flood plains, and thus so many areas having leading economic functions have been exposed to the high risks of natural disasters including landslide-related disasters.

The Japanese economic society experienced a drastic change after the Second World War. During the decade after the war (1945 to 1955), the aim of the restoration and conservation of the national land devastated by the war was mainly executed. Then, during the period from 1956 to 1970 when the remarkably high economic growth was achieved, establishment of the industrial foundation such as traffic communication facilities including highway networks and construction of dams for water resources development, was focused on aiming at coping with the shortage of social capital hindering the advancing economic industrial activities and increasing the efficiency in terms of macro economy. Since 1970, however, the strain of the vigorous economic growth manifested, which turned the stress into improvement of the living environment which has been relatively ignored. The highly developed land utilization associated with the high economic growth accelerated the accumulation of the property in these alluvial plains which are below river water stage during flooding, and mountainous areas and hilly areas have been highly developed for housing and industrial use. In recent years, the rising land price in urban areas has further accelerated the urban sprawl. The resultant progress in development and land utilization in potentially dangerous areas has lead to the more frequent occurrence of various natural disasters such as landslide-related disasters. Namely, since the subject areas to be conserved are approaching dangerous areas in recent years, an increase in damage caused by sediment-related disasters including debris flows, landslides and slope failures has occurred. The Tamanoki Landslide in Omi Town, Niigata Prefecture in February 1985 (10 killed, 7 houses totally or partially destroyed) and the Jizukiyama Landslide in Nagano City, Nagano Prefecture in July 1985 are two examples. Thus, the public has become more concerned about sediment-related disasters including landslide. As a result, in spite of the low economic growth, preventive technology and projects have been more and more demanded. In addition, the frequent occurrence of landslide disasters caused by large-scale civil engineering works associated themselves with dam, housing and road constructions has resulted in a strong demand for preparation of improved hazard maps and techniques for prediction of landslide initiation.

In Japan, it is assumed that response to the landslide phenomenon began around the era when the Japanese people settled down to agriculture, but no clear record is known. However, the fact that the names of "Yamanuke" and "Tsue" recorded in ancient documents can be found now in landslide areas suggests an awareness of the landslide phenomenon by people from very ancient times.

Slopes in landslide areas which are gently inclined and have abundant ground water have been utilized for communities, paddy rice production and farming. For instance, a far-stretching paddy field in Nakakubiki Area, Niigata Prefecture is located in a landslide region. Another example is in Iya, Tokushima Prefecture, where small communities are formed on little gentle slopes in the steep mountainous area. In these areas, it is assumed that the people suffered from frequent landslide disasters. The oldest landslide disaster recorded in a document dates back to the Kamakura era. Since then, it is recorded that landslide disasters took place frequently in Hokuriku Region which was the center of rice production resulting in serious damage to houses, temples and cultivated lands. Preventive measures against landslide at that time include piling of pine logs to protect ridges in paddy fields and small-scale torrent works, but they had no way to cope with large landslides except by just praying to God. The legend of human sacrifice transmitted in Sarukuyoji in Itakura Town, Nakakubiki-gun, Niigata Prefecture, supports this legend, and human bones and 800-year-old coins were accidentally discovered in 1937. This proved the legend.

Thus, people living in landslide areas have tolerated landslide hazards for many years, but they devised various methods to predict landslides based on animal behavior, vegetation conditions and meteorology from their long experience. There are many traditions helpful even now in various areas; special attention being required after heavy rain, more frequent lanslides after a tremendous snowfall following a drought or in the next year after a less rainy year, the possible occurrence of a landslide when bamboo blooms, and the possible occurrence of a landslide when snakes appear after a heavy rain.

Thus, people could take only a passive attitude towards the landslide phenomenon mainly based on their own experiences. Studies for scientific explanation of landslide phenomenon, mechanism and landslide preventive measures were started after enactment "the Landslide Prevention Law" in 1958. Before this time, landslide prevention was traditionally carried out as a part of erosion control projects in accordance with the Sabo Law and conservation facility projects in accordance with the Forest Law and projects in accordance with agricultural land conservation projects, with fairly good success. Nevertheless, it was needed to unite organically measures to prevent the landslide phenomenon which could not be coped with by these projects. For this reason, the Landslide Prevention Law was promulgated, which intends to optimize plans concerning landslide prevention projects and their implementation and to establish immediately drastic measures to prevent landslide, such as strict control over any acts harmful to landslide prevention and effective and appropriate actions for house removal and improvement of agricultural facilities within landslide areas in order to prevent or alleviate any possible damages. Currently, landslide projects in accordance with this law amount to approximately 66.5 billion yen (468 million US dollars, 1986).

It is expected that changes in structures of urban area technical innovation, maturation of the information-oriented society, and formation of an ageing society will further proceed towards the 21th century. Thus, it is required to promote landslide prevention projects, intensify disaster prevention technologies and systems and develop science and technology concerning landslide in order to conserve the national land and assure the security of the people.

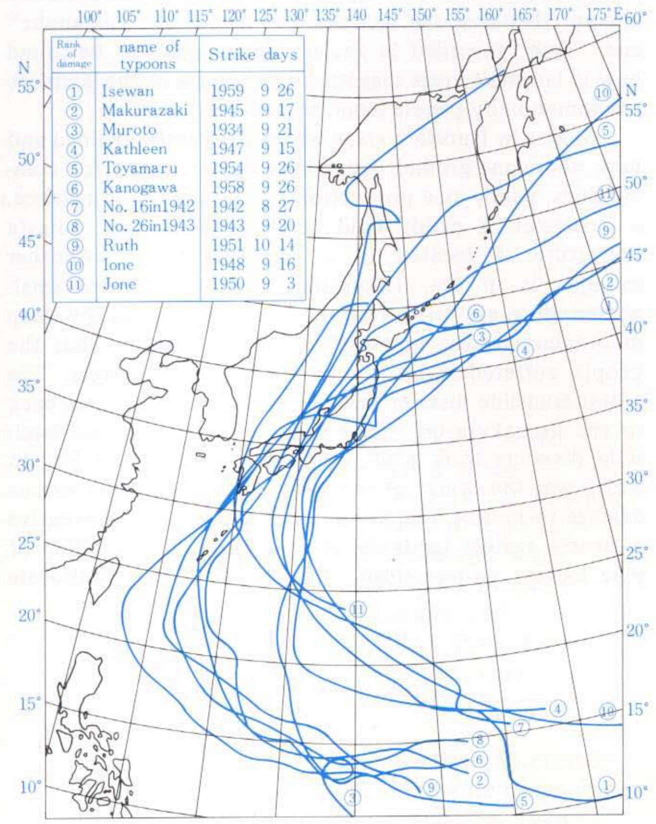


Fig. 1-1 Course of typhoons

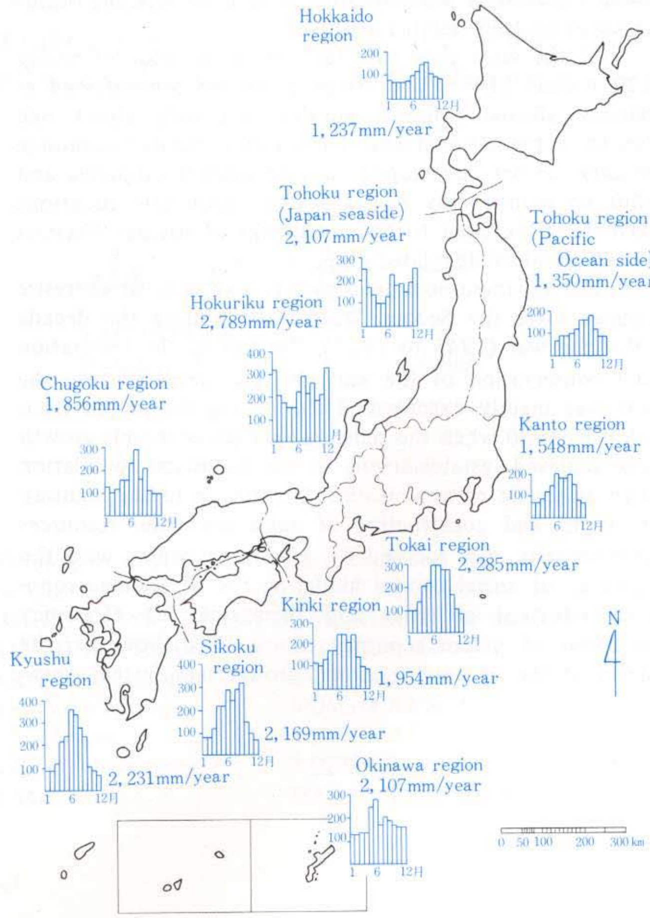


Fig. 1-2 Regroval hyetgraph of precipitation

2. Landslides and Slope Failures in Japan

Both landslides (Jisuberi) and slope failures (Hokai) are two forms of earth collapse in which the slope of a hillside or part of the face of slope loses its equilibrium state and moves downward after being subjected to the action of a provoking cause such as groundwater. These are natural phenomena of similar kinds, and it is difficult to define the landslides and failures by clearly separating them from each other, but they have several characteristics peculiar to each form and thus are being handled as different kinds in Japan.

Typical examples in Japan of features for distinguishing landslide from slope failure are shown in Table 2.1. The difference between them is clarified in this Table mainly based on primary cause such as geology as well as the form of motion. A landslide has a large scale and moves slowly on a relatively gentle slope, so that its sliding mass is little disturbed. On the other hand, the failure has a small scale and occurs on a steep slope and thus its moving speed is high and its sliding mass is considerably disturbed.

Table 2-1 Difference between landslide and slope failure (slope failures)

	Landslides	Slope Failures
Geology	Occur in places with particular geology or geological formation.	Slightly related to geology.
Soils	Are mainly active on cohesive soil such as slip surface.	Frequently occur even in sandy soils (decomposed granite, top soil, Shirasu, etc.)
Topography	Occur on gentle slopes of 5° to 20° and often have plateaushaped topography in the upper portions.	Frequently occur on the slopes steeper than 30°
Situation of activities	Continuous, or repetitive occurrences.	Occur suddenly.
Moving velocity	Speed is normally low at 0.01 to 10 mm/day.	Extremely high speed of more than 10 mm/day.
Masses	Have little disturbed masses and often move while maintaining original form.	Have greatly disturbed mass.
Provoking causes	Are greatly affected by groundwater.	Are affected by rainfall intensity during rainfall.
Scale	Have a large scale between 1 and 100 ha.	Have a small scale. Average volume of collapsed material is about 440 m^3 (18.8 m wide, 21.1 m long, 1.6 m deep).
Symptom	Have cracks, depressions, upheavals, groundwater fluctuation, etc. before the occurrence.	Have few symptoms and suddenly slip down.
Gradient	10° to 25°	35° to 60°

The scale of landslides is widely varied from extremely large ones to small ones close to that of slope failure, and one of factors directly expressing its features is the gradient of ground surface. As shown in Fig. 2-1, the gradients of landslides are concentrated in the range of relatively gentle slopes between 5° to 20°. On the other hand, slope failures have scales and shapes, each of which are close to each other, and their dispersion is small. Generally, a typical failure has a small scale with a depth of 1 to 2 m on a short slope having a slope height of 10 to 30 m and a steep gradient of 30° to 60°. Therefore, the form of movement of the failure is naturally different from that of a landslide having, for example, a slope length of 100 to 200 m and a depth of 20 m.

The above is also apparent from the relation with rainfall as the provoking cause. Landslides involving large volumes of earth often occur after the end of heavy rains rather than in the middle of heavy rains. In contrast, slope failures having extremely quick motions frequently occur before or after the rainfall peak.

Landslides and slope failures that have occurred in Japan are classified and tabulated based on the scale and gradient in Fig. 2.1 (A) and (B). If the intersection between the cumulative curves of both can be assumed as the boundary point of classification, then the boundary point

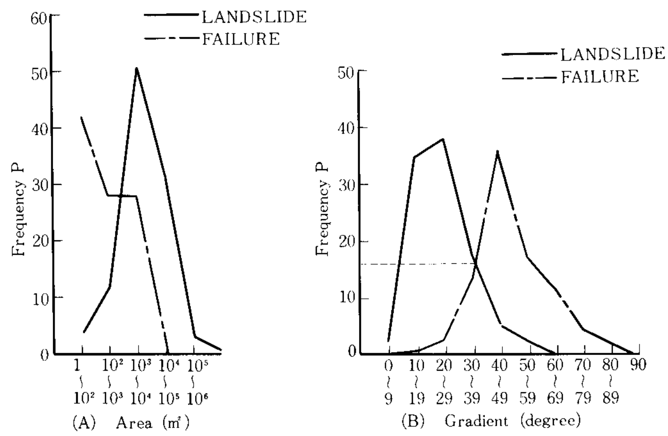


Fig. 2-1 Topographic characteristic of landslide and failure

will have an area of several hundred square meters and a gradient of 30°. Of course, there is an intermediate portion which cannot be clearly classified into any particular one of them. Generally speaking, landslides are characteristic in that the area is larger than 1,000 square meters and the gradient is gentler than 30°

3. Geology and Geomorphology in Landslides

The Japanese islands are situated on the border zone between the Eurasian continent and the Pacific ocean, and are located on the subduction zone of the Pacific ocean plate and the Phillippine Sea plate beneath the continental crust, according to ocean-floor spreading hypothesis. Therefore, recent geodynamic phenomena, such as seismic activity, volcanic activity, recent crustal movement and fracture patterns, are altogether concerned with the subduction zone.

In the Japanese islands, the recent tendency of crustal movements is continuous upheaval in mountainous regions, and in contarst, subsidence in alluvial plains and intramountain basins. In other words, the topographical arrangement of mountains and intra-mountain basins, hilly highlands, terraces, and alluvial plains well coincides with Quaternary crustal movements. Consequently, plutonic and metamorphic rock masses, which formed genetically in deeper portion below the surface, crop out and constitute the mountainous regions. Also, peculiar characteristics in structure, texture and fracture systems which are principally possessed according to their genesis are emphasized owing to releasing from underground confined pressure, and turned into open discontinuities such as joint, foliation and fissure. Differential weathering and erosion are progressive at and near the surface of each rock body, and structural relief is formed in mountainous regions. Continuous increase of relief and downward erosion and successive weakenings of rock masses by weathering tend to become unstable on mountain slopes. At the final stage, large-scale down and outward slope movement occur by a break of equibrium, which are recognized as the term of landslides, slope failures, avalanches and other mass movements.

The following yearly cycles of precipitation are recognized in Japanese islands, namely: the "Bai-u" front in June, and transient but heavy rainfall by typhoon in summer-autumn. Snow-melt water in April-May is the characteristic on the continental side of the northern Japanese islands. Therefore, such precipitations are the direct cause of slope movements. Groundwater, which is constantly recharged into the ground, accelerate mechanical and chemical weathering as indirect but important causes of slope movements.

The geological constitution of the Japanese islands are complicated because the islands are situated in a mobile belt of the world and subduction zone of ocean plate beneath the continental plate as shown in Fig. 3-1. Based on detailed studies of geological succession and depositional environment of sedimentary sequences, igneous activities and the affected crustal movements, the following five units are distinguished. They differ from each other in physical, mechanical, hydrogeological and engineering geological characteristics and geomorphological features, especially the nature of mass movements as one of the recent geodynamic processes or geomorphological development. Each unit is subdivided into a few subunits as shown in Fig. 3-2, based on the engineering geological characteristics such as consolidation, spacing of open discontinuities, etc..

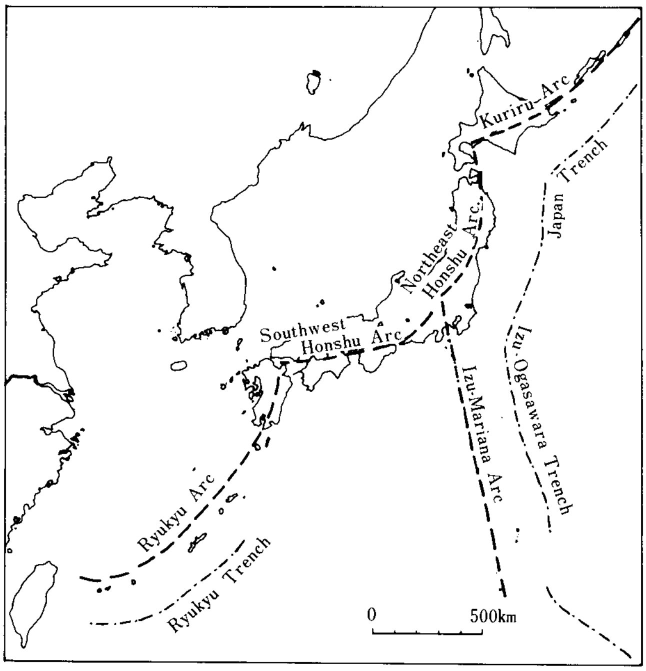


Fig. 3-1 Trenches and island arcs around the Japanese Islands

Unit 1: Sequences of marine clastic sediments, submarine volcanic rocks of Paleozoic ~ Middle Mesozoic; Lithofacies of the sequences were formerly called as "eugeosynclinal facies". They are composed predominantly of pelitic rocks, siliceous rocks such as chert, submarine volcanic rocks and associated igneous rocks such as metagabbro, metabasalt which are called generally greenstones, and serpentine. Limestones are intercalated as lenticular bodies and limited in distribution. High-pressure metamorphic belts, low-pressure regional metamorphic belts and weakly or non-metamorphosed belts are distinguished. The belts trend parallel to longitudinal axis of island arcs, and subdivided into tectonic provinces or terranes based on geological age of sedimentary rocks and metamorphism affected. Although grade of metamorphism shows gradual changes fundamentally, each provinces are in contact by tectonic line or narrow tectonic belts. The rock constitute mountainous regions which are characterized geomorphologically by structural relief and accordance of summit level. On the engineering geological point of view, discontinuities such as texture, fracture, foliation and schistosity are predominant. The unit is subdivided into the following three subunits as shown in Fig. 3-1.

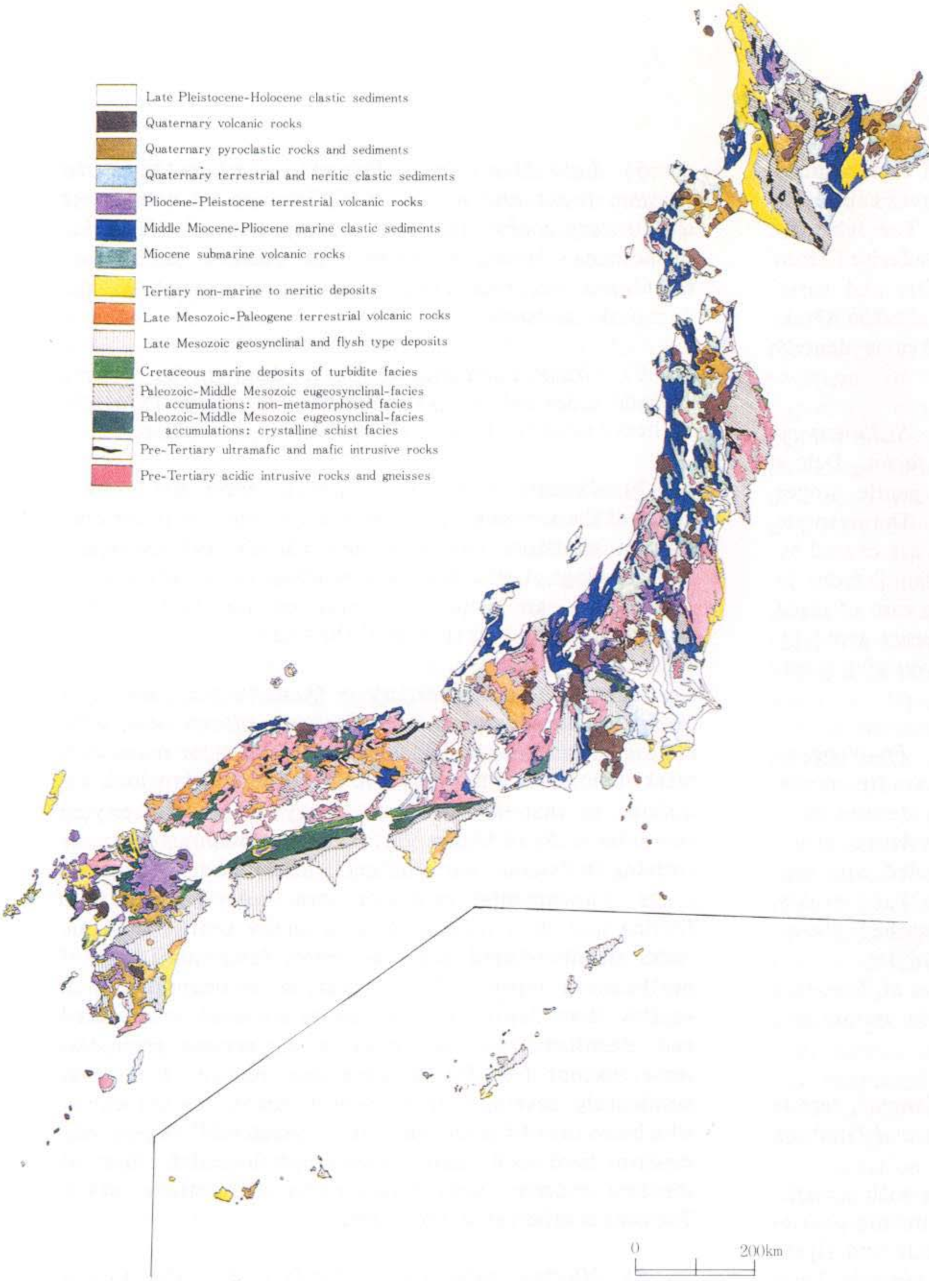


Fig. 3-2 Major engineering geological division of Japan

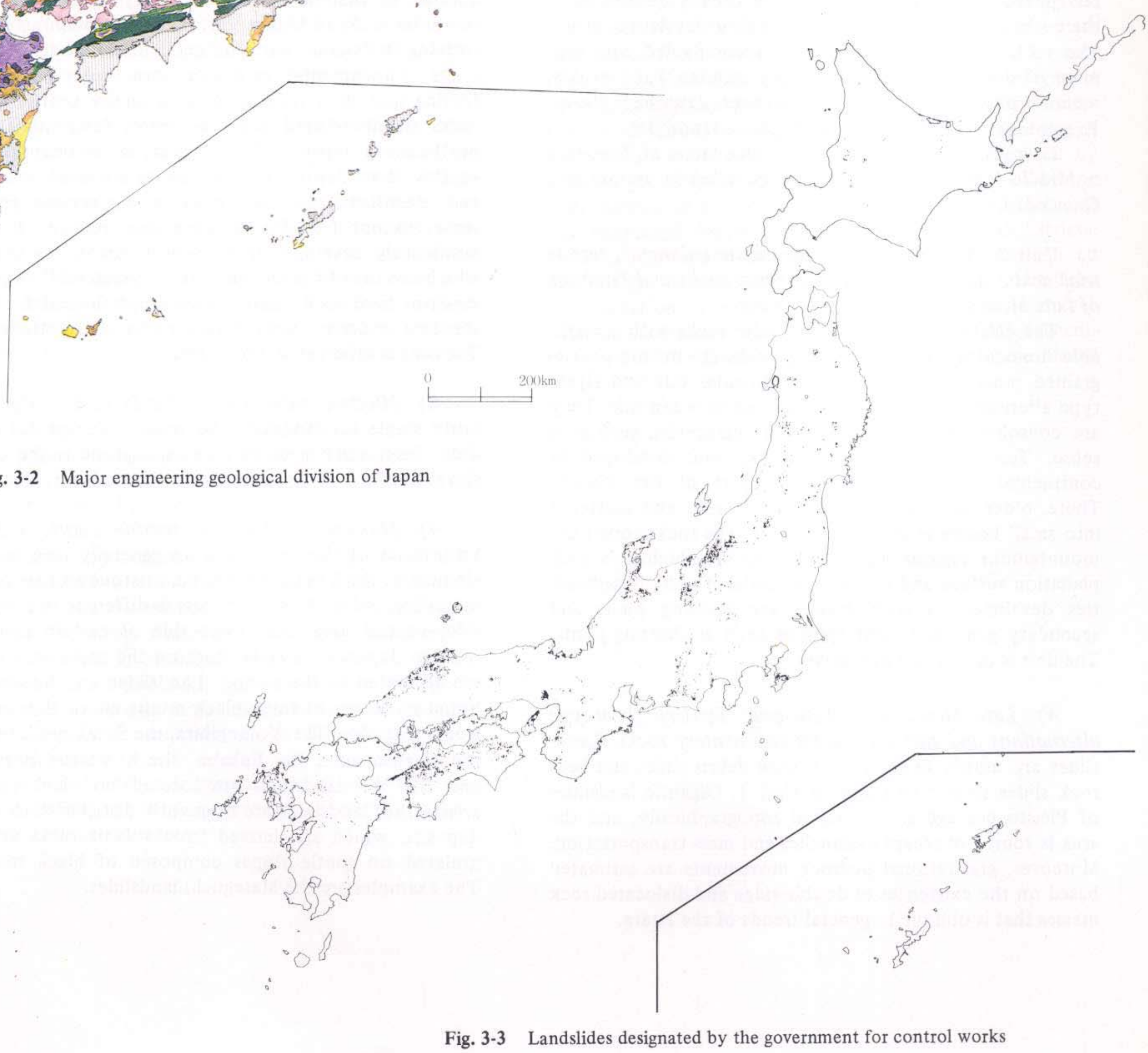


Fig. 3-3 Landslides designated by the government for control works

1) *Paleozoic ~ Middle Mesozoic Sedimentary Sequences, Crystalline schist facies:* Debris creeps and slow debris slides are the most typical landslides. The debris or colluvium on gentle slopes are in most cases derived from weathered crystalline schist, especially pelitic and basic. The examples illustrated in this booklet are the Ozaki and the Maruyama landslides. Landslide area is densely distributed pelitic and basic schist.

2) *Paleozoic ~ Middle Mesozoic Sedimentary Sequences, weakly or non-metamorphosed facies:* Debris creeps and slow debris slides occur on gentle slopes although the distribution is relatively sparse. The example is the Tosaki landslide. Rapid bedrock slides are caused by heavy rainfalls brought by typhoon and "Bai-u" front in June-July, such as the Wada landslide. In the case of rapid bedrock slide, the surface of rupture is appears generally along the boundaries between clayslate and overlying chert, limestone or sandstone.

3) *Serpentine and greenstone of Pre-Neogene Tertiary:* Debris creeps and slow debris slides are frequently recognized in the areas. The debris is usually derived from the rocks and overlie on the surrounding clayslate or shale. The rocks comprise tectonic belt accompanied with segment of sheared igneous rocks (Pre-Cambrian?) and weakly metamorphosed sedimentary sequences described above. Examples are the Choja and the Higashio landslides.

Low pressure regional metamorphic facies of Paleozoic ~ Middle Mesozoic sequences are included in granite and Gneiss of Unit 2.

Unit 2: *Neritic—non-marine clastic sediments, terrestrial acidic and intermediate volcanic rocks and Granites of Late Mesozoic ~ Paleogene Tertiary:*

The clastic rocks overlie the older rocks with remarkable nonconformity. Sedimentary rocks are mainly coarse-grained molasse-type facies in continental side and flysh-type alternation of shale and sandstone in ocean side. They are consolidated and hard rocks in engineering geological sense. Terrestrial volcanic rocks are well developed in continental side of southwestern part of the islands. There, older rocks are frequently separated and scattered into small bodies as shown in Fig. 3-2. The rocks constitute mountainous regions with steep slopes or highlands with planation surface and enclosed meander. Open discontinuities developed in rock masses are bedding plane and secondary generated joint systems such as sheeting joints. The unit is usbdivided as follows.

4) *Late Mesozoic ~ Paleogene Tertiary flysh-type alternations and turbidite facies sedimentary rocks:* Landslides are mostly debris creeps, slow debris slides and bedrock slides similar to those of Unit 1. Gigantic landslides of Pleistocene age are estimated topographically, and the area is source of recent avalanches and mass transportation. Moreover, gravitational bedrock movements are estimated based on the existences of double-ridge and dislocated rock masses that is oblique to general trends of the strata.

5) *Late Mesozoic ~ Paleogene Tertiary terrestrial volcanic rocks and underlain shallow sea or non-marine sedimentary rocks:* The area is fairly stable for landslide phenomena. However, debris and bedrock slides have sometimes occurred along fracture zones such as the Tamanoki landslide.

6) *Granites and gneisses:* Severe disasters due to rapid surficial slides and debris flows have been caused frequently by heavy rainfalls. Large-scale landslides are very rare.

7) *Tertiary non-marine—neritic sediments:* Lithofacies of the sediments are so-called cyclothem-type alternation of sandstone and shale intercalating coal seams and tuff. Geological structure is monoclinal or slightly folded. Tuff seams are important cause of slip surface. The Hirayama landslide is typical of the area.

Unit 3: *Neogene Tertiary ~ Quaternary sequences of marine clastic sediments and submarine volcanic rocks with associated plutonic rocks:* They cover the older rocks with marked nonconformity and show general trends which are oblique to that of older rocks. They distribute overlying the older rocks in higher portion of mountainous region or forming hilly-land surrounding the mountains of older rocks. Fundamental geological structure of the unit is folding and their inclination is generally gentle. Volcanic rocks are distributed along the central longitudinal axis of northeastern Japan and the coast of continental side in southwestern Japan. The sediments are semi-consolidated and classified into soft rocks in engineering geological sense, except for altered submarine volcanic rocks predominantly developed in the lower part of the sequences, which are called "green tuff". The "green tuff" is generally massive, hard and jointed. Geomorphological features of the area underlain sedimentary rocks is essentially cuesta. The unit is subdivided into as follows:

8) *Miocene submarine volcanic rocks:* The area is fairly stable for landslide phenomena, except for surficial slide. Intercalation of tuff and mudstone is the cause of slip surface.

9) *Miocene ~ Pliocene marine clastic sediments.* Lithofacies of the sediments are generally thin basal conglomerate, thick black mudstone, siltstone and sandstone in ascending order. Total thickness is different in continental side, central area and ocean side of eastern and southwestern Japanese islands, because the sedimentary basins are separated in the period. Landslides are densely distributed on slopes of thick black mudstone or thin intercalations of tuffite. The Yomogihira, the Sarukuyoji, the Baba, the Chausuyama, the Fukami, the Kosei the Haginomine and the Yui landslides are located on black mudstone area. Other landslides are frequently distributed in colluvial deposits, which are derived from volanic rocks and accumulated on gentle slopes composed of black mudstone. The examples are the Maseguchi landslides.

10) *Miocene ~ Pliocene terrestrial volcanic rocks:* Lithofacies are mainly basic lavas with intercalations of tuff-breccia, tuff and conglomerate. As the rocks are very porous and permeable, they hold groundwater which accelerates slope movement. The rocks are distributed forming mesa with surrounding very steep slopes. Landslides are densely distributed in colluvial deposits which are piled upon surrounding gentle slopes underlain by older rocks. Rapid bedrock slides are caused by heavy rainfalls, as described in Nagasaki district.

Unit 4: *Shallow sea or non-marine sediments and terrestrial volcanic rocks and pyroclastic sediments of Quaternary period:* They cover older rocks with nonconformity, and forms hilly-highlands, lava plateaus and terraces. The sediments are semi-consolidated or unconsolidated. In general cases, most of the clastic sediments are consealed below alluvial plain or terrace. Therefore, uppermost part of clastic sediments crop out at the margin of terrace, or lowermost part crops along the margin of Quaternary sedimentary basin. Lavas, welded tuffs, pumice-fall deposits, pumice-flow deposits and volcanic mud-flow deposits are the principal lithofacies of terrestrial volcanic sediments. The sediments are not affected by crustal movements except for those along the fracture zone of Quaternary period. The unit is subdivided as follows:

11) *Quaternary terrestrial and neritic clastic sediments:* The sediments are chiefly semi-consolidated or unconsolidated layer of gravel, sand with occasional silt and clay intercalating lignite seams. In some areas, they are covered by weathered volcanic ashes. Landslides are sporadical and small in size as described in the Ogoto-Kushibayashi landslide. Surficial or shallow slides and earthfalls are caused by heavy rainfalls. Prediction of rapid slope failures are present problems, because recently urbanized districts are generally sprawling towards the area.

12) *Quaternary pyroclastic rocks and sediments:* They consist of terrestrial welded tuff, pyroclastic deposits. They are very permeable and unconsolidated. They forms lava plateau or terraces with nearly vertical cliffs. Consequently, earthfalls are caused by heavy rainfalls.

13) *Quaternary volcanic rocks and associated volcanic mud-flow deposits:* There are many active and dormant volcanoes in the Japanese islands. Some part of volcanic rocks constituting the steep stratovolcanoes have been severely altered by pneumatic and hydrothermal activities. Under the condition combined with increasing vapor and pore-water pressure, rapid and large landslides occur and change into violent avalanches and debris flows rushing down along valleys. Earthquake, heavy rainfall and snow-melt water are examples of landslide trigger. Examples of earthquake-induced landslides are those occurring in the south-eastern foot of the Ontake volcano.

Unit 5: *Late Pleistocene ~ Holocene shallow sea deposits and the other terrestrial clastic sediments, and volcanic rocks formed by Holocene volcanic activities:* Volcanic rocks are involved with subunit 13 of unit 4.

14) *Shallow sea or non-marine deposits which filled the valley of Worm-maximum age and non-marine clastic sediments of intra-mountain basins at the same age:* The deposits are usually called "alluvium" in Japan. Their depositional surface is plains where the greater part of cities, agricultural fields and industrial districts have been developed recently. Landslide phenomena is failures in artificial fills on the plain.

Noticable deposits are frequently found on gentle slopes in mountainous regions and hilly lands. Generally, they are omitted on common geological maps in Japan, but geomorphologically estimated as colluvium, detritus, mudflow deposits and the other products from gigantic mass movements. The above-mentioned deposits and topographic features are called "fossil landslides" or "old landslides". For fossil landslides, the source area, which is surrounded by main and lateral scarp with horseshoe-shape, is well preserved for a long time after the occurrence. Initial features of fossil landslide are gradually destroyed by erosion. Dislocated rock masses are weakened, disintegrated by weathering and gradually eroded away. In this connection, most landslides of present time are interior moving of sliding mass or derived deposits which are recognized by detailed geomorphological study. Recently, maps showing distributions of the above-mentioned topographic features and estimated deposits are published in several districts. Fossil landslides are considered to occur in Pleisocene based on ^{14}C age determination and other evidence, caused by instabilization of bedrock in the period of climatic change between interglacier and glacier age. Most landslides recently found in the Japanese islands occur within these "fossil landslides".

4. Landslide Investigation and Prediction

First, Landslide Investigation states how the investigations for supplying information required when formulating landslide prevention plans are being carried out in this country. Then, the investigations for predicting the landslide occurrence will be explained. Geological and topographic approaches are being taken for predicting the places and scales of landslide occurrence in this country while the method based on instrumentation has been developed for predicting the failure time of landslides.

Chapter 1 Landslide Investigation

The investigation required for formulating a landslide prevention plan is normally made through several steps such as preliminary survey, reconnaissance and detailed investigation. In the preliminary survey, general information is acquired by gathering topographic maps, air photos and relevant papers. Upon completion of the preliminary survey, the reconnaissance is started in the field, in which it is important to comprehend the characteristics of landslide areas by means of observation and additionally to begin to formulate a landslide prevention plan that will be finally prepared in the stage of detailed investigation. Shown in Table 1 is the arrangement of the survey items for the detailed investigation. Results of these surveys are analyzed and judged in order to clarify the various characteristics of landslide blocks to be surveyed and the causes and mechanism of their motions and also to obtain numerical data necessary for slope stability analysis. These are the informations required when formulating the landslide prevention plan.

Methods of Finding Overall Characteristics of Landslide Areas

1. Air-photo Interpretation and Remote Sensing

Air-photo interpretation is one of the most important techniques in landslide survey.

It is used to understand geomorphic features of a wide area in detail, and allows us to assume the mechanism of the formation of the slope and the trend of possible changes, to determine a moving or moved area for each unit, and to prepare a landslide distribution map. Very elaborate aerial photograph interpretation can lead to the discovery of cracks, uphill-facing scarplets and swellings on the slope which are premonitory phenomena of landslide, and in some cases it can make the identification of the moving area possible even in the initial stage of the landslide activity. A comparison between aerial photos before and after the initiation of the change allows us to understand quantitatively the ground surface deformation. With aerial photos at various stages, then we can trace the developmental process of the landslide.

The Government of Japan repeatedly takes air-photos with a scale of 1/10,000 to 1/40,000, and anyone can purchase them. And thus air-photo interpretation is made very often. In the landslide investigation, air photos with larger scales are taken and utilized occasionally.

Remote sensing by artificial satellite or aircraft is also used recently in the landslide investigation. Especially, thermal-infrared imagery can express mainly water conditions near ground surface and has the possibility of finding the places where landslides are likely to occur and determining the progress of landslide.

Table 4-1 Survey items and methods in landslide investigation and the frequency of their use

Survey items	Survey method	Frequency of use
Survey for roughly determining the properties of landslide areas	Air photo interpretation and remote sensing	B
	Underground temperature	C
	Seismic prospecting	B
	Natural radioactivity prospecting	C
	Electric prospecting	C
	Electric logging	C
Surveying ground surface displacement	Surveying on the ground	A
	Aerial photogrammetry	B
	Measurement by extensometer	A
	Measurement by tiltmeter	A
Surveying displacement in the earth & slip surface	Drilling	A
	Measurement by pipe strain gauge	A
	Measurement by inclinometer	A
	Measurement by movement meter	C
Surveying ground water pressure acting on slip surface	Groundwater level measurement	A
	Pore water pressure measurement	C
Surveying ground water & bearing	Water quality analysis	C
	Groudwater tracing	B
	Groundwater prospecting	A
	Pumping test	C
	Groundwater simulation	C
Soil test	Physical test	A
	Strength test	A
Hydrological test	Precipitation observation	A
	Snow cover observation	B
	Thaw observation	C

Frequency: A: Used at al mostall sites. B: Used at most sites. C: Used where required

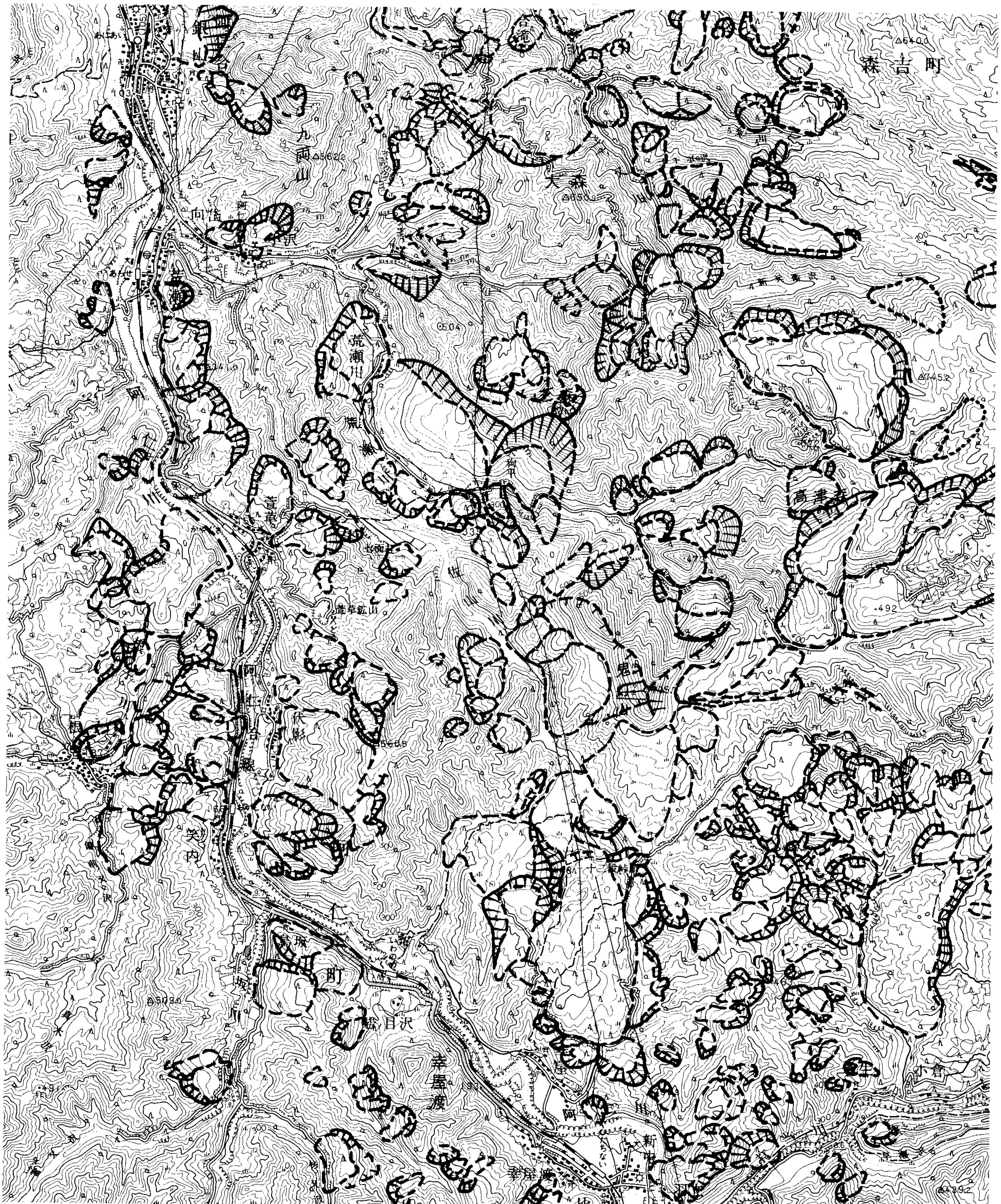


Fig. 4-1 Landslide form distribution map based on air photos

2. *Underground Temperature Survey*

Underground temperature near groundwater veins tends to decrease in summer and increase in winter compared to their adjacent area. Therefore, there is a possibility of estimating the location and scale of groundwater veins, that may affect the outbreak of landslide, based on 1-m deep underground temperature surveyed by thermister thermometer.

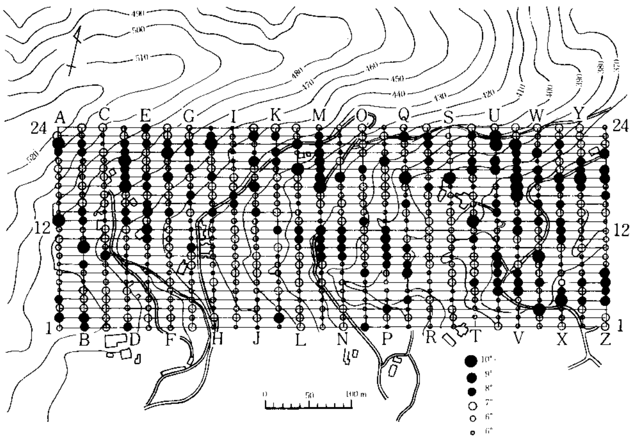


Fig. 4-2 Distribution of 1-m deep underground temperature

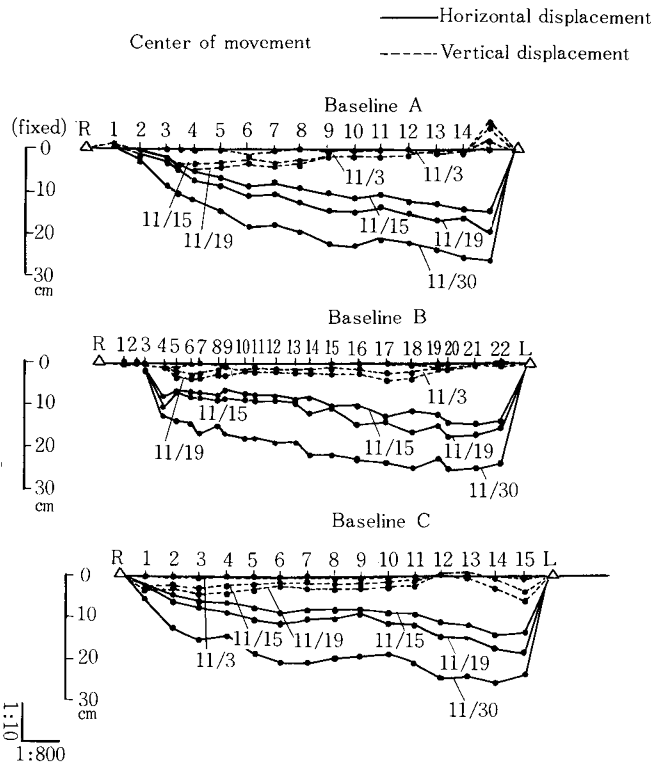


Fig. 4-3 Ground surface movement by offset survey (horizontal and vertical displacement)

3. *Seismic Prospecting*

In the seismic prospecting, P-wave refraction method is used, but recently S-wave refraction method is more often added for more accurately classifying velocity layers. Also, shallow layer refraction method has been developed for clarifying the strata composition of landslide including the location of slip surface.

4. *Natural Radioactivity Prospecting*

The natural radioactivity prospecting is for clarifying the presence of faults or fissures related to landslide by measuring radioactive gases rising up from the underground.

5. *Electric Prospecting*

The electric prospecting is for checking the underground conditions by utilizing the difference in electric properties of strata or rocks, and specific resistance method is used in the landslide investigation. Both horizontal and vertical prospecting methods are available as specific resistance method. If an apparent specific resistance distribution map is prepared based on the horizontal prospecting, then the conditions of groundwater flow can be estimated.

6. *Electric Logging*

The electric logging is for checking in detail the vertical distribution of specific resistance by utilizing bore holes and is occasionally used for surveying groundwater distribution.

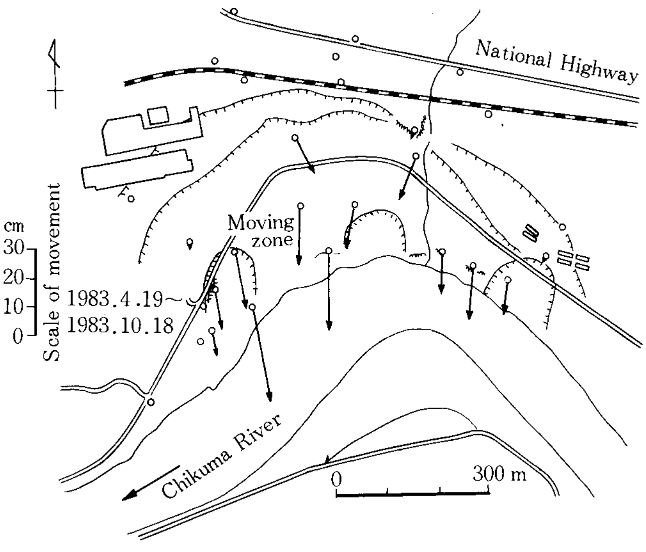


Fig. 4-4 Situation of landslide movement measured by electro-optical distance measurement

Surface Displace Measurement

1. Ground Surveying

One of the methods of accurately knowing the ground surface displacement due to landslide is the surveying of observation points on a landslide mass. As a relatively simple method, offset of the posts from a base line are measured. Those posts, in initiation, were driven on the landslide mass along the base line set between both fixed posts on stable land. For more accurate measurement, the position of measuring points on a landslide mass is determined by triangulation or trilateration using electro-optical distance meter. Recently, however, the displacement is often measured three-dimensionally from one point on a stable land by using total station system capable of simultaneously performing angle measurement and distance measurement.

2. Aerial Photogrammetry

Where the movement of landslide is large, the surface displacement can be measured by the aerial photogrammetry taken in a different time. The aerial photogrammetry is characteristic in that the displacement can be measured plane-wise with an uniform accuracy. If the scale of air photo is 1/5,000, the measuring error is less than 10 cm.

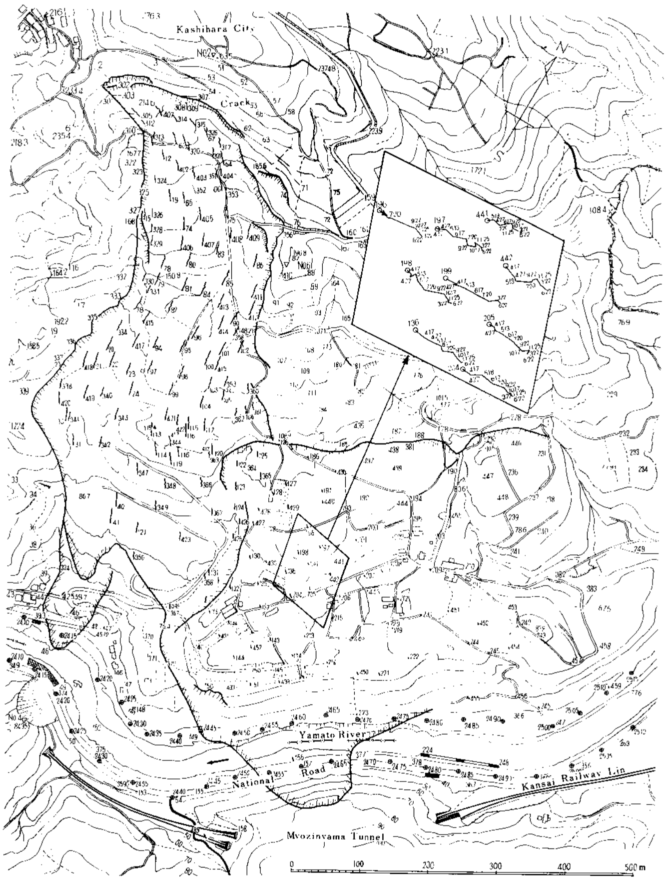


Fig. 4-5 Movement vectors measured by aerial photogrammetry

3. Measurement by Extensometer

The extensometer is a device for measuring relative displacement between a point on a landslide mass and a point on stable land and is widely being used in the survey for finding the speed of a sliding mass. Normally, many extensometers with self-recording systems are installed between main scarp. Motion of landslide mass can be continuously known by using extensometers, so that the strain rate effective for forecasting failure time can be calculated. It can be also used as data for producing alarm.

4. Measurement by Tiltmeter

Tiltmeter is used for determining small ground fluctuation. Its main purpose is to judge whether a potential landslide remains or whether landslide fluctuation is in an active stage or final stage. Bubble-tube type tiltmeters are popular.

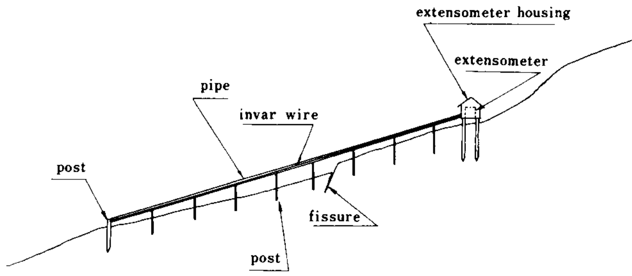


Fig. 4-6 Setting of an extensometer

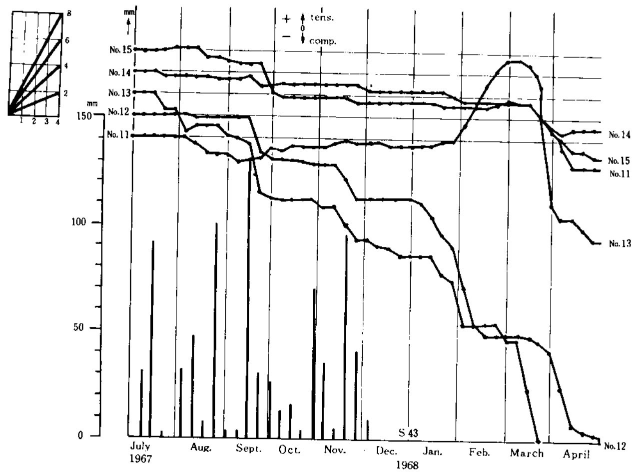


Fig. 4-7 Daily variation of displacement velocity (No. 12–14 point measurement)

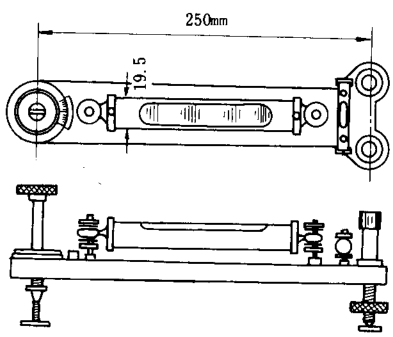


Fig. 4-8 Structure of a bubble-tube type tiltmeter

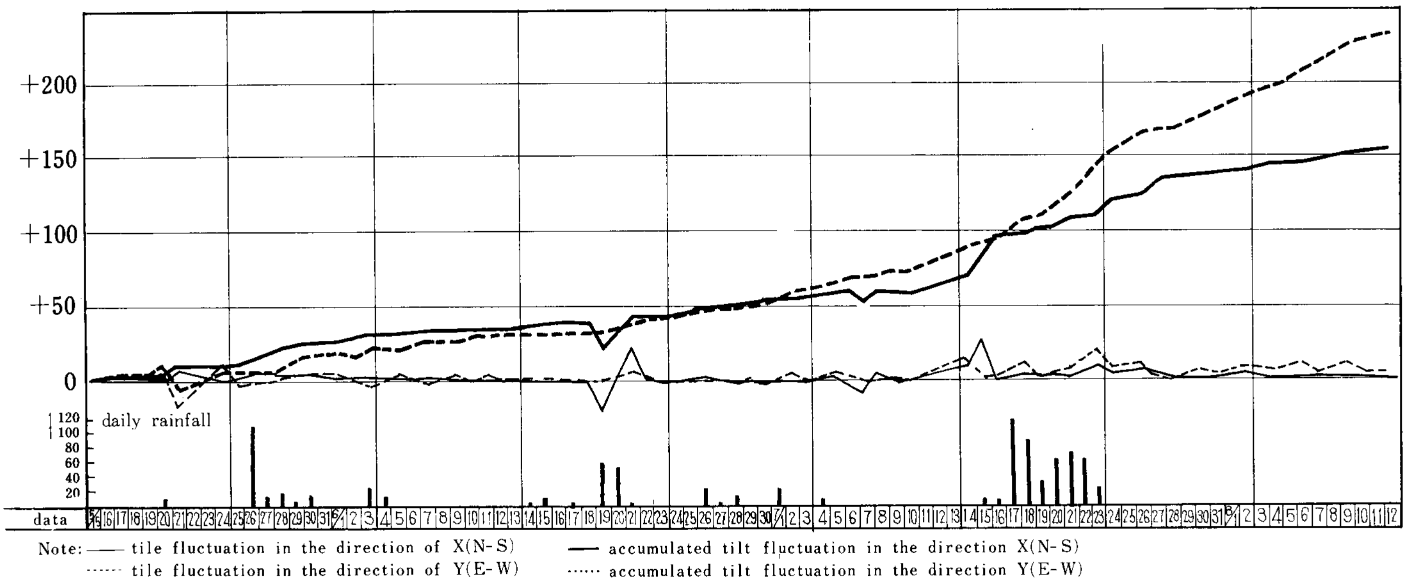


Fig. 4-9 Measurement result of tiltmeters

Surveying in the Earth Displacement and Slip Surface

1. *Drilling*

Drilling is a method for determining the stratum configuration inside and outside of a landslide, and the location of slip surface can be mostly clarified by careful observation of boring cores. Also, drilling is able to take samples of soil tests stated later, and bore holes can be utilized for measuring earth displacement in the earth and surveying groundwater.

2. *Measurement by Pipe Strain Gauges*

Pipe strain gauges comprise a couple of paper strain gauges adhered to a vinyl chloride pipe and are installed in a bore hole. They are used for electrically measuring flexural strain in pipe due to landslide. Results of measurement are extremely useful for determining the depth of slip surface. Pipe strain gauges were developed in Japan.

3. *Measurement by Inclinometer*

The inclinometer is a device for measuring the bend of a bore hole created by landslide and is effective for knowing the depth of slip surface. Inclinometers are available in two types; one type with a sensor to be suspended from ground surface into bore hole for measuring tilt at a given depth, and the other type is to be fixed and installed in a bore hole.

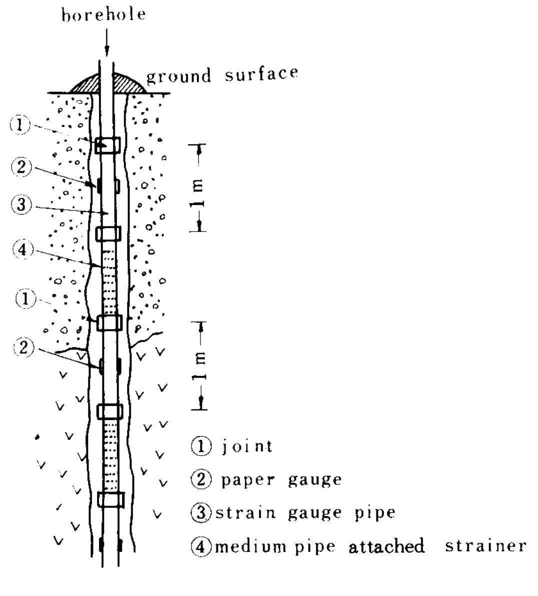


Fig. 4-10 Setting of a pipe strain gauge

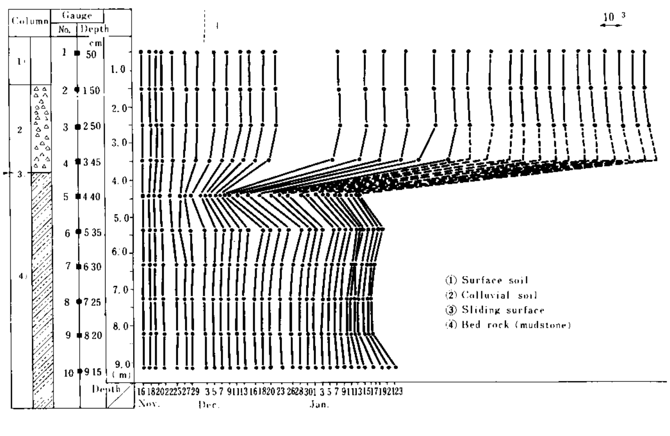
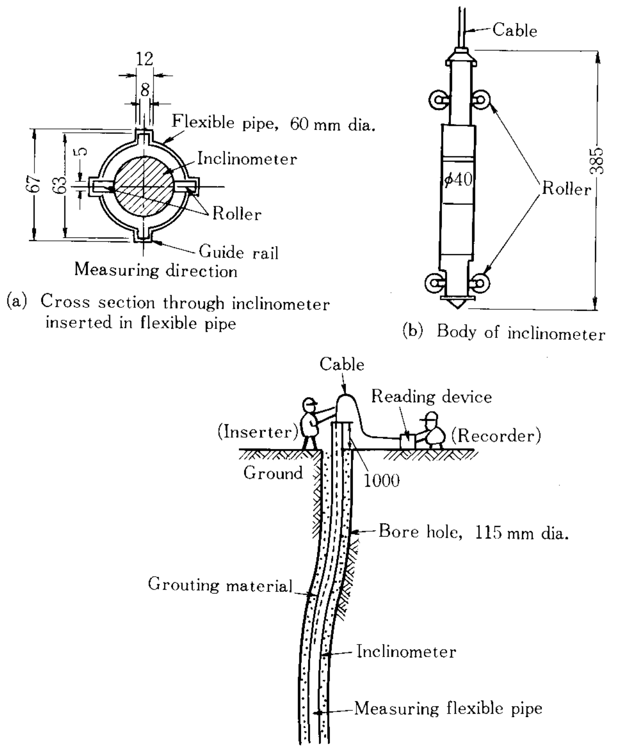


Fig. 4-11 A description of a measurement result of a pipe strain gauge



(a) Cross section through inclinometer inserted in flexible pipe

(b) Body of inclinometer

(c) Measurement of horizontal displacement of ground by insertion type inclinometer

Fig. 4-12 An example of insertion type inclinometer (unit: mm)

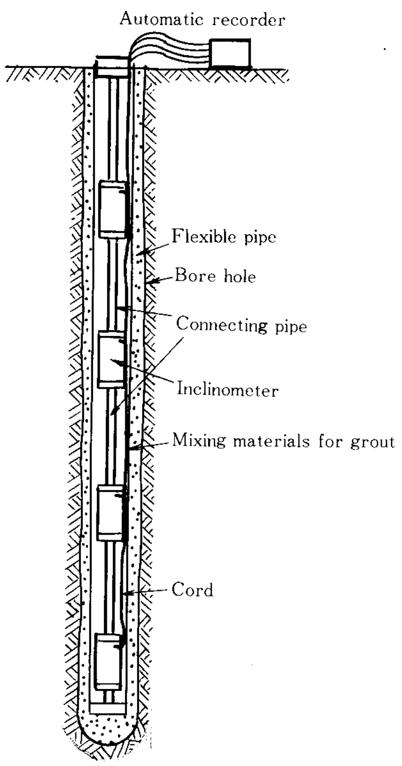


Fig. 4-13 An example of fixed type inclinometer (using both flexible pipe and connecting pipes)

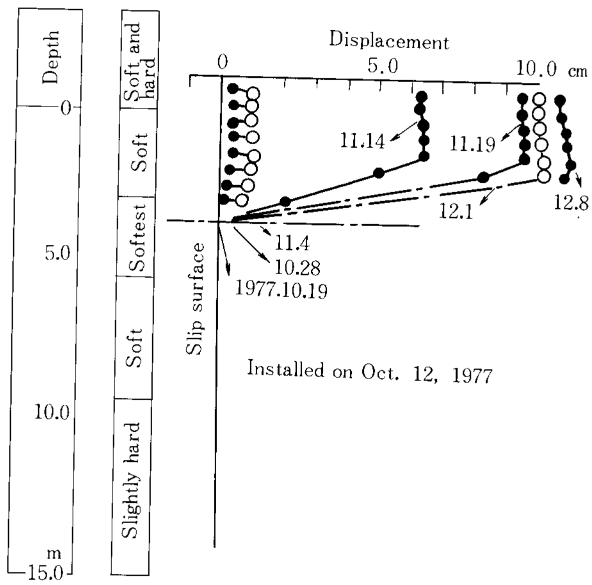


Fig. 4-14 A description of a measurement result of a inclinometer

4. Measurement by Movement Meter

The movement meter is a device for measuring the travel of landslide by measuring the elongation of its wire, the tip of which is anchored to a portion below its slip surface. A multi-layer movement meter is a device for continuously measuring the elongation of wires fixed to the various levels of a wall of a bore hole and is used for judging the depth of slip surface and observing long-term earth movement.

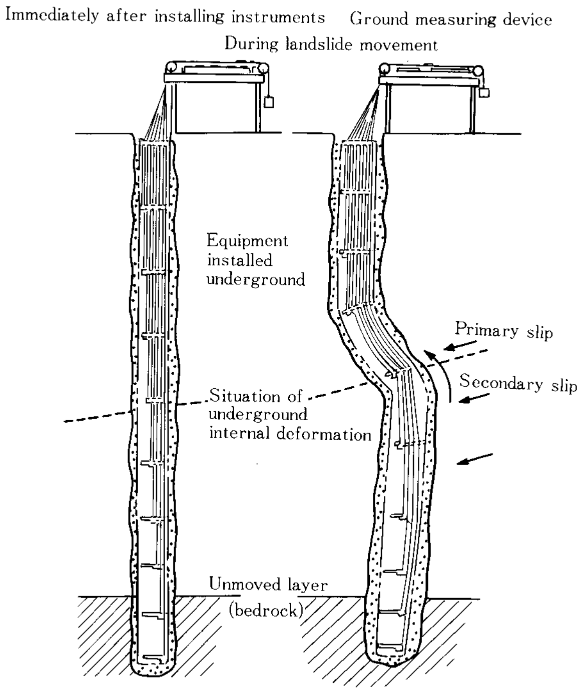


Fig. 4-15 Wire type muiti-layer movement meter

Groundwater Survey

It is necessary to know the hydrogeology of a landslide area and its vicinity to formulate a landslide prevention plan using groundwater drainage.

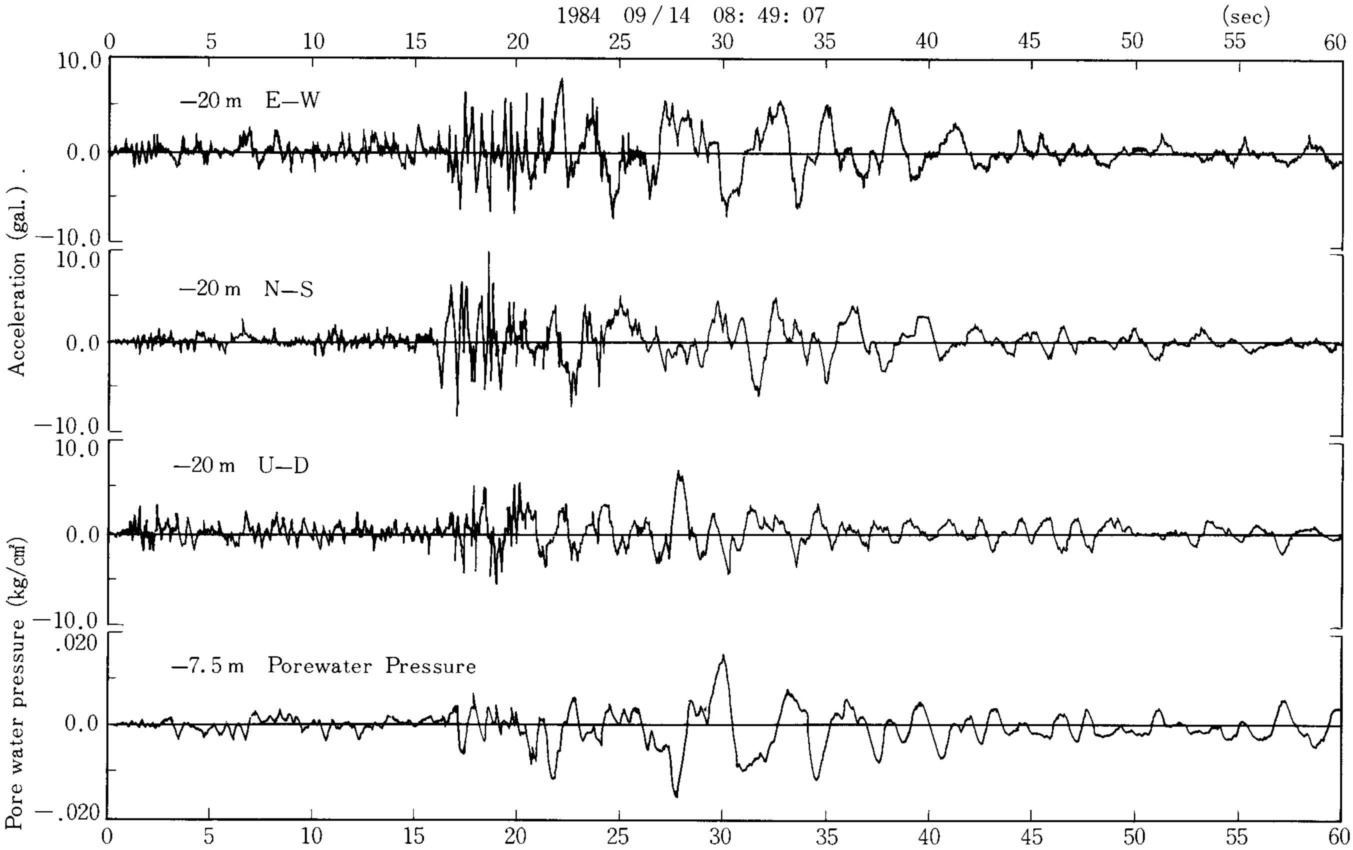


Fig. 4-16 Earthquake motions and pore water pressure fluctuation during an earthquake in the western part of Nagano Prefecture (Observation area: Yui landslide in Shizuoka Prefecture)

1. Surveying Groundwater Pressure (water level) Acting to Slip Surface

Groundwater level survey is conducted by utilizing bore holes. Two measuring methods are available; the method of manually measuring the depth of groundwater level, and the self-recording measuring method using such as float type or water pressure type water level recorder.

In the case of pore water pressure measurement, measuring devices are installed near the slip surface. However, it is difficult to accurately embed pore water pressure gauges in soil layers and to eliminate the influence of free groundwater in nearby area, so that groundwater level that can be measured relatively easily is normally measured and used for stability analysis of slopes as a substitute for pore water pressure. Recently, dynamic pore water pressure caused by earthquake is now being measured. (Fig. 4-16 & Fig. 4-17)

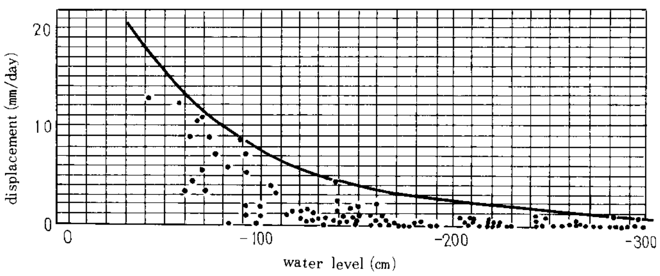


Fig. 4-17 Relationship between displacement velocity and groundwater level at a landslide

2. Groundwater Prospecting

This survey is made to find the location of groundwater flow in bore hole in landslide area. The electric resistance of water in bore holes which was decreased by electrolyte partially recovers caused by supply of groundwater. This change with time is measured, and the location of groundwater flowing layer and the flowing situation are vertically analyzed. This survey was also developed in Japan. (Fig. 4-18)

3. Groundwater Tracing

This survey is performed for confirming planewise the flow of groundwater expected in various investigations by using bore holes and the points of spring water in landslide areas and the adjacent areas. As a method of tracing, it is tracer input and detect. Then, based on the results, a groundwater constant-velocity contour map is prepared and then the flow of groundwater is clarified. (Fig. 4-19)

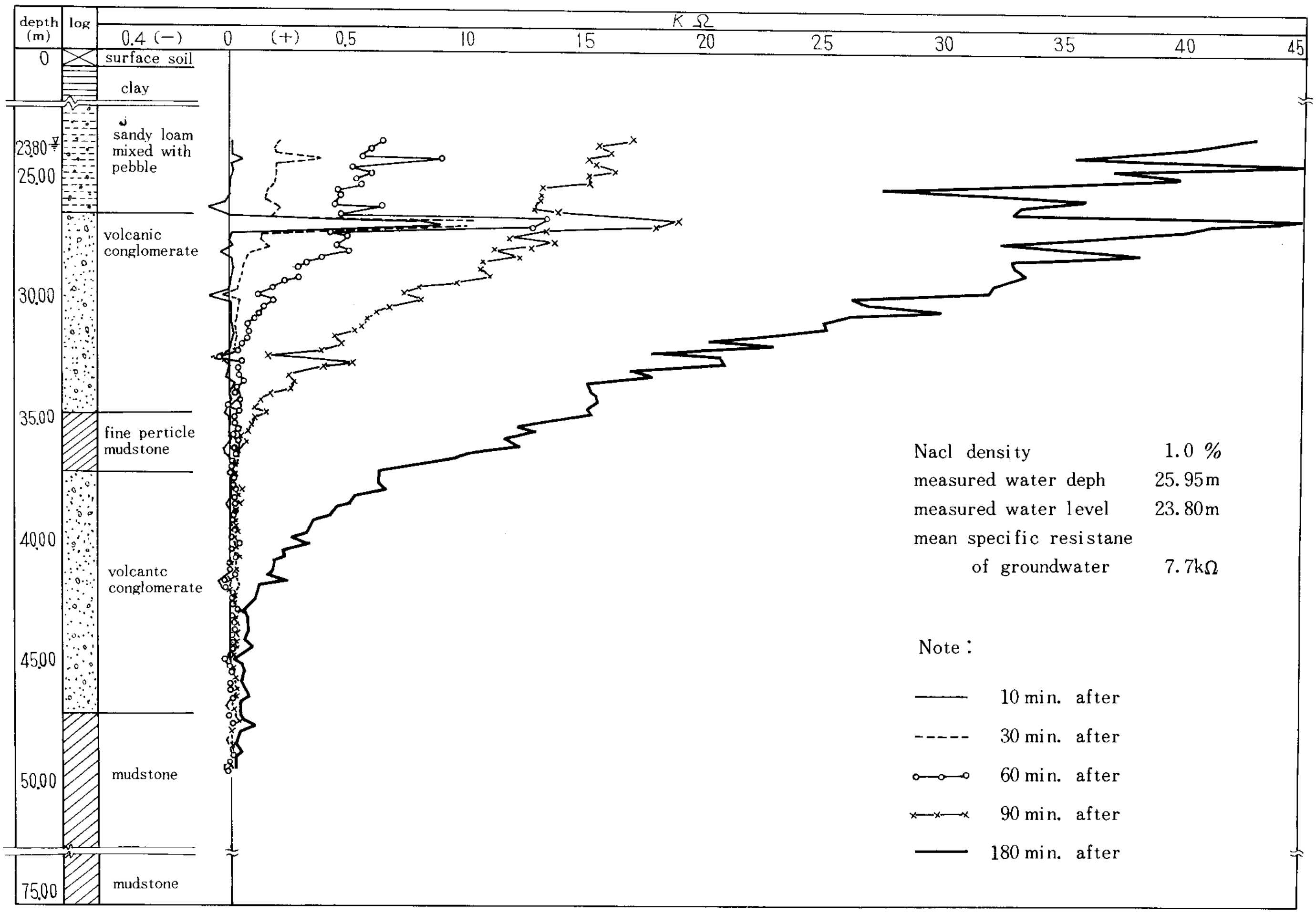


Fig. 4-18 Groundwater prospect at Nakagiyama, Gunma Prefecture

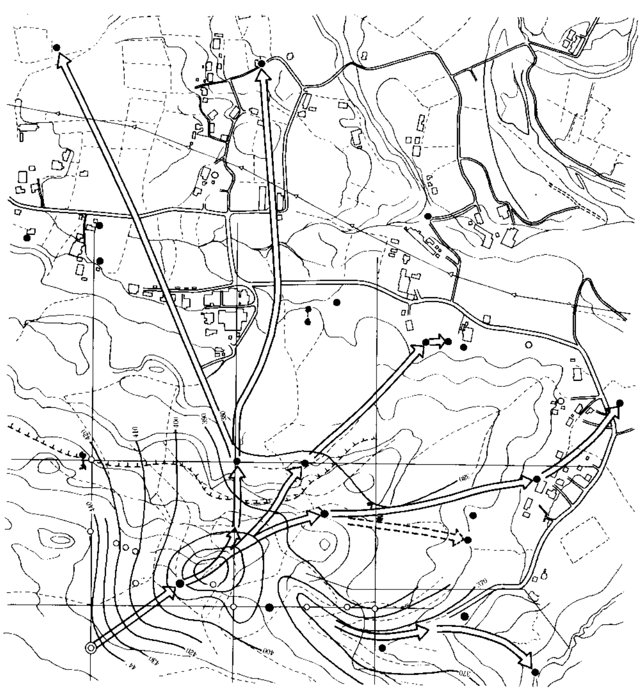


Fig. 4-19 Results of groundwater tracing test

4. Groundwater Simulation

It is not easy to quantitatively survey the behavior of groundwater. However, as a result of the introduction of the groundwater simulation, the analyzing methods for various problems of groundwater have been greatly improved. But the reliability of these methods is still insufficient and many verification holes are required, so that these methods cannot be easily employed. Nevertheless, the behavior of groundwater can be more easily known quantitatively by groundwater simulation.

5. Pumping Test

According to this test, the coefficient of permeability and storage coefficient of permeable layer are determined from groundwater depletion curves obtained at observation holes near a pumping well, and then the groundwater level and influence area affected by drainage are estimated. This test is performed as a survey for clarifying the landslide mechanism and designing drainage method. Available as the measuring methods for this test are the balance method and the non-balance method.

6. Water Quality Analysis

This analysis is conducted to estimate the groundwater-bearing environment by analyzing the water quality of samples taken from the outcrop of groundwater distributed in landslide area and its vicinity. Items are electric conductivity, water temperature, pH, 4.8 alkalinity, Cl, SO_4, SiO_2, Ca, Mg, Na and K. Chemical components are shown in rhombic diagram (Fig. 4-20).

7. Soil Tests

Physical properties and mechanical properties of clay sampled in landslide area, especially the slip surface, are checked for analyzing the stability of landslide and planning prevention works.

1) Laboratory tests

These tests are performed to find the shear strength of soils and include triaxial compression test, shear box test and ring shear test. And the triaxial compression test is normally adopted.

In the laboratory dynamic tests, mainly the cyclic shear tests are conducted, which include cyclic triaxial test, cyclic simple shear test, etc. These tests can provide mainly the evaluation of liquefaction resistance of sandy soils and the dynamic stress-strain relations of soils ranging from sandy soils to cohesive soils. Frequency range is normally from 1 Hz to 2 Hz, but the range is sometimes to more than 10 Hz.

2) In-situ tests

In-situ tests are adopted occasionally since it is difficult in many cases to make accurately the measurement in the field.

However, the unconfined compression test is a simple shear test and thus this test is widely being used as a means of knowing soil conditions in the field.

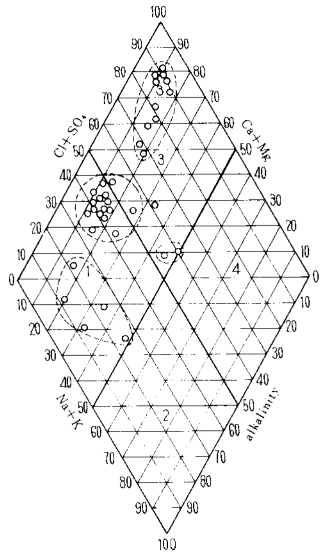
8. Hydrological Survey

1) Rainfall observation
2) Snow cover survey
3) Thaw survey

Chapter 2 Prediction of Landslides

Hazard Maps

Maps for predicting places where landslides may occur are attemped to make in Japan, too. The map has fine arranged meshes, and the possibility of failure occurrence is estimated for each mesh by slope angle, physical constant of soil and so on. This is made for all meshes on the map in order to judge dangerous places. These maps apply to slope failures by rainfall and earthquake.



1. Carbonate Hardness
Waters containing calcium and magnesium bicarbonates as main constituent
2. Carbonate Alkali
Waters containing potassium and sodium bicarbonates as main constituent
3. Non Carbonate Hardness
Waters containing earths chloride and sulfate as main constituent
4. Non Carbonate Alkali
Waters containing alkali chloride and sulfate as main constituent such as waters mixed with as water and fossil brine

Fig. 4-20 Rhombic diagram to classify groundwater characters

Even the landslide landform map made from aerial photo interpretation is considered as one kind of hazard map in view of avoiding landslide disaster. This kind of distribution map had been prepared in small area, but recently these maps have been made for wider regions. The Hokkaido and the Tohoku Districts were published.

Prediction of Failure Time

Various methods of measuring the movement of landslide mass and therefrom predicting the time of occurrence of slope failure have been proposed, such as the method of measuring the movement of ground surface, the method of measuring the movement in ground, and the method of measuring the progress of failure in ground by Acoustic Emission. But only the method based on the observation of displacement by extensometers is being applied to the prediction of the time of occurrence of slope failure.

The following three methods are often utilized for predicting the time of occurrence of slope failure based on the changes in moving speed of landslide mass:

(1) Graphic analyzing method using tertiary creep curves.

(2) Graphic method showing estimated allowance time by using semi-logarithm.

(3) Method using the inverse number of moving speed.

Figs. show the prediction of the time of occurrence of failure based on the observation records of the movement of some landslides (Figs. 4-22, 23, 24).

Also proposed were the formula for approximately predicting the time of occurrence of failure based on strain speed in steady creep state.

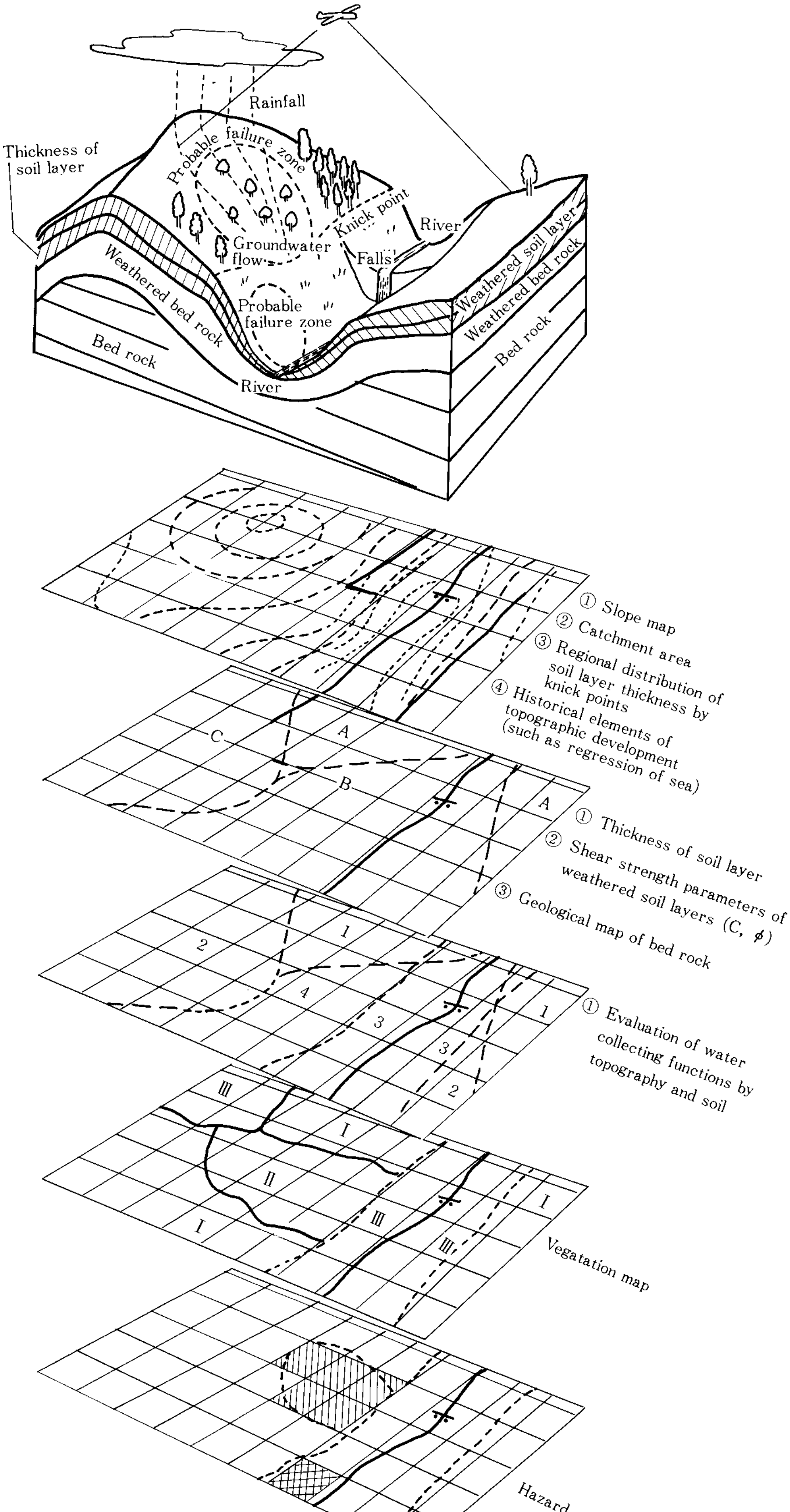


Fig. 4-21 Hazard Map

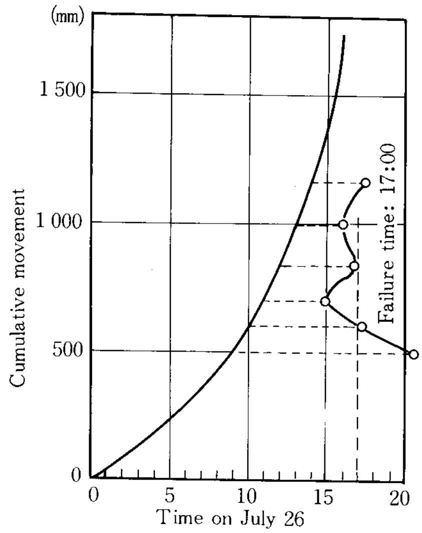


Fig. 4-22 Graphic solution of tertiary creep curve

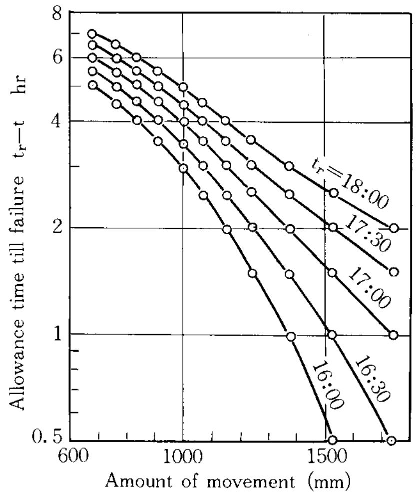


Fig. 4-23 Method using semi-logarithm

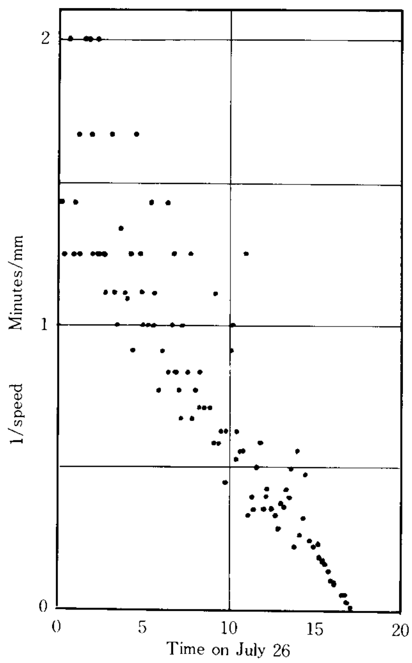


Fig. 4-24 Method using inverse number

5. Landslide Control Works

Landslide control works are implemented after explication of causes of landslide occurrence and its mechanism in accordance with the following procedure:

Landslide control works include prevention works and detention works. The former intends to stop or mitigate a landslide motion by changing the natural conditions such as topographical, geotechnical, and ground water conditions at a landslide site, while the latter aims at detaining a part of the landslide motion or the entire landslide motion using structural control works.

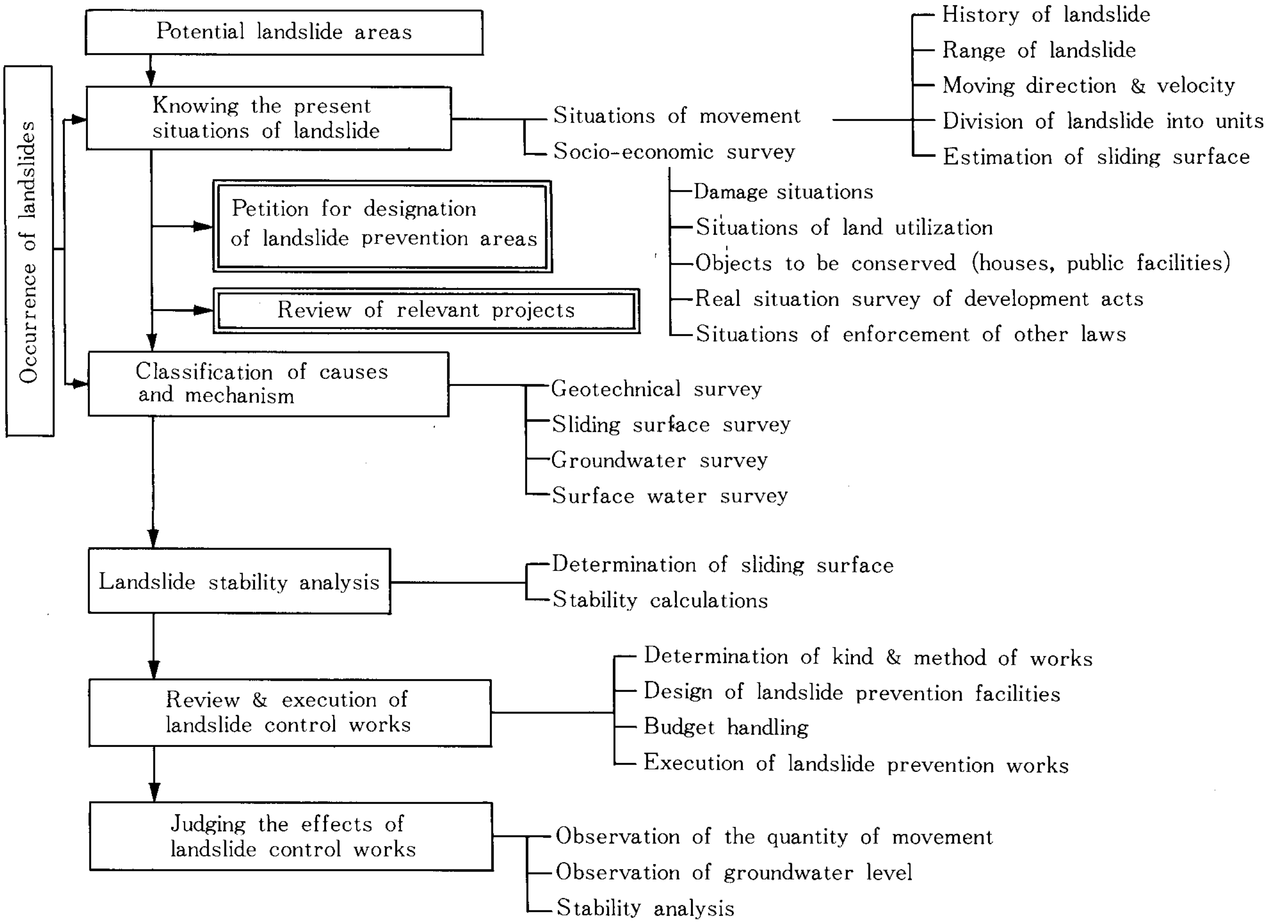


Fig. 5-1 Procedure of landslide control works

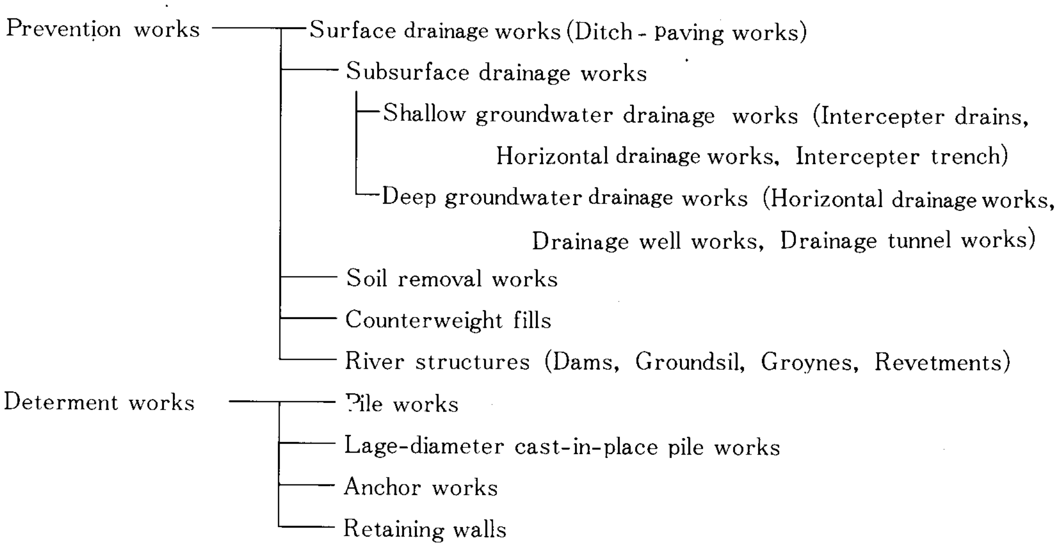


Fig. 5-2 Kinds of landslide control works

a) Surface Drainage Works

Surface drainage structures include collecting ditches and drainage ditches. With allowance of a deformation of the ground to some extent, flexible members or materials convenient in maintenance are used. Corrugated half pipes or short U-shape pipes are adopted with a stop pile or a lateral drain boring every 10 to 20 m. Drainage ditches may be concrete-lined water channels with large cross section or U-shape corrugated water channels with groundsils at the both upper and lower ends. In particular, bending sections and junction points of the ditches very often require water catchment basins for spill prevention.

Interceptor

In principle, interceptor drains are placed 2 to 3 m under the ground surface. Asphalt sheets, synthetic rubber sheets or vinyl sheets are placed over the bottom. The length of one drain is shorter than 20 m, and in case of a distance longer than 20 m or bending, water catchment basins are placed to turn collected water into surface water. Therefore, ditches and interceptor drains are very often adopted (see Figure 5-4 (1)).

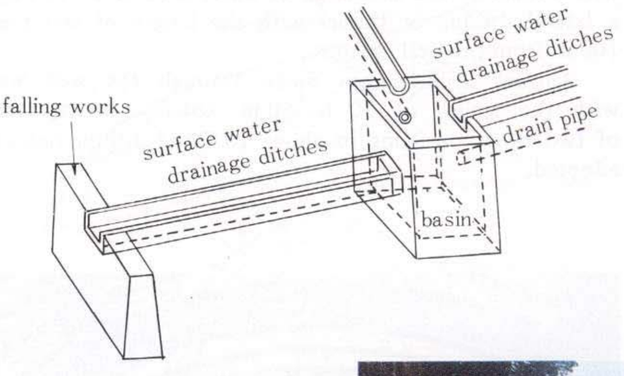


Fig. 5-3 Surface drainage system

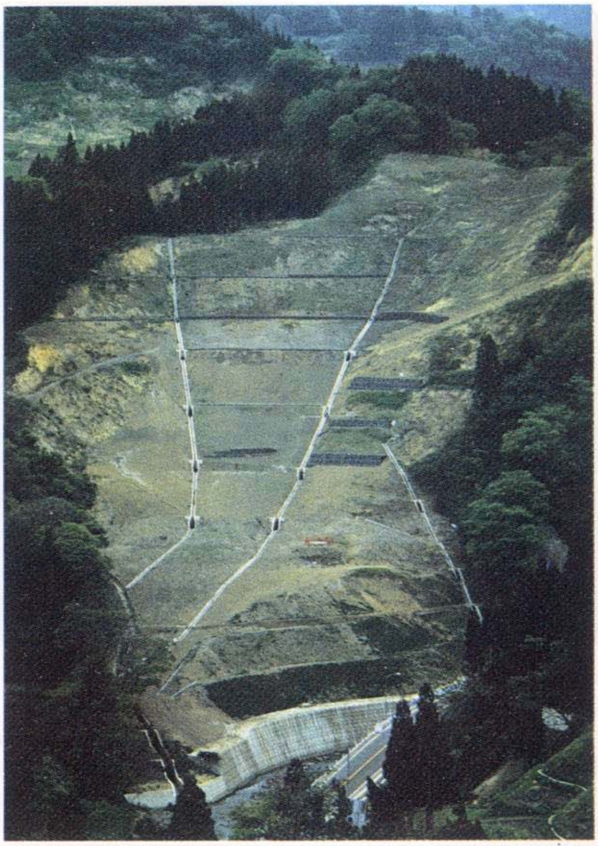


Fig. 5-5 Surface drainage works and soil removal works to reduce the weight of the sliding mass

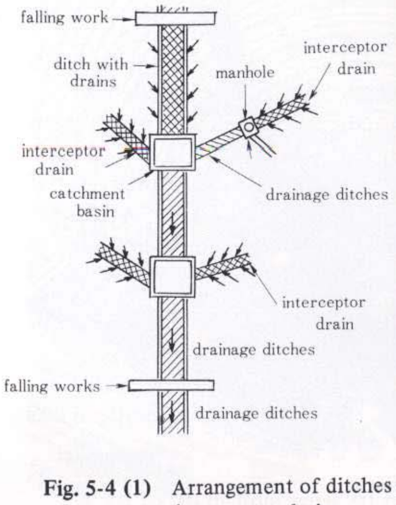


Fig. 5-4 (1) Arrangement of ditches and interceptor drains

Fig. 5-6 Surface drainage ditches with corrugated half pipes

Fig. 5-7 Construction of an interceptor drain

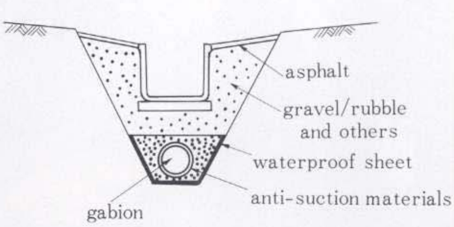


Fig. 5-4 (2) An example of drainage ditches with interceptor drain

Groundsils

Groundsils are constructed in an area where a torrent or a river erodes severely at the lower part of a landslide. A check dam and river revetment works are jointly used. In order to cope with a deformation due to a landslide flexible steel frames are widely used.

Fig. 5-8 A groundsil using flexible steel frames

b) Horizontal Drainage Boring

Horizontal drainage boring works with 30 to 50 m length are used to drain shallow ground water lying below 3 m from the ground surface. Where the bore hole reaches an aquifer, perforated pipes (mainly vinyl chloride pipes or iron pipes) are inserted around the aquifer, and the outlet of the drain pipe is protected with gabions or concrete walls.

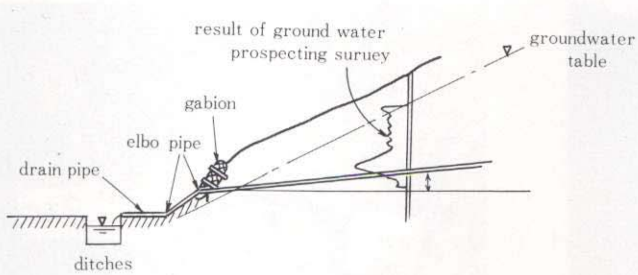


Fig. 5-9 Horizontal drainage works

Fig. 5-10 Drilling works for subsurface drain

Fig. 5-11 Outlet of horizontal drain pipes

c) Drainage Well Works

Drainage wells with 10 to 25 m depth and 2.5 to 4.0 diameter are constructed at a site with relatively stable ground. The well bottom and its surroundings are covered with concrete, and discharge of water is achieved through a lateral drilling or tunnel with the length of less than 100 m from the well bottom.

Lateral drillings are made through the well wall with the length of 30 to 50 m. Usually, arrangement of two raws consisting of about 16 to 24 drilling holes is adopted.

Fig. 5-13 A drainage well using steel materials

Fig. 5-14 A drainage well using reinforced concrete segments

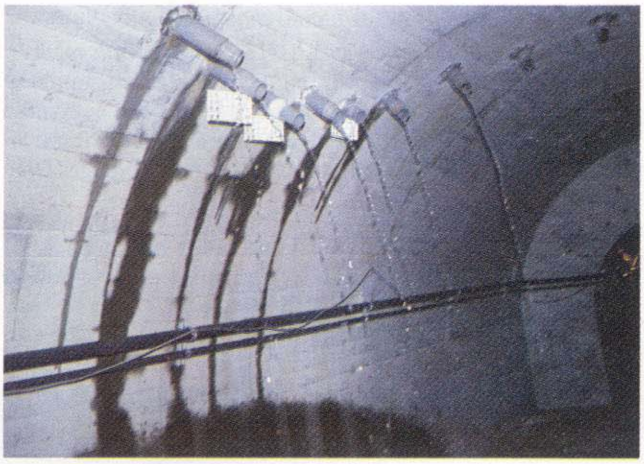


Fig. 5-16 Inside of a drainage tunnel

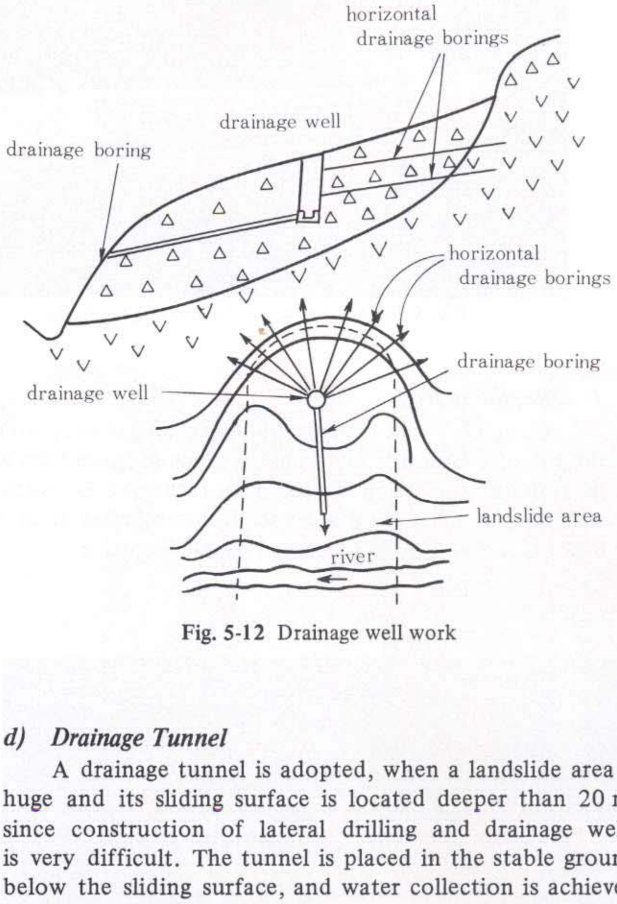


Fig. 5-12 Drainage well work

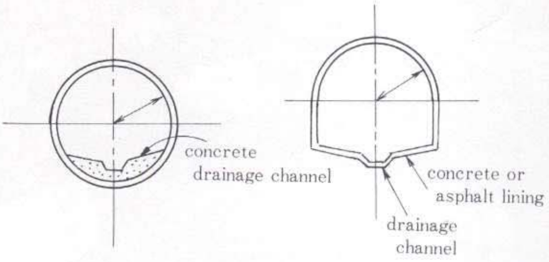


Fig. 5-15 Cross section of drainage tunnels

d) Drainage Tunnel

A drainage tunnel is adopted, when a landslide area is huge and its sliding surface is located deeper than 20 m, since construction of lateral drilling and drainage wells is very difficult. The tunnel is placed in the stable ground below the sliding surface, and water collection is achieved mainly by drilling through the sliding surface with 30 to 80 m lateral drilling within the sliding mass.

e) Soil Removal Works

This work is one of those in which we can expect the surest effect. Generally, it is widely applied to small- and medium-scale landslides.

f) Pile Works

A 10 to 40 m hole with 30 to 50 cm diameter is made by drilling mainly at the lower part of a landslide to insert a steel pile, thick steel pile, cast-in-place reinforced concrete pile or composite pile reinforced by H steels inserted in a steel pile.

Fig. 5-17 Pile works

g) Large-diameter Cast-in-place Pile Works

In these works, a well with 10 to 40 m depth is mechanically or manually dug for constructing a cast-in-place pile with 1.5 to 5 m diameter to place reinforced concrete. This technique is applied, where the ground condition in the landslide area does not allow the use of large-sized boring, driving force of the landslide is too strong to use an ordinary pile, or the bending moment yielded in the pile is too large.

Fig. 5-19 Under construction of the cast-in-place piles

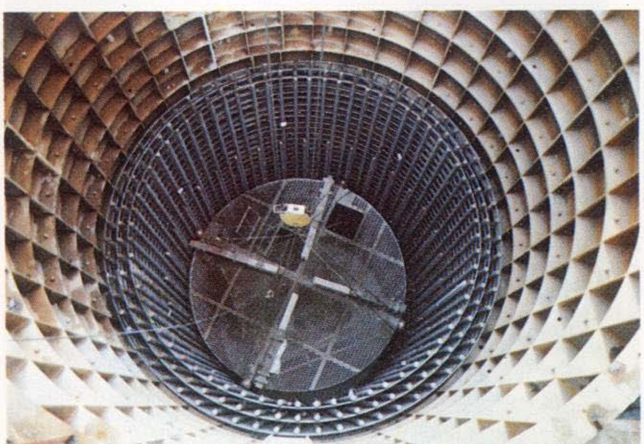


Fig. 5-18 Inside of a shaft using steel segments

h) Anchor Works

In recent years, anchor works have been widely adopted to detain a landslide. Anchoring works are economical method, because highly strong steel members can be used in relatively small holes as tensile members.

It is a method to add detention force at the lower part of a landslide, and thus applied in an area with steep ground surface where steel pile works are not adequate because of a failure at the downside of the piles. Steel bars or steel wires can be used as tensile materials, and drilling holes for steel members are 116 to 150 mm in diameter.

Fig. 5-20 Anchor works to detain a landslide

i) Retaining Walls

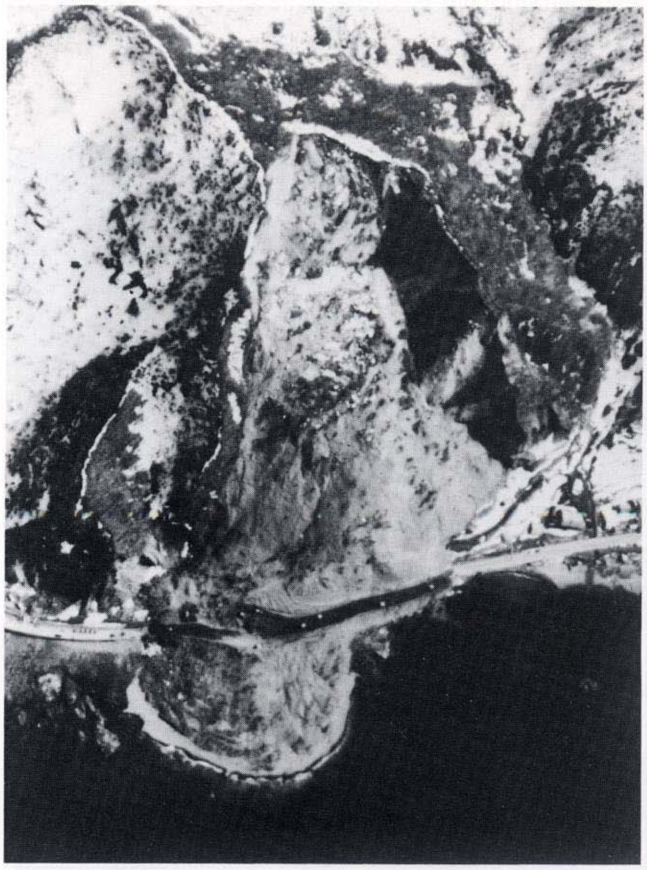
A retaining wall (usually frame, gabion) is built around the toe of a landslide and banking is made around the wall to stabilize the whole slope. This technique is espcially effective in controlling a landslide with upheaval at the lower part and a landslide caused by earth cutting.

Fig. 5-21 An example of retaining wall works

6. Recent Landslides Photos

Kodomari Landslide

Location Bikuni, Shakotan Town, Hokkaido (140°37'E, 43°17'N).
Scale Length 350 m, width 150 m and depth 50 m.
Damage The landslide occurred on April 17, 1978 and damaged the road of Furubira-Kamoenai line. The sliding mass thickly covered the roadbed and projected out in the Japan Sea. Fortunately, no casualties were documented; but life and economic activities in this area were disrupted seriously by the traffic interruption.
Geology, Mechanism and Type This area belongs to "Green Tuff Region" composed of volcanic and sedimentary rocks in Neogene Tertiary. In the landslide site, Miocene intrusive rocks, consisting mostly of microdiorites, covers this area. These intrusive rocks were altered by hydrothermal activity into silicified and clayey rocks, and sheared by fault movement. Under these geological circumstances, a large number of small landslides have occurred in this mountain slope. The slide originated along the crack and blocks rapidly cascaded down along the steep slope over 36° inclination as a rock avalanche. The movement was triggered by the groundwater supplied from a heavy rainfall as well as snowmelting.
Control Works The control works consisted mainly of a counterweight fill works at the foot of landslide and soil removal works at the top of the slide. Then the surface drainage works and retaining-wall works were constructed.
Present Condition This landslide is now almost stable.



Condition immediately after landslide occurrence (April 1978)

Condition after completion of control works (August 1983)

Maseguchi Landslide

Location Maseguchi, Nou Town, Niigata Prefecture (138°04'E, 37°02'N).
Scale Length; 1,650 m, Width; about 950 m, Depth; 30 to 40 m.
Damage A 200 ha slope at the Mt. Gongen (1,108 m) suddenly started sliding, and destroyed 53 houses. The huge amount of sliding material buried the Nou River running at the end of the slope and run into the Kuzure community on the opposite bank.
Geology, Mechanism and Type The base rock of this area consists of Miocene Noudani Formation mainly composed of mudstone, and the sliding mass is composed of mudstone also.

The area is located in the east wing of the Yakeyama anticline, and the Noudani Formation inclines at a gentle angle of 20° to 40° to the NE direction. The landslide slope forms a so-called dipping structure against slope. A fault with N30°E and 30°N crosses the landslide area, and in the south of the fault a clear linearment can be traced. On the other land, a low angle fractured zone is identified almost in parallel to the bedding plane in the upstream sections of Hisonomata River. It is also identified by a boring survey. Thus, the wide spread of the fractured zone is distributed on the upper slope of the landslide area.

The materials of landslide mass are grouped into muddy soil originating in mudstone and gravel compound soil originating in the porphyrite. In the upper slope, the gravel compound soil lies over the muddy soil, and the total thickness of the colluvium is 30 to 40 m. In the lower slope, muddy soil of 10 m thick is more dominant.

It is assumed that the formation mechanism of the colluvium originating in mudstone which spread under another colluvium from the porphyrite and the physical properties of the host rock are the two major causes of the landslide occurrence. That is, the formation was formed when the low angle fractured zone groups along the bedding plane formed a part of the slip plane, and in addition repeated landslide activities before 1947 and weathering for a long period have resulted in the physical property of extremely low shear strength of this formation. Furthermore, it is assumed that abundant ground water supplied from Mt. Gongen greatly contributed to decrease the strength of soil in the slip surface. Along with these factors, an earthquake in the thawing season is assumed to increase drastically the landslide activity which had accumulated in many years.

Control Works Works to prevent the reoccurrence of movement in the landslide area were based on controlling the valley beds.

Major control works include erosion control dams, groundsils, groynes and revetments.

Present Condition In April 1973, a local landslide of 150 m wide and 200 m long occurred. Currently, the area is used for pasture mainly.

Bird's-eye view immediately after landslide occurrence (May 1947)

Tamanoki Landslide

Location Omi Town, Niigata Prefecture (137°39′E, 36°59′N).

Scale Length; 110 m, Width; 70 m, Height; 70 m, Depth; 10 m, Area; 1 ha, Estimated volume; approximately 40,000 m^3.

Damage A landslide occurred on 15 February 1985. This landslide resulted in a disaster with 7 houses destroyed, 10 persons killed and 4 injured. The slide soils and falling trees buried National Road Rout; 8 causing traffic interruption.

Geology, Mechanism and Type The Tamanoki Area located in the west end of Niigata Prefecture adjoins Toyama Prefecture. In this area, narrow coast plain of about 200 m wide is located between the Japan Sea and steep mountains.

The geology consists of tuff breccia, tuff and andestic lava of the late Cretaceous to the paleogene Futomiyama Formation. These rocks are highly consolidated and hard but fractured by tectonic movement, resulting in the presence of faults or large joints accompanying fractured zones.

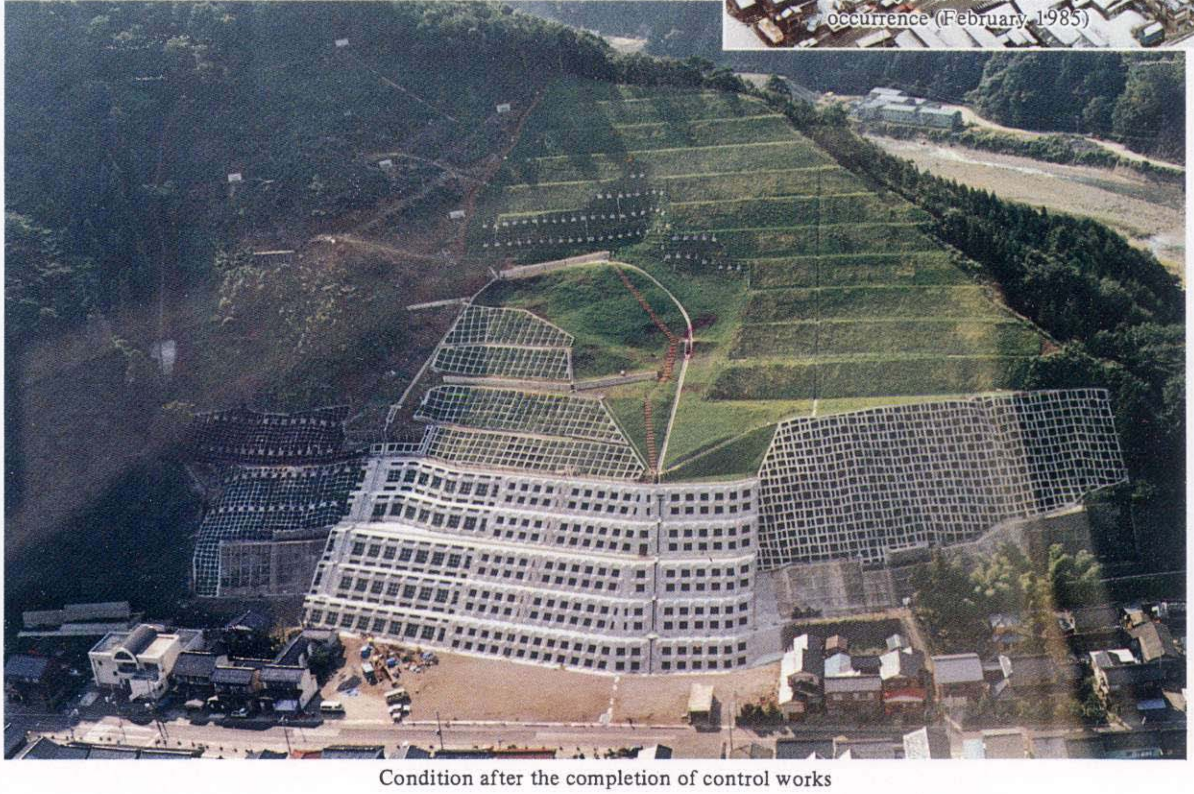
This landslide was not a creep type landslide in old landslide areas which widely spread in Niigata Prefecture, but a rather rare type of landslide with very fast velocity on a steep slope of fractured volcanic rocks.

The abnormally heavy snowfall since late 1984 (maximum snowcover depth of about 2 m) and the subsequent warm weather in the early February along with several days of rainfall before the landslide occurrence seems to have been the direct trigger of the landslide.

Control Works Major control works include anchoring works, soil removal work, piling, and drainage borings.

Present Condition Since the completion of control works in 1986, the sliding activity declined with no sign of landslide.

Bird's-eye view immediately after landslide occurrence (February 1985)



Condition after the completion of control works

Yomogihira Landslide

Location Nagaoka City, Niigata Prefecture (138°54′E, 37°22′N).

Scale Length; 250 m, Width; 130 m, Depth; 15 m, Area; about 3 ha, Volume; about 500,000 m^3.

Damage The landslide, which occurred on 17 May 1984 in the Yomogihira Area destroyed 7 houses, and buried the river for 230 m in length, and damaged 380 m of municipal road and 1 ha of cultivated fields.

Geology, Mechanism and Type The strata of landslide area is mainly composed of an alternation of dark gray mudstone and gray to white tuffaceous sandstone of the Shiiya Formation in Neogene. And its eastside area is covered with andesite pyroclastic rocks.

The appearance of buried trees with the slide deposits in the landslide block and the other observations indicate that the landslide was a reactivation of the colluvial mass which was formed by an ancient landslide movement. The slip surface is found in weathered mudstone.

A secondary mud flow occurred in the toe area of the blockcompressed. However, the water content in the mud flow was rather low due to the low ground water level resutted in the temporary landslide stress and the absence of precipitation before the landslide.

Control Works Control works include mainly ground water drainage and surface water drainage works, piling and retaining works.

Present Condition Currently, no sign of sliding phenomena is observed on the ground surface, and no strain accumulation is recorded in monitoring instruments. Thus, a certain degree of stability is maintained.

Bird's-eye view immediately after landslide occurrence (May 1984)

Sarukuyouji Landslide

Location Itakura Town, Niigata Prefecture. (138°18′E, 37°01′N).

Scale Length; 1,500 m, Width; 50 to 100 m, Depth, 4 m to 15 m (7 m in average), Area; 11 ha.

Geology, Mechanism and Type • This landslide is one of landslides distributing radially around Mt. Jougayama (571.6 m) which consists of on fractured intrusive porphyrite. Its surrounding areas are underlain by a black mudstone of Neogene. Intrusion of the porphyrite caused significant zone in the mudstone. The mudstone has also been remarkably weathered and softened.

The annual displacement of the landslide until 1975 was fairly large, as much as 2 to 6 m in the most active upper part, with gradually decrease lower down, and at the foot of the slope was from 20 to 30 cm.

The colluvial soil in the area consists of a brown clay layer to a depth of 1 to 2 m from the ground surface and a blue-gray clay layer of 3 to 4 m thick under the brown layer. The landslide was composed of several units. The date of same movement observation up to now indicate that the landslide activity those began around October, followed by very active movement in the middle November due to repeated snowfall and thawing. Then, around December with the highest snow-cover the movement reached the climax.

Control Works Landslide control works mainly include drainage of surface run-off and shallow ground water.

Bird's-eye view of landslide site

Baba Landslide

Location Arai City, Niigata Prefecture (138°21'E, 36°18'N).

Scale Length; 400 m, Width; 150 m, Depth; 10 to 20 m, Area; 6 ha, Volume; approximately 600,000 m^3.

Damage In a hillside called Osoyashiki in the Kamibaba Area on the Baba river, movement started slowly around 1 p.m. on 25 January 1981. The slide mass buried Baba River and caused damage to 250 m of municipal road and 4 ha of agricultural land, and 8 houses were destroyed.

Geology, Mechanism and Type The landslide is divided into 2 parts, namely the upper tension part and the lower compression part. At the top of the landslide, main scarp of 10 m high was formed. The main scarp was formed along a bedding plane of black mudstone. Behind the main scarp, secondary scarps of 2 to 3 m high were formed on 27 February. The direction of the secondary scarp is also controlled by the geologic structure.

The landslide activity discontinued about 2 weeks after the occurrence. During this period, the horizontal displacement was only about 50 cm in the lower slope, while the vertical displacement in the upper slope reached about 5 m.

The area along Baba River is underlain by layers of mudstone and sandstone of Neogene. There layers extend along the anticlinal axis of the NNE-SSW direction.

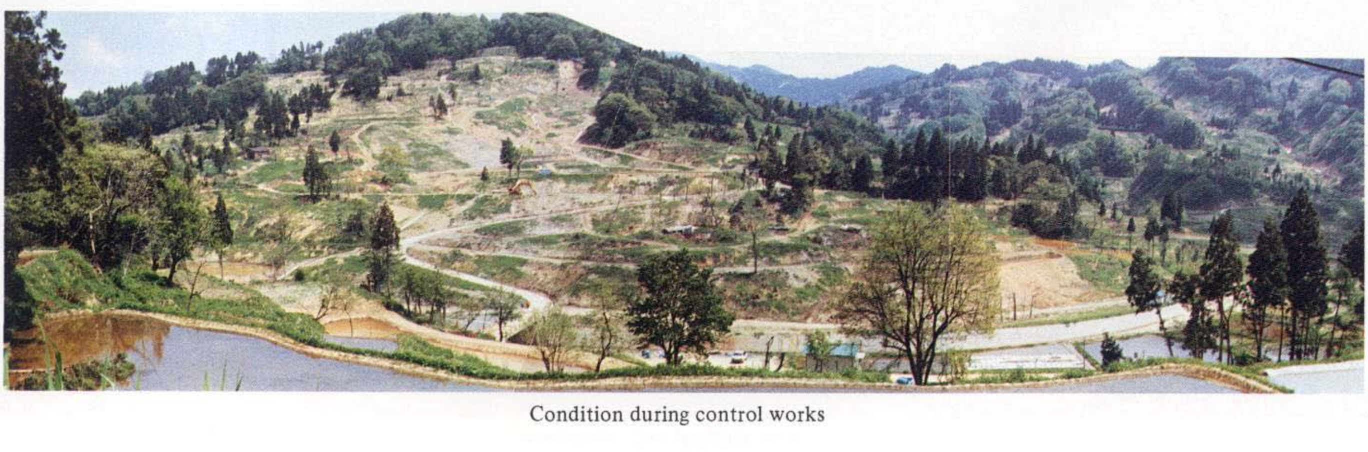
The bedrock of the landslide area consists mainly of the black mudstone called the Shiiya Formation.

Because of the over-hold structure of this area, many small cracks as well as faults are formed, which reduce the rock strength and promote permeation of ground water into the deep layers.

Control Works Ground water which caused the landslide exists in a huge quantity under more than 10 m from surface, and it is highly related with the rainfall. Thus, ground water drainage works mainly by drainage well works, and shallow ground water drainage works by open culvert channels works have been conducted.

Present Condition Heavy rain associated with the Typhoon No. 18 in July 1982 resulted in the reoccurrence of landslide activity in a part of the upper slope. But after that, no sliding phenomena have been observed. The slope where the control works have already been completed is now utilized as a paddy field.

Bird's-eye view immediately after landslide occurrence (January 1981)



Condition during control works

Chausuyama Landslide

Location Shinonoi, Nagano City, Nagano Prefecture (138°7′E, 36°35′E).

Scale Length; 2,000 m, Width; 130 to 430 m, Area; 46 ha, Estimated volume; 9,000,000 m^3.

Damage Landslide broke up 12 ha of cultivated land and 20 ha of forest land located on the hillslope. In addition, 4 houses were relocated.

Geology, Mechanism and Type The movement of the slide is believed to originate from the Zenkoji Earthquake in 1847.

First crack emerged in the mountain slope in 1884. In the beginning, a slow, creep type movement was observed in an 800 m length in the upslope.

Since around 1930, mountain slope moved downward pushing out and extending the length to 2,000 m. The upslope movement is a rock slide, while the downslope movement is a slide of the disturbed soil mass.

The geology consists of Miocene rhyolitic tuff and overlying alternation of sandstone-mudstone. The landslide took place mainly in the area of alternating bed of sandstone and mud-stone.

Control Works Various control works have been constructed since the 1920's, especially after 1965 control measures were actively conducted.

The works include drainage tunnel, drainage wells, steel pilings, intercepter trenches, surface drainage, etc.

Present Condition This landslide was very active until 1970, but since then has been gradually stabilized. The land devastated by the landslide has been restored as a botanical garden.

Twenty five lifesize dinosaur models are provided in the park for children.

This botanical garden was later combined with Nagano Prefectural Zoo which was built in neighbouring site outside of the landslide area, becoming a wide park area.

Site of landslide occurrence is currently used for a dinosaur park (May 1983)

Condition after landslide occurrence (October 1969)

Condition after control works (September 1982)

Jizukiyama Landslide

Location Nagano City, Nagano Prefecture (138°14′E, 36°40′N).

Scale Length; 700 m, Width; 500 m, Area; 25 ha, Estimated Volume; 5,000,000 m^3.

Damage Casualities; 29 killed and 4 seriously injured.

Damage to houses; 50 houses totally destroyed, 5 houses half destroyed and 9 houses partially destroyed.

There was also damage to agriculture, forestry, water supply system, welfare facility and others.

Geology, Mechanism and Type Cracks appeared on the slope during the thawing season in 1981, and creeping of slope continued intermittently. After unusual heavy rain during the rainy season (June to July) in 1985, the slope suddenly slid down at 5 p.m. on 26 July. The majority flow of the sliding mass moved southeastwards, and hit the Yuya Housing Complex at the foot of the mountain.

Furthermore, another flow of the sliding mass ran southward and hit aged people sanitarium (Syoujuen Home) and the Bohgakudai housing Complex. Twenty-six old people living in the sanitarium were killed.

The landslide movement happened in a sudden collapse in weathered rock zone and it thrust old colluvial soil mass downward.

This area is largely composed of Miocene rhyolitic tuff, and the tuff was markedly affected by hydrothermal alternation with abundant montmorillonite. The rock is fractured due to many faults.

Control Works Since the land mass stood still after sliding, control works and restoration works were immediately conducted. The control works include; drainage wells, large diameter cast-in-pile works, drainage tunnels, anchor works, pile works and surface drainage works.

Condition under control works (April 1987)

Bird's-eye view immediately after a landslide occurrence (July 1985)

Haginomine Landslide

Location Kinasa Village, Nagano Prefecture (138°10'E, 36°04'N).

Scale Length; 2,200 m, Width; 60 to 200 m, Area; 40 ha, Displaced volume; 2,350,000 m^3.

Damage 40 ha of forest; 15 ha of agricultural land; 3 houses destroyed; 25 families (95 persons) evacuated; 7 road sites; 3 bridge sites.

Geology, Mechanism and Type Around 11 a.m. on 18 April 1973, the north slope (H = 30 m, L = 450 m) of Mt. Iizuna (1,200 m) slid down with a sudden burst. The sliding mass became muddy flow with a huge amount of ground water, and sped down Wanadezawa and Miyazawa, resulting in damage to houses and cultivated land. The mud flow a down 2,000 m distance up to the Susobana river. Further around 11 a.m. 18 April 1974 (just one year later, the sliding mass remaining on the mountain slope (700,000 m^3) caused mud flow and damaged restoration works. This area mainly consists of volcanic rock, sandstone and mudstone of Miocene. This formation was severely affected by weathering due to folding and faulting and quite vulnerable to landslide.

This landslide could be initiated by thawing (snow cover of 2 to 3 m) and rainfall water which saturated porous tuff breccia and weathered mudstone formation, causing capping rocks to slide down along the impervious sandstone bed.

Control Works Immediately after the sliding stopped, control works were carried out to remove groundwater in the sliding mass, and to stabilize the unstable mass, same works were conducted as follow; drainage tunnel, horizontal drainage, drainage wells, intercepter drains, pile works, erosion control dam, retaining works, and soil removal.

Present Condition Since the completion of the drainage tunnel in 1981, the slope has been stable. A rice field of 27 ha was redeveloped as it was before the landslide and the damaged slope was restored nearly to the original features.

Bird's-eye view of landslide site (October 1976)

Yui Landslide

Location Yui Town, Shizuoka Prefecture (138°33′E, 35°05′N).

Scale Length; 3 km; Width; 1 km; Area; 264 ha.

Damage In this area, 26 blocks of landslides in total have occurred since 1781. Recent ones occurred at the Terao Area in 1961 and at the Nigorisawa Area in 1974. These two landslides damaged JNR Tokaido Line, National Road Route 1 and many houses.

Geology, Mechanism and Type The area is located east of the Itoigawa–Shizuoka Tectonic Line, and in the south-west part of Fossa Magna. The Iriyama thrust fault runs in a south-north direction along the Yui River located near the east edge of the area. The area is situated south-west of this fault. This area consists of Miocene Okouchi formation in the Hamaishidake conglomerate in the Pliocene and is partly Pleistocene Terao formation alternating bed.

The site consists of alternation of sandstone, mudstone, conglomerate with agglomerate partly above the mid-slope. The surface from the mid-slope to the top is covered with loam and sandy loam mixed with gravel. The down slope area is covered with loam and sand and gravel deposit over the mudstone formation.

Control Works The criteria of control works are based on the rainfall in the heavy rain in July 1974 (daily rainfall of 546 mm, and hourly rainfall of 78 mm) and the probable Tokai earthquake. Conventional control/preventive works are being adopted for each landslide block, and at the same time special control works are taking account of earthquake-resistance or retaining structures to prevent secondary sliding at the toe.

Control works implemented so far include soil removal works, torrent control works, surface drainage works, subsurface drainage works (intercepter drains, horizontal and vertical drains, drainage wells, and intercepter trenches), steel pipe piling, anchoring, soil retaining works and planting, and since 1987 large diameter cast-in-pile work have been constructed.

Bird's-eye view of landslide site (July 1987)

Kamenose Landslide

Location Kamenose, Kashiwara City, Osaka Prefecture (34°35′N, 135°39′E)

Scale The Kamenose landslide consists of two big landslide units; Toge area and Shimizudani area, which influenced each other.

Altitude; 25 to 200 m, Gradient; 20° in average, Area; 87.2 ha.

Damage In recent years, large scale landslides occurred in 1903, 1931 and 1967, which caused serious damage such as closure of Yamato River, collapse of national railway tunnel, disruption of national road, destruction of houses within the landslide area, and wide river flooding upstream of the landslide area.

Of these landslides, the landslides occurring from 1932 to 1982 extending about 32 ha in Toge area raised the river bed of Yamoto river, consequently the upstream reaches in Nara prefecture suffered seriously from flooding. In addition, a JNR tunnel passing through the landslide area collapsed.

The landslide in 1967 in Shimizudani area had a scale of 200 to 300 m in wide, 800 m in long and 15 ha in area. This landslide triggered a landslide in the Toge area, finally resulting in the outbeak of a large-scale landslide covering the whole Kamenose area of 50 ha.

Geology Mechanism and Type The landslide area lies on a base of granites, overlain in two formations consisting of pyroclastic deposits and lavas. A surface deposit covers these two formations. The zone of movement is 30 to 40 m deep in average with the maximum depth at over 80 m, and mostly occurring at thin tuff layer intercalated andesite formation, or top of tuff or tuff breccia contracting the upper andesite formation.

Control Works Control works were first commenced by the Osaka Prefectural government but fullscale control works started in 1962 as a National government project. Almost all landslide control techniques developed in the country have been applied.

Major works include such prevention works as drainage tunnels with drainage borings, drainage wells, and large scale soil removal in the top of the landslide area, and detention works of steel pipe piling and large diameter cast in pile works.

Major landslide control facilities which have been completed by 1986 since the start of the government's project in 1962 are drainage tunnels, horizontal and vertical drainage, drainage wells, surface drainage, large-diameter cast-in-piles, pile works, and soil removal works.

Present condition By the end of 1986, total project costs of 18.5 billion Yen have been spent for the Kamenose landslide control. For Shimizudani area the control works are in fairly good progress to nearly completion. For Toge area the stability in the upslope area seems to have been secured, but control of the most active unit in the downslope area is further required. Thus, the construction of gigantic cast-in-piles with maximum diameter of 6.5 m and maximum depth of 100 m, never experienced in Japan.

In the light of the social and economic significance of the Kamenose landslide control works, a telemetering system which connects various instruments for observation such as inclinometers, extensometers, rain gauge, etc. placed in the field with the local construction office was introduced in 1986 for the purpose of real-time observation of landslide movement.

Bird's-eye view of landslide site

Hirayama Landslide

Location Yoshii Town, Nagasaki Prefecture (129°01'E, 33°15'N)

Scale Length; 670 m, Width; 800 m, Depth; 70 m, Area; 56 ha, Sliding volume; 19 million m^3.

Damage The landslide which occurred in 1913 caused damage to 29 ha of paddy field, 14 ha of field, housing land and roads. Of 23 houses in this area 22 houses were obliged to be moved to another place.

Geology, Mechanism and Type The base rock of this area consists of Miocene Sasebo formations, and it is covered with Hachinokubo gravel formation and Hokushou basalts in the late Pliocene to Pleistocene. This very big landslide is a typical Hokushou type rock glide.

A marked depressive crack zone was formed around the crown, while the sliding mass moving actively and continuously. In the beginning, the landslide showed a feature of one block glide, but in due course of time it split into several blocks. The sliding surface was distributed in thin tuff with a coal layer.

Control Works Control works mainly including underground drainage works have been carried out. In particular, the systematic plan of groundwater drainage where drainage wells and drainage tunnels are combined has been adopted since 1975.

Bird's-eye view of landslide site

Fukami Landslide

Location Wajima City, Ishikawa Prefecture (135°58'E, 37°21'N)

Scale Width; 200 m, Length 500 m, Area; 10 ha, Depth; 30 m. This landslide can be divided into two areas; Fukami and Washidake.

Damage Movements have been recorded several times in the past, and the most recent took place from 1974 to 1975. The displacement of this movement reached to 2.5 m in the Hukami area and 0.7 m in the Washidake area and damaged many houses and a national road. Part of the residents were evacuated and traffic control was conducted over the national road at the most active time.

Geology, Mechanism and Type The area is placed on the Anamizu formation in the early Miocene, over which a tuff layer and a mudstone layer is distributed, and colluvial deposit produced in old landslides overlie these layers. The slip surface occurred in the mudstone layer.

This landslide movement is characterized by the presence of too much ground water and the distribution of many faults.

The landslide is a type of re-sliding of a past landslide and gradual movement from the upper to the lower level due to a huge amount of ground water.

Control Works Landslide control works conducted include mainly ground water drainage works such as drainage tunnel works and drainage well works, and with additional intercepter drains and coastal protection works.

Present Condition The landslide in the Fukami area has almost become stable because of the effect of the control works since 1983, while the sliding movement in the Washidake area is still observed at about 1 to 2 cm annually.

The landslide was caused by the erosion of the toe of the slope by sea wave action and the presence of a huge amount of ground water supplied into the landslide unit from the lineament running east-west at the head of the two areas and from the fault in both sides of Hukami area. The direct cause was abnormal rise of the pore water pressure caused by rainfall and thawing.

Results from the investigation prove that the landslides in Hukami and Washidake areas have almost the same slip surface in depth near the border between the two areas, and sliding took place interactively.

Control Works Landslide control works include mainly subsurface drainage works, as well as surface drainage works and seashore erosion control works. The subsurface drainage works included; 21 drainage wells, one drainage tunnel, and horizontal drainage works. Furthermore, a coastal work are under construction for erosion control at the landslide toe.

Present Condition The landslide in Hukami area has almost stabilized since 1983, by the effect of the control works. On the other hand, the landslide in Washidake area is still active, although its annual displacement is as minor at 1 to 2 cm.

Bird's-eye view of landslide site (1983)

Choja Landslide

Location Niyodo Village, Kouchi Prefecture (133°08'E, 33°31'N)

Scale Length; 900 m, Width; 150 to 300 m, Area; 68.4 ha

Damage This landslide movement first took place in 1792, and a storm rainfall in 1886 caused about a drastic movement with resultant damages to about 40 houses. Similar damages were recorded in 1890. The Typhoon No. 9 in 1963 resulted in the biggest flood in the past, by which all of river dike on the foot of this slide were lost, and followed by very active movement at many sites in the landslide area (maximum depression of 2.0 m, and marked displacement of about 5.0 m).

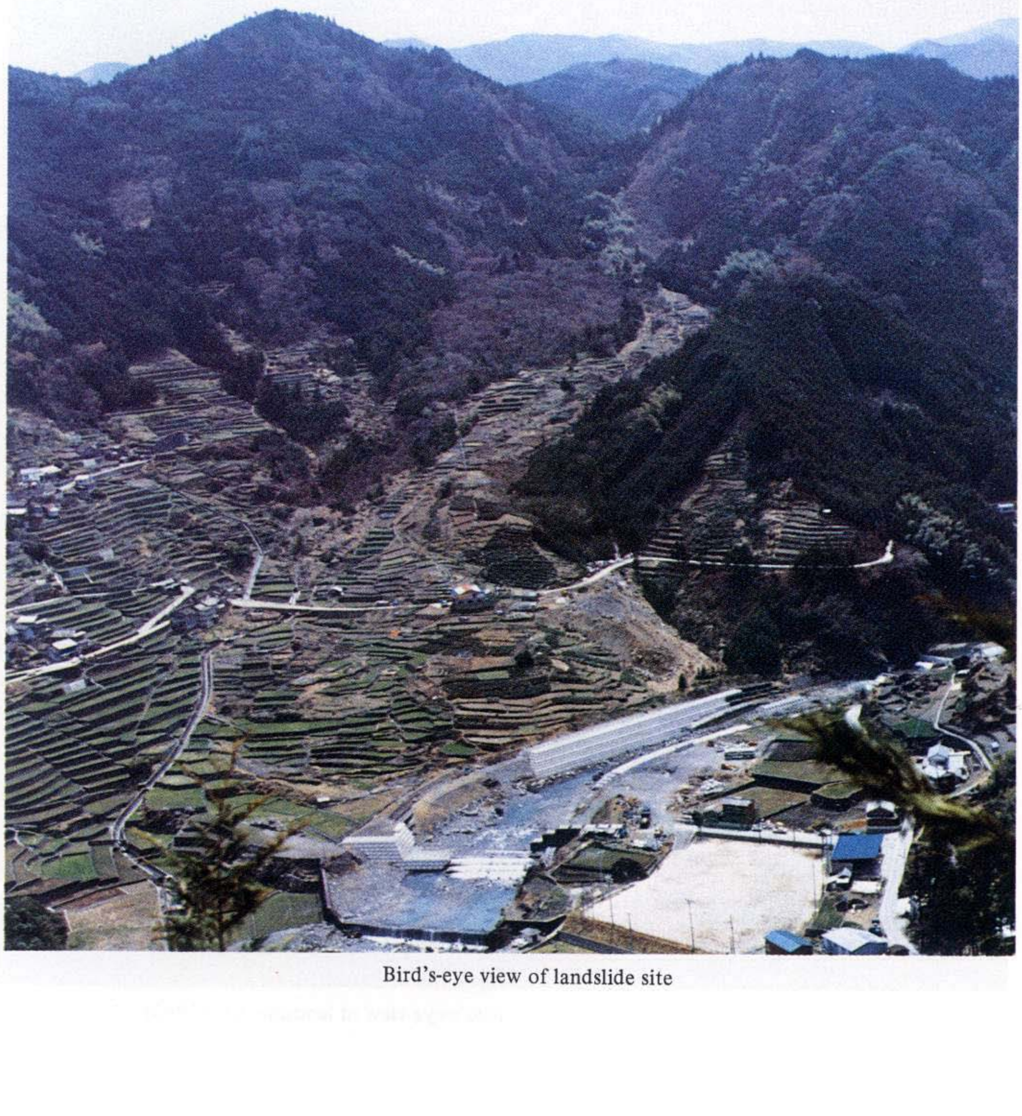
Geology, Mechanism and Type This area belongs to the Kurosegawa Tectonic Zone, which is mainly composed of slate, shalstein, and serpentinite as well as sandstone, limestone, and igneous rocks. The geological structure is fairly complicated with many faults and many sheared zone and fractured zones can be observed.

The sliding body consists mainly of colluvial soil at the toe of this slide, rock fragments at the middle part, and weathered rocks at the upper part.

Most of the sliding surface is formed on weathered slate and serpentinite.

Control Works Main control method for this landslide include drainage tunnel works which was conducted since 1978. The tunnel has recorded very much groundwater drainage; especially in heavy rainfalls more than 5 ton/min., drainage has been achieved. Other works include 8 drainage wells, intercepter trench works, and erosion control works for revetment works and check dam works of Choja River.

Present Condition At first stage the control works by drainage wells seemed to be very effective in stabilizing the landslide, but lateral erosion in Choja River at the toe of slide still continued and sliding movement changed to be active again. Since then, the tunnel work at the middle part conducted from 1978 has become effective with a decrease in the movement since 1983. However, we have some problems because no control work has been carried out for the upper part.



Bird's-eye view of landslide site

Ozaki Landslide

Location Takakura Machi, Takahashi City, Okayama Prefecture (133°33′E, 35°52′N)

Scale Width; about 400 m, Length; 350 m, Area; 7.5 ha, Sliding volume; 1,650,000 m^3

Damage This landslide which took place on 12 April 1985 with about 100 mm rainfall was activated during the subsequent rainy season with 362 mm rainfall, resulting in damages to 400 m of national road, 4 houses and 2 ha of cultivated land on 29 June, and at that time the displacement velocity was 10 mm/day.

Geology, Mechanism and Type This area consists of pelitic crystalline shist and greenschist belonging to the Paleozoic formation, both of which have marked fissility along their schistosity. In them the pelitic schist is more fractured by the fault movements. The geological structure in this area indicates the presence of synclinal axis extending southwestwards, and has a dipping structure at 15° to 30° against the slope, forming a type of weathered rock slides.

Control Works In order to stabilize this landslide, anchoring work and groundwater drainage by wells have been conducted.

Bird's-eye view of landslide site

Higashio Landslide

Location Kaminaka Town, Tokushima Prefecture (134°21'E, 33°50'N)

Scale The landslide is located about 30 km south west of Tokushima City, and covers 14.94 ha between 550 m and 830 m altitude facing east-south. The average gradient of slope is about 23° with gentler gradient at the toe part.

Damage The original time of the landslide occurrence at this area is not clear. After a typhoon in 1934, control works were commenced. Although these control, movements continual and rather active, numerous big cracks appeared on the hillside in 1954. Occasional damage such as a 2 m depression in the road resulted.

Geology, Mechanism and Type This landslide is located on a serpentinite zone where igneous rocks intrude into the Chichibu Paleozoic formation.

In terms of the hydrological and geological structure, the area is divided into three units; ground water recharge zone (cracked and weathered zone), ground water flowing zone, and weathered and clayey zone. By the 1929 typhoon, this landslide changed to active, and in 1934, the control works were commenced.

Control Works The serious damage in 1954 led to the implementation of a fullscale landslide control project mainly based on drainage works. At the same time, a survey to analyse the landslide mechanism was conducted to make effective control planning.

On the bases of these results, systematic drainage works were conducted, including drainage tunnel works with vertical borings. In addition, horizontal drainage works, ditches paving works, and some consolidation dam constructions have been carried out.

Present Condition Displacement observation shows no sign of marked movement in the last several years, and also observation of inclining also indicates no sign of strains at the sliding surface. Thus, a stable condition has been maintained.

Bird's-eye view of landslide site

Owakudani and Sounzan Landslides in Hot Spring Area

Location Hakone Town, Kanagawa Prefecture (130°02′E, 35°14′N)

In hot spring areas, large scale landslide disasters frequently break out due to the alteration and agrilization of the base rock caused by volcanic vents and hot fluids.

Owakudani and Sounzan are located in the north side and on the northeast slope of Mt. Kami Yama (1938 m), in Hakone volcano.

Scale Owakudani area; Length; 800 m, Width; 400 m
Sounzan area; Length; 1,200 m, Width; 100 m

Geology The Hakone volcano was formed in the middle to late Pleistocene on the basement of volcanic rocks in the Neogene and the Yugawara volcano in the Quaternary. The volcano was formed through 2-time crater depressions and 3-time volcanic activities. Geothermal zones associated with fumarolic activities spread in these areas. The terrestrial heat has altered markedly the surrounding two-pyroxene andesite lava and tuff breccia and promoted silicification and argillization, resulting in an unstable slope.

The argillized zone where kaolin minerals and alunite increase intensively contains montmorillonite in many cases. The silicified zone largely consists of silica minerals. The slip zone is very vulnerable to even a very minor impact, which tends to be the cause of landslide.

Mechanism and Type The Owakudani valley is a steep slope of 2,000 ha in area at 950 to 1,200 m in altitude. There, several landslides broke out in the recent history, such as in 1910, 1935, 1948 and 1950. In particular, the slide in 1910 was of big scale with flowing out of a huge amount of debris, which buried the Hayakawa valley with resultant serious damages on the downstream communities. In 1935, a failure took place at the source of the Owaku dani Valley, and it has left a clear scarp we can see now. A huge amount of debris has deposited under the scarp, and a marked fumarole phenomenon can be seen at the foot of the scarp.

In Sounzan, a failure took place at the source of the Suzawa dale in July 1953. The resultant debris flow reached about 2 km downstream at the average velocity of 7 m/sec. The collapsed material was 800,000 m^3. The debris flow buried about 7 ha of forestry and destroyed 17 erosion control dams.

The cause of the landslide is in a conical depressed ground at the head of the Suzawa dale, surrounded by a steep slope characterizing an explosion crater. Exhalation of hydrogen sulfide and hot fluid resulted in the hydrothermal process of the base bedrock between 20 and 25 m in depth, forming an unstable condition of the lapilli.

Control Works Main control methods for this landslide include erosion control works of banking, dams, hillside works and revetments. Also, groundwater drainage by intercepter trenches has been conducted. In addition, gas exhaust drilling works have been conducted.

Present Condition In Sounzan, no appreciable change has been noted during these years.

Sounzan area

Owakudani area

Landslide Caused by the West Nagano Prefecture Earthquake

At 8:48 on 14 September 1984, an earthquake of 6.8 magnitude with the epicenter at Otaki Village, Kiso District, Nagano Prefecture, broke out, resulting in many landslides and slope failures mainly around Otaki Village. The damages caused by especially large-scale landslides on the south slope of Mt. Ontake and in the Matsukoshi area are described.

Mt. Ontake Landslide

Location Otaki Village, Nagano Prefecture (137°33'E, 35°49'N)

A large-scale collapse-type landslide broke out due to the big earthquake on the south slope of Mt. Ontake. The collapsed mass flew down about 10 km of River Denjo, forming a mud flow. The mud flow at the rate of about 70 km an hour stripped off 575.5 ha of forestry. This was a rare, serious disaster in the country.

Scale Length; 1,400 m, Width; 328 m, Maximum depth; 191 m, Area; 41.18 ha, Sediment quantity; 35,720,000 m^3 (only within the landslide area where a mud flow broke out).

Damage Human damage; 16 persons killed.

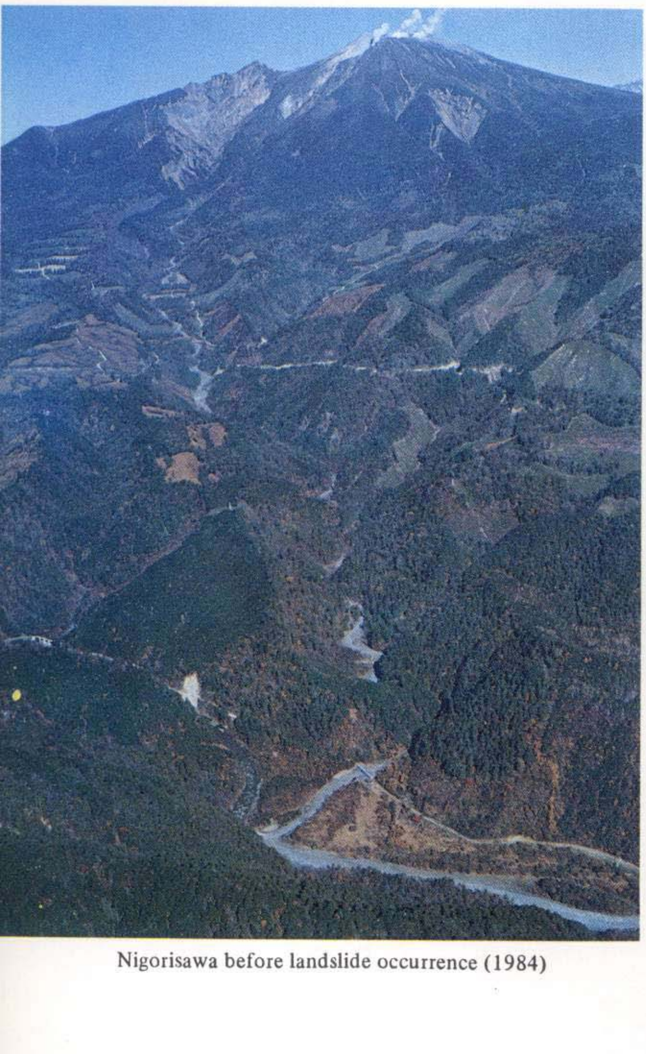
Total loss of 40,800,000,000 Yen on agriculture, forestry, civil engineering facilities, welfare facilities and others.

Devastated land area due to the mud flow of 575.5 ha.

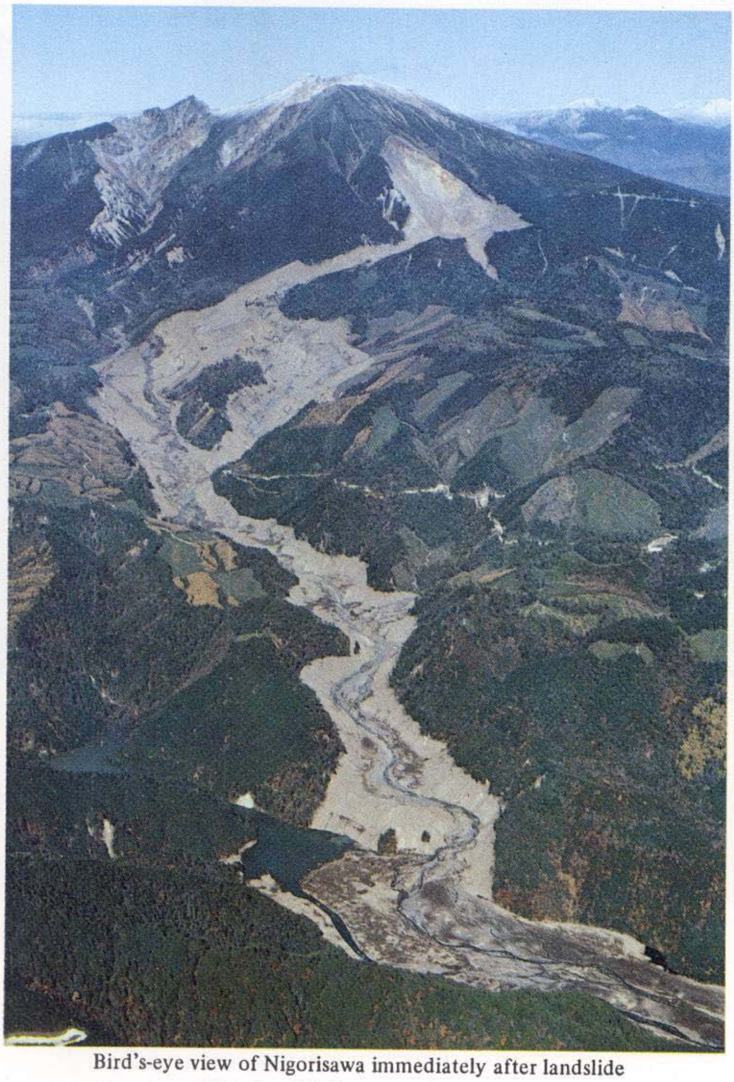
Geology, Mechanism and Type Mt. Ontake, an active volcano, consists of Nohi rhyolites and granites as the base, which is covered with volcanic products. This large-scale landslide broke out on the slope consisting of these volcanic products.

Control Works A huge amount of the deposit in River Denjo and River Otaki was fixed with erosion control dams, and planting was carried out to control ground surface erosion on the devastated slope and the landslide area.

Control works implemented by the end of 1986: Twenty six concrete dams, 13 block dams, 22 steel framing dams, 450 m revetment works, and 120 ha slope works.



Nigorisawa before landslide occurrence (1984)



Bird's-eye view of Nigorisawa immediately after landslide occurrence (October 1984)

Matsukoshi Area

Location Matsukoshi, Otaki village, Nagano Prefecture (137°33'E, 35°48'N)

Scale Length; 250 m, Width; 150 m, Area; 2.6 ha, Sediment quantity; 250,000 m^3

Damage Human damages; 13 persons killed

Damaged houses 6 totally destroyed, 17 half destroyed, 40 partially destroyed, one completely destroyed factory (Concrete manufacturing)

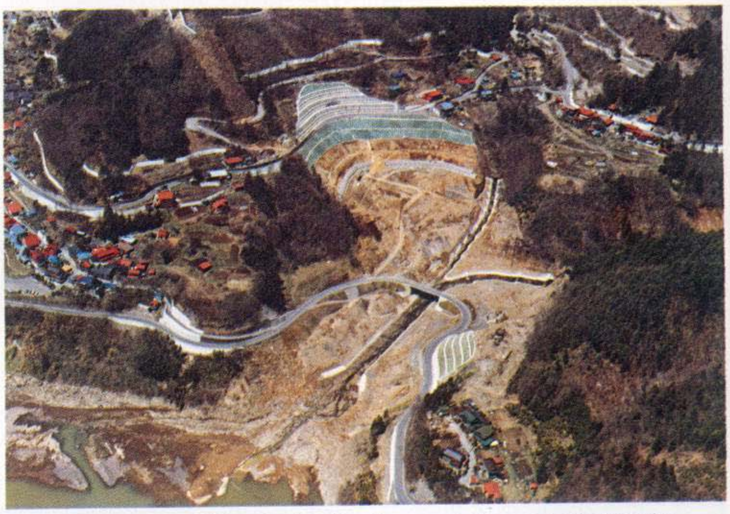
Public Facilities Roads, rivers, bridges, forestry and cultivated land

Geology, Mechanism and Type A landslide broke out with the earthquake, and the moving sediment formed a mud flow with the collapse and run on the opposite bank.

Geologically, sand stone, slate and chart in the Paleozonic form the base, which is covered with a thick layer of viscous sediment originating in volcanic ash mainly of mud flow-type deposit. This landslide took place with a slip surface on the top surface of eruptive pumiceous tuff.

Control Works Two drainage wells, horizontal drainage works, intercepter drains, and restoration works for road, bridge, and river.

Present Condition Otaki Village seriously damaged by both the earthquake and the landslides has been restored by restoration work to a situation leaving almost no trace of the disastrous result just after the outbreak the villager life was also recovered.



Bird's-eye view of Matsukoshi after the completion of control works (April 1986)

Bird's-eye view of Matsukoshi immediately after landslide occurrence (September 1984)

Kosei Landslide

Location Ooe Town, Yamagata Prefecture
(140°5′E, 38°20′N)

Scale Width; approximately 400 m, Depth; approximately 400 m, sliding volume; 5,600,000 m^3

Damage In April 1984, a landslide broke out, forming a main scarp of 20 to 40 m height at the head. In the middle part, a road was moved horizontally by 15 to 30 m, and a field swelled or inclined. On the other hand, at the toe of the landslide, the slide material buried River Kosei about 90 m, resulting in the formation of a landslide lake for 500 m length in the upstream area.

Geology, Mechanism and Type This landslide area consists of mudstone, silt stone and tuff with relatively unconsolidated condition of the Miocene Hongo formation. Faults and folds form a fractured zone as a whole. Since weathered layer reaches 20 to 40 m in depth, and a failure plane appears in these weathered rocks or under them, the landslide is considered to be a type of weathered rock landslide. The cause of landslide is assumed as follows; heavy thawing of 2 m snowmelting due to a sudden temperature rise in the early April supplied a huge amount of ground water into the landslide area, with a resultant increase in the pore-pressure near the slip surface.

Control Works Revetment works, drainage well works, horizontal drainage works, pile works, intercepter trench, concrete cribe works, and soil removal works.

Present Condition Up to now, almost all of the major control works have been completed, and the landslide movement has become slowly.

Bird's-eye view immediately after landslide occurrence (April 1985)

Condition during control works (November 1986)

Yachi Landslide

Location Higashinaruse Village, Akita Prefecture (140°41'E, 39°06'N)

Scale Length; 1,300 m, Width; 950 m, Area; 123 ha, Sliding volume; 35 million m^3.

Damage The landslide took place by the heavy rain in September 1984 and blocked the Naruse River, with resultant heavy damages in a community located 10 km downstream.

Geology, Mechanism and Type The area consists of Miocene shale and the slip surface is within a thin tuff layer interbedded in the shale. The landslide is a dip slide of which the inclination coincides with that of the bedding plane.

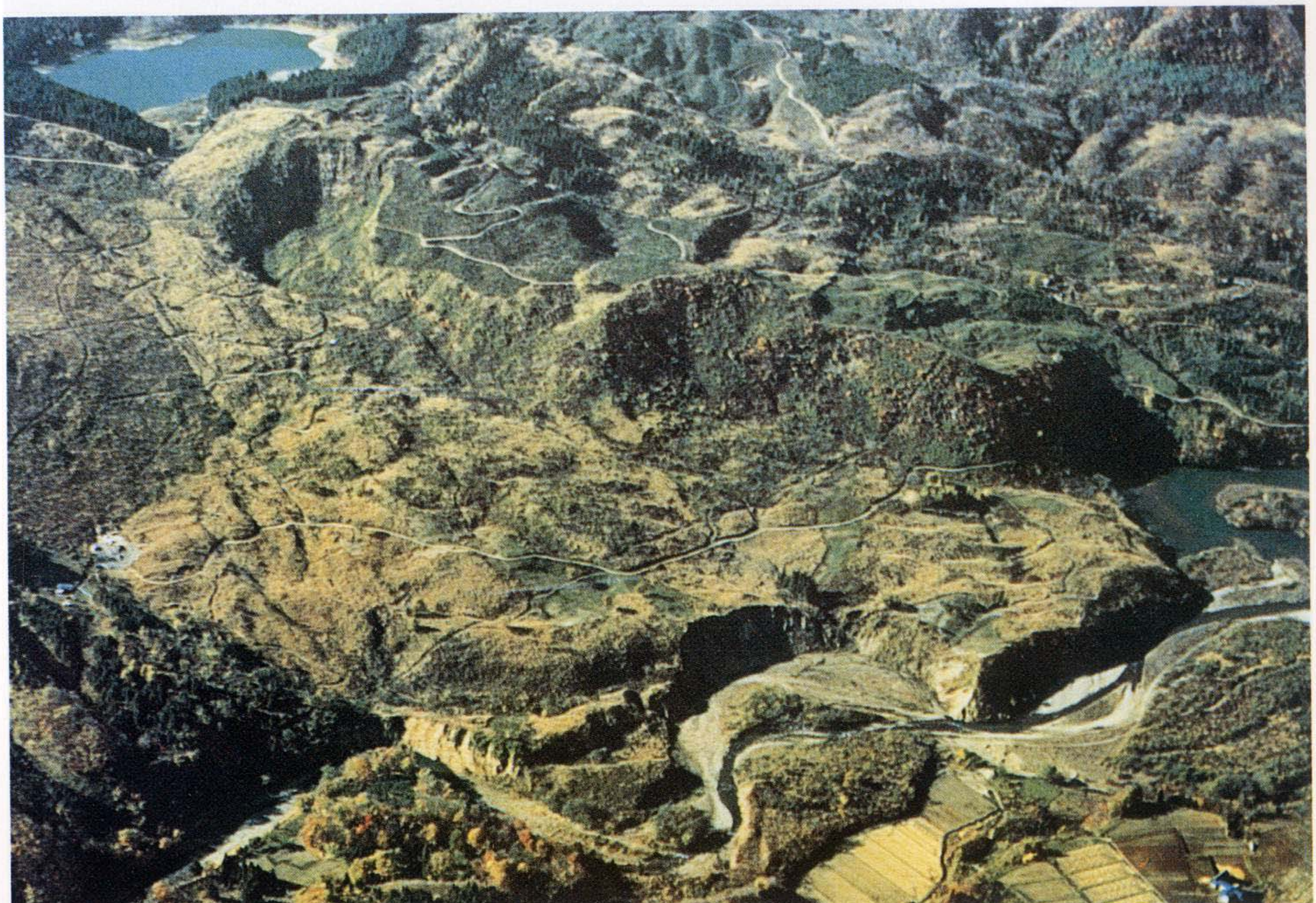
The landslide is divided into 4 blocks, and the toe of the landslide went across the River Naruse, as shown in the photo.

There is a marsh with no outlet at the head of the landslide area, and the rise in the marsh water level during the thawing season is the major cause for the landslide.

Control Works Started in 1982 mainly to drain the ground water supplied from the marsh. The works include drainage well works, drainage tunnel work, horizontal drainage works, and intercepter trench.

Present Condition The progress in the works has shown a good result. In particular the completion of the drainage tunnel in 1984 for the purpose of draining the ground water from the marsh resulted in rapid stabilization of the landslide movement.

In future, the drainage tunnel which has already been completed will be further extended to control the water level of the marsh during a thawing season for the control of the landslide activity, and banking works are planned for the River Naruse at the toe of the landslide area.



Bird's-eye view

Takada Landslide

Location Kamogawa City, Chiba Prefecture (140°03'E, 35°06'N).

Scale Length; 1,000 m, Width; 200 m, Depth; 10 to 15 m, Area; 13 ha.

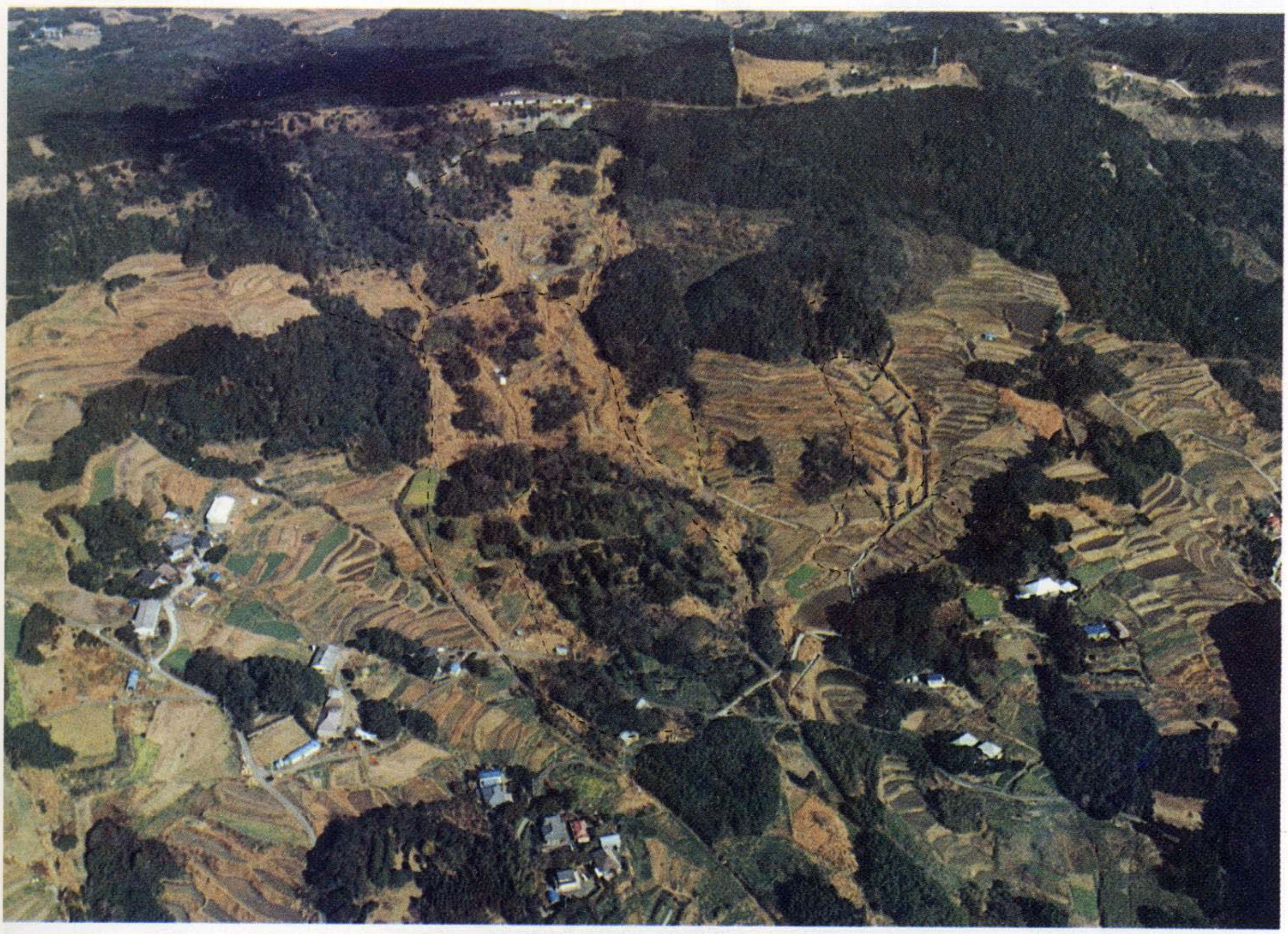
Damage The landslide which took place on 25 March 1952 devastated 13 ha of cultivated land and forestry, and destroyed the municipal road, houses, and a bridge. Reoccurrence of landslide in the same area on 29 November 1979 devastated 9 ha of cultivated land and forestry.

Geology, Mechanism and Type The geology consists of shale and sandstone in Paleogene Mineoka formations, and alternation of sandstone and shale strata in Neogene Takazuru Formation, shale in Furubou Formation, and ultra basic rocks including serpentinite.

The landslide is due to the reactivation of slide mass, and is of a type of mechanism of that sliding phenomena extending gradually from the upper part to the lower part along the sliding slope.

Control Works Surface water and ground water drainage works which contains many drainage wells have been conducted.

Present Condition The area which slide in 1952 and 1979 maintains a certain degree of stability, but in the adjoining east slope, an active sliding has been observed since June 1984 with resultant devastation in the range of 300 m length, 70 m in length, 5 m in width, 5 m in depth and 1.7 ha in area. Implementation of surface water drainage works have led to stabilization of the sliding.



Bird's-eye view of landslide site

Landslide around the Odo Dam Reservoir

Location Tosaki, Niyodo Village, Kochi Prefecture (133°05'E, 33°32'N)

On the right bank of reservoir 3.6 km upstream of the Odo dam site of River Niyodo.

Scale Width; about 150 m, Height; about 100 m.

Geology, Mechanism and Type The landslide occurred on 19 April 1982, when the water level reached 204 m in initial filling of the Odo dam reservoir.

The geology consists of three strata of siliceous schalstein, chert and alternation of chert and slate from the inferior appearance.

Structurally, the area is located at the south wing of an anticline with a east-west axis. As to the strike and dip of the formations, the area crosses diagonally the above mentioned fold axis, and inclines towards the south.

It is assumed that the landslide in this area was triggered by the movement of a colluvial deposit type landslide at the lower part of the slope, which further led to the occurrence of a large-scale base rock-type landslide at the upper part near the 300 m altitude accompanying a secondary landslide further above.

Control Works Anchor works; In addition to this, hill side works and sodding works were conducted.

Present Condition Retest filling test of the reservoir after the control works were completed showed no sign of changes on the slope nor any abnormality in monitoring instruments. The slope has been in a stable conditon since then.

Crack occurrence at landslide head (April 1982)

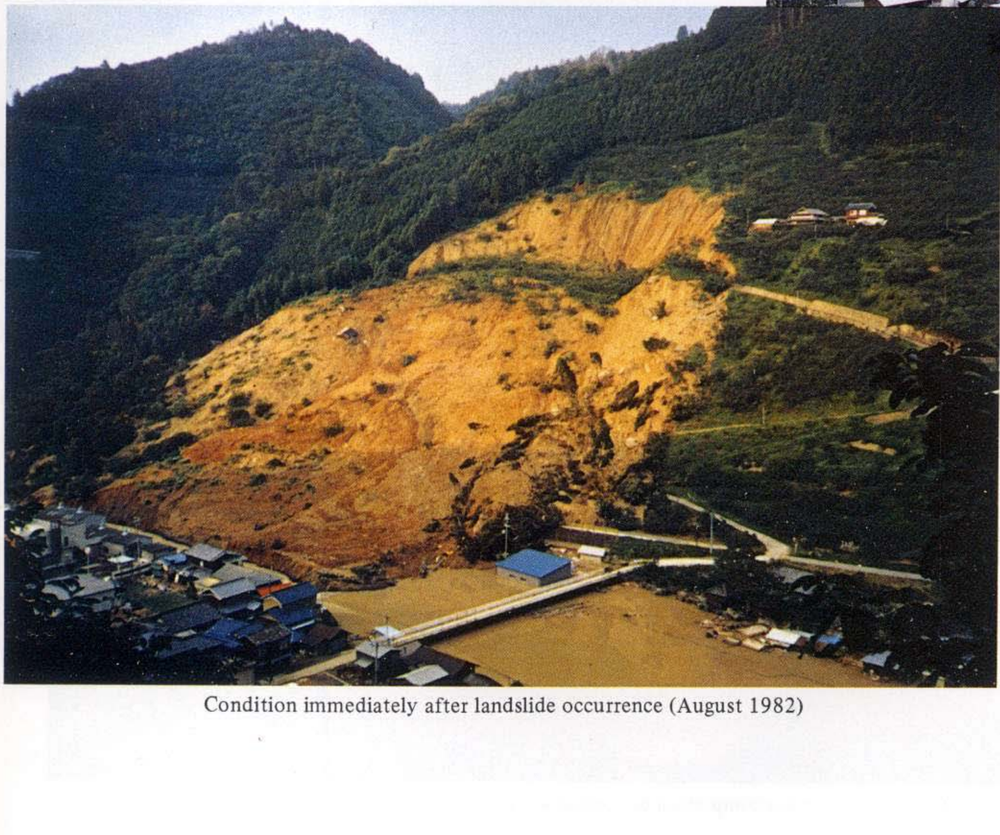
Condition after the completion of control works

Wada Landslide

Location Wadayanase, Nishiyoshino Village, Nara Prefecture (135°44'E, 34°18'N)
Scale Length; approximately 225 m, Width; 230 m, Area; 4.5 ha; Sliding volume; 500,000 m^3.
Damage The landslide occurred twice at 2 a.m. and 8:25 a.m. on 4 August 1982. The sliding mass blocked Nyuu River, resulting in the damage of houses, field and a road inundated. A sign of landslide was perceived in advance, which fortunately allowed the people to take an appropriate evacuation with no casualities to humans.
Geology, Mechanism and Type This landslide is located near the boundary between the Sanbagawa Zone and the Chichibu Zone, and geologically this area is mainly composed of slate formations in the Chichibu Zone which are markedly broken by tectonic activities. Its geological structure is; N70°E strike with 30° dip toward the north side. Therefore, the landslide movement direction is almost conformable to the dip of the formation, which shows that the site was both morphologically and geologically prone to landslide.

During the period from 0 a.m. in 1 to 4 p.m. on 3 August before the landslide outbreak, a 401.5 mm rainfall was recorded due to a typhoon. This abnormal initial precipitation is assumed to have induced the landslide. The 500,000 m^3 sliding mass did not slide at once, as mentioned before, but it is assumed that the failure of the lower unit took place first, followed by the slide of the upper unit through loss of balance.
Control Works Since the soil removal works was required to ensure the river cross section and to restore the road, mainly soil removal works and trimming hillside works at the head of the slope were conducted. In addition, to be protected such as houses, the river and the road, pile works were made to ensure higher factor of safety.
Present Condition The remedial works were conducted for 3 years from 1982 to 1984 at the cost of approximately 1,500 million Yen, and at present stability of the slope has been recovered.

Condition after the completion of control works



Condition immediately after landslide occurrence (August 1982)

Ogoto Landslide

Location Ogoto Town, Otsu City, Shiga Prefecture (35°05′N, 135°54′E)

Scale Length; 200 m, Width; 50 to 100 m, Depth; 5 to 10 m.

Damage The damage included cutting of a large-diameter water supply pipe, partial destruction of a pool owned by Ogoto Primary School, partial deformation of hotels located in the upper and lower parts of the landslide, and devastation of paddy fields within the landslide area.

Geology, Mechanism and Type Geologically, the area consists of a silty clay layer belonging to the Kobiwako group and valley bed sediment deposited on the group. The valley bed sediment is a very soft silt layer with N value of 2 to 3. Two slip surfaces are identified in this layer. A much higher montmorillonite content near these slip surfaces is observed in comparison with that at other depths.

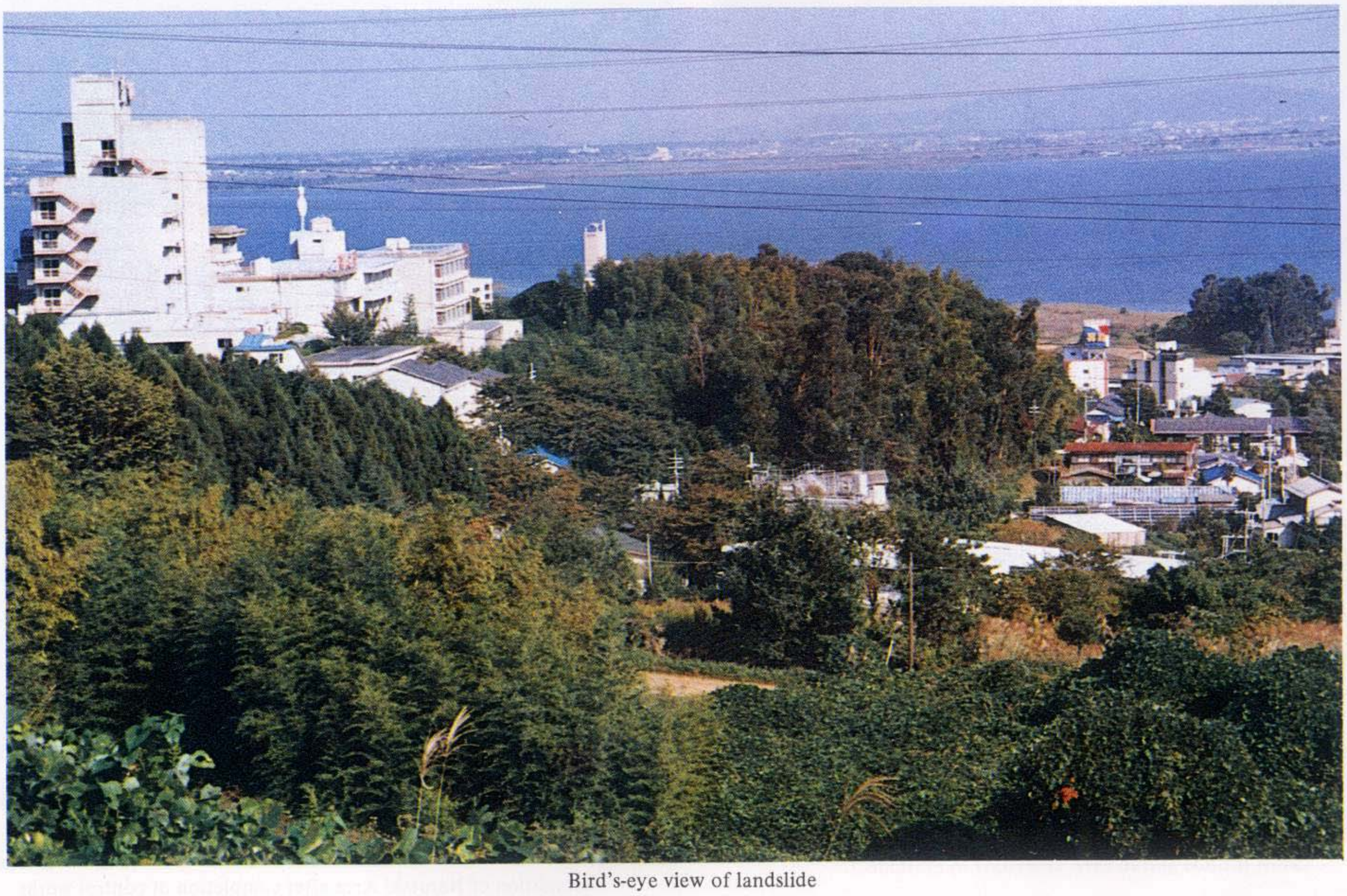
Fill was banked on the ground where originally soft valley bed sediment is laid. In 22 July 1967 when the amount of banking reached about 3,000 m^3, the landslide suddenly took place. One of the reasons is assumed to be a shallow ground water vein formed in the valley bed sediment was crushed by the banking.

This phenomenon resulted in accumulation of a huge amount of water behind the ground water vein with an unstable condition of the valley bed sediment and the overlying fill. Thus, the landslide movement started. The water supply pipe running along the landslide area was thus broken, and consequently the water was supplied to the sliding mass which had been in the unstable condition. Finally, on 22 June the violent activity took place.

The order of the landslide movement is recognized at first in the upper of the artificial fill. The activity responds very sensitively to a small increase in load: During July and August in 1973, water of 3,000 tons was charged in the water storage tank near the head of the landslide, and then a marked movement was observed from the upper to lower part of the landslide. This load is equivalent to 1% weight of the upper sliding mass. This phenomenon indicates a very sensitive response of a landslide in which landsliding has been once triggered and the difficulty in utilizing such land where landslide has once occurred.

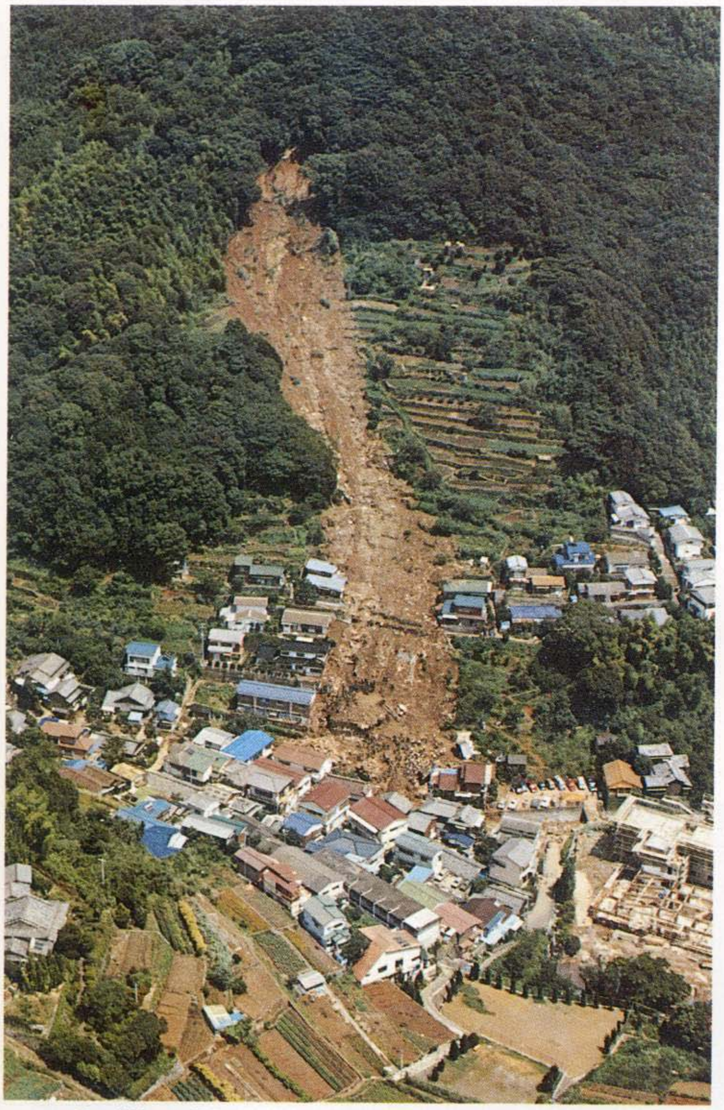
Control Works Drainage wells, horizontal drainages, and pile works.

Present Condition Observations of the movement and discharged ground water were conducted during 1967 and 1978. These results show a great effect of the control works after the movement in 1967, but the decreasing drainage ability since then has caused a slow annual movement of 5 to 10 cm.



Bird's-eye view of landslide

Slope Failures due to Nagasaki Storm



Condition of Narutaki Area immediately after the calamity occurred (July 1982)

The Nagasaki Disaster refers to the disaster caused by localized torrential downpour mainly in Nagasaki City.

The rainfall began on 23 July 1982 with daily rainfall of 527 mm and hourly rainfall of 111.5 mm, which is the new record since the Nagasaki Oceanographic and Meteolorogical Station was in service. Nagayo Machi located the north of Nagasaki City recorded the highest hourly rainfall in Japan of 187 mm from 19.00 to 20.00.

The rainfall caused many landslide, slope failures and debris flows (in Nagasaki Prefecture), resulting in a disastrous calamity of 299 killed and missing persons.

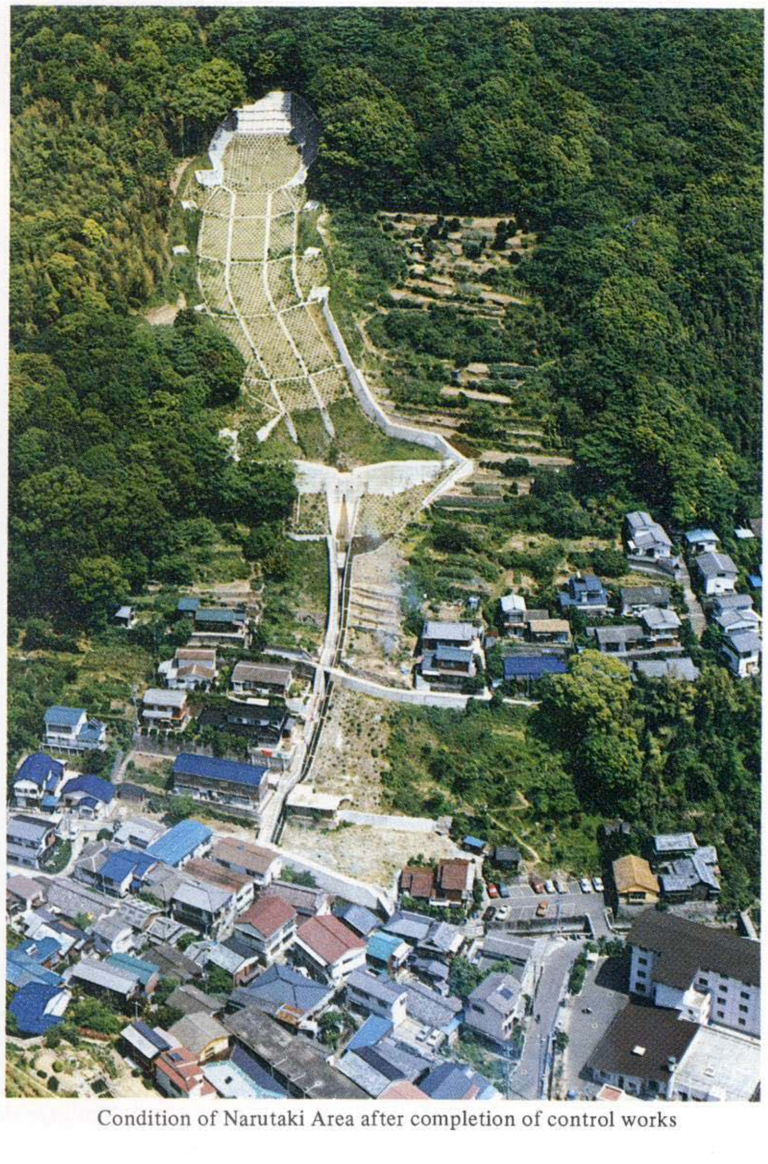
Location Narutaki Area and Okuyama Area, Nagasaki City, Nagasaki Prefecture (129°53′E, 32°44′N).

Scale and Damage

(1) Narutaki

Width of the slope failure; 40 m, Length; 300 m, Average slope inclination; 22°.

Twenty four killed and missing persons, and 10 totally destroyed houses.



Condition of Narutaki Area after completion of control works

(2) Okuyama

Width of the slope failure: 120 m, Slope length; 285 m, Average slope inclination; about 25°, Volume; 16,800 m^3.

Twenty-four killed and missing persons, and 12 totally destroyed houses.

Geology, Mechanism and Type Both areas belong to the Nagasaki volcanic rock area. Nagasaki volcanic rocks mainly consist of andesite lava and tuff breccias. These effusive rocks are mineralized to soft rocks in the due course of weathering.

In Narutaki a slope failure occurred at the upper part of the slope, and the majority of the sliding mass was left on the slope. But the sliding mass eroded the talus deposit and weathered rocks in the lower slope, turned into a debris flow and struck houses at the toe of the slope forming a mud flow.

In Okuyama, slope failure in heavily weathered rocks at the upper part of the slope and erosion of the debris and heavily weathered layer in the lower part caused slope collapse in a wide area.

Control Works

(1) Narutaki

Dam works (8 m high, 64 m long), Intercepter trench, hillside works.

(2) Okuyama

Small check dam, retaining walls, intercepter trench and slope stability work, hillside work, spraying, covering, planting and revetment works.

Present Condition In both areas the above-mentioned control works have been completed. Since the sliding mass in these areas completely slipped away, the control works were designed to stabilize the unstable fallen deposit.

Condition of Okuyama Area immediately after calamity occurred (July 1982)

Condition of Okuyama Area during control works

Maruyama Landslide

Location Nakasone, Iyomishima City, Ehime Prefecture (133°33′E, 33°50′N)

Scale Width; 180 m, Length; maximum 240 m, Area; 43,200 m, Average thickness; 35 m, Volume of sliding mass; 1,000,000 m^3

Damage The Shikoku Expressway of about 11 km total (length from Iyomishima I.C. to Doi I.C.) which was put in service for the first time in March 1985 as a National Expressway in Shikoku is located near or across the Median Tectonic Line. Thus, difficult construction works were expected. In the Maruyama site near the Median Tectonic Line, a large-scale earth cutting with the total amount to be removed of about 200,000 m^3 resulting in a long slope with about 40 m height (6 steps) planned. Excavation was very carefully conducted, while monitoring the ground behavior, and at the stage of about 130,000 m^3 cutting completed pile works were conducted to detain landslide. In spite of these counter-measures, with the advance in excavation cracks due to the landslide movement were observed on the slope, and finally the above-mentioned large scale landslide broke out.

Geology, Mechanism and Type Red soil develops on the surface layer, under which lutaceous crystalline schist lies. Some parts are markedly weathered bearing clay in some joints. Several clay layers, which are supposed to be old slip surface caused by rock slides, appeared on the slope.

Control Work The control works for the primary landslide include pile works that were conducted.

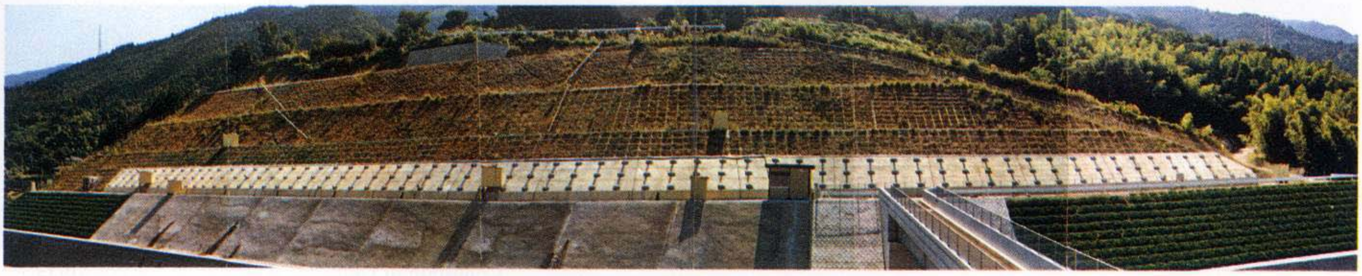
This area was judged to have potential danger of landslide, and the construction works were made while conducting behavior observations with various monitoring instruments. During the work, pile works were made to prevent the outbreak of landslide. In spite of these measures, an inclino meter indicated an abnormal displacement with the advance in excavation. The depth of the slip surface was much deeper than the expected one, and the landslide with much larger scale than supposed occurred. Then, since March 1982 the excavation work has been discontinued to make more careful observations with more behavior monitoring instruments and examine the mechanism of the landslide and control measures.

The control works for the secondary slide include; a drainage tunnel, horizontal drainage works, pile works, and anchor works.

Present Condition The landslide in excavation which was much more serious than expected made the control works very difficult.

The control works were completed in March 1984, and results of the behavior observation indicate a tendency of stabilizing after the completion of the works. For monitoring of the ground, observation will be conducted for another several years.

Condition prior to landslide occurrence. White line shows a superhighway scheduled to be constructed.



Condition during control works

7. Organizations Concerned with Landslide Study and Control

Japan Landslide Society

This Society was established in 1964. It has about 2000 members composed of researchers and engineers specializing in geology, topography, geophysics, civil engineering, erosion control, forestry, agricultural civil engineering and other fields concerned with landslides, from universities and colleges, research institutes, public organizations, consultants and private enterprises.

"Landslide", the journal of the Society, is published quarterly, and 90 editions have been already published. The contents are mainly research papers, and the Japanese editions are accompanied by English synopses.

General assembly and conference are held once every year as a rule, and normally there are 500 to 1000 participants and 40 to 80 papers are reported in every conference. In addition, symposiums and field workshops sponsored by the Society and its branches are held in various places throughout the country.

For international activities, the Society held the 1st International Symposium on Landslide Control in Kyoto, 1972. Then, the 2nd International Symposium on Landslides and their Control was organized by the Society in Tokyo, 1977. This symposium was continued to the 3rd International Symposium on Landslides in New Delhi, 1980, and further was followed by the 4th International Symposium on Landslides in Toronto, 1984.

The Society also joined or organized "Landslides Field Trip" with American Colleagues in 1979 (in U.S.A.), 1980 (in Japan) and 1983 (in U.S.A.) to exchange experiences and discussion in field. This was followed in Japan again during 23-31 August, 1985 as the 4th International Conference and Field Workshop on Landslides, which was supported by the United Nations, the USA National Research Council et al., 202 persons joined it and 81 papers were published. This meeting is to be continued as the 5th International Conference and Field Workshop on Landslides in Australia and New Zealand, 1987. The China-Japan Joint Field Workshop on Landslides will be also organized in China in 1987.

To provide an opportunity to exchange ideas and informations continually, the Japan Landslide Society will publish an International news letter "Landslide News" from 1987.

President: Shinichi Yamaguchi
Address: Kaga Bldg., 5-50-7, Shinbashi, Minato-ku, Tokyo 105.
Phone: (03) 432-1878

National Conference of Landslide Control

The Conference is composed of the governors of the 46 Prefectures of Japan. It is intended to contribute to improvement of the techniques of the member prefectures through investigation and study and disclosure of landslide records every year.

Chairman: Governor of Niigata
Address: 4-1, Shinko-cho, Niigata 950
Phone: 025-285-5511

Forestry Conservation Research Association

The Association was established in 1956 with forestry conservation engineers as its members for enhancing forestry conservation technology and developing business activities through the exchange of technical informations and the meetings for reading research papers.

The Association comprises the president served by the Director of Forestry Conservation Division of the Forestry Agency and about 6,400 members with 8 branch offices located across the country.

Activities of the Association include the publication of its journal for presenting research papers and exchanging views as well as the holding of meeting for reading research papers once a year. In addition, each branch office independently publishes journals and holds meetings for reading research papers.

President: Director, Forestry Conservation Division
Address: c/o Forestry Conservation Division, Forestry Agency, 1-2-1, Kasumigaseki, Chiyoda-ku, Tokyo 100
Phone: (03) 502-8111

The Japan Association of Landslide Control Techniques

The Association was organized in 1974 by consultants and contractors engaged in landslide control works and the manufacturers and dealers of the materials, machines and measuring instruments related to the control works. The Association is publishing a technical journal "Landslide Control Techniques" and holding lecture meetings, and is thus exerting efforts for extension of the landslide techniques, study of new control methods and development of new measuring instruments.

President: Shigenobu Sakano
Address: 5-30-7, Shinbashi, Minato-ku, Tokyo 105
Phone: (03) 438-0493

Universities and Colleges

Academic studies of the landslides are being conducted by researchers in the universities and colleges individually or jointly.

Sabo Technical Center (STC)

This Center was established in July 1975 mainly for preventing disasters due to landslides and debris-flows avalanche and improving and applying prevention techniques.

Many committees comprising specialist members in various related fields were established for solving problems by effectively carrying out surveys, plans, countermeasures and researches for preventing damages due to landslides, slope failures, debris flows and avalanches.

In addition, the problems of these disasters become more important also in foreign countries in recent years, and thus the Center is offering overseas technical cooperation and receiving trainees.

President: Shingo Azagami
Address: Seisen-Ichigaya Bldg., 3-4, Sadohara-cho, Shinjuku-ku, Tokyo
Phone: 03-267-8014

Public Agencies

a) Ministry of Agriculture, Forestry and Fisheries—Control of landslides for conservation of farm and forest land.
b) Ministry of Construction—Control of landslides and slope failures related to rivers, highways, dams and dwelling sites.
c) Japanese National Railways—Control of landslides for protection of railways.
d) The Japan Highway Public Corporation—Control of landslides related to specified highways.
e) Local Governments—Control of landslides coming under the jurisdiction of the respective local governments.

Research Institutes:

a) National Research Center for Disaster Prevention
Address: 3-1, Tennodai, Tsukuba-city, Ibaraki 305
b) National Research Institute of Agricultural Engineering
Address: 2-1-2, Kannondai, Tsukuba-city, Ibaraki 305
c) Forestry and Forest Products Research Institute
Address: Matsunosato-1, Kukisaki-machi, Inashiki-gun, Ibaraki 305
d) Geological Survey of Japan
Address: Higashi 1-1-3, Tsukuba-city, Ibaraki 305
e) Public Works Research Institute
Address: Asahi-1, Tsukuba-city, Ibaraki 305
f) Geographical Survey Institute
Address: Kitazato-1, Tsukuba-city, Ibaraki 305
g) Railway Technical Research Institute
Address: 2-8-38, Hikari-cho, Kokubunji-city, Tokyo 185
h) Central Research Institute of Electric Power Industry
Address: Abiko 1646, Abiko-city, Chiba 270-11

Academic Societies

a) Erosion Control Engineering Society
b) The Japanese Society of Soil Mechanics and Foundation Engineering
c) Japan Society of Civil Engineers
d) Geological Society of Japan
e) Japan Society of Engineering Geology
f) The Japanese Forestry Society
g) The Association of Japanese Geographers
h) The Japanese Society of Irrigation, Drainage and Reclamation Engineering
i) The Japan Society of Photogrammetry
j) The Japanesè Geomorphological Union

8. Index Map of Landslides Illustrated