LANDSLIDES IN JAPAN

The Japan Society of Landslide
National Conference of Landslide Control

1980

Preface

Japan is internationally noted for the frequent occurrence of landslides. Such landslides are attributable largely to the topographical and geological peculiarities and characteristic meteorological environment of the country.

Further, the damage arising out of landslides is strikingly great compared to most other countries. As the reason for this, it is believed that with the rapid restoration of the national land after the War and the succeeding high rate of economic growth, the limited land was utilized to the highest extent for development of the national land, resulting in an expansion of the area vulnerable to damage and increase of articles susceptible to damage.

The government was very anxious about the increasing damage of landslide and thus enacted a law concerning landslides in 1958 in order to implement radical control measures.

On the other hand, to promote study on landslides, Japan Society of Landslide was established in 1964 so that researchers and engineers in the various fields would cooperate and exert efforts toward the clarification of landslide phenomena.

Through such efforts, the whole aspect of the landslides distributed throughout the country became apparent, while landslide investigation techniques made remarkable progress.

For control of landslides, a number of works were carried out with budgetary appropriation increasing year after year, while the improvement and development of control methods noted appreciable progress.

Now, following the "Landslides in Japan" Nos. 1 and 2 published already, we now present No. 3, representing the recent condition of landslides in Japan and the actual situation of the landslide investigations and control works. It is a pleasure for us if the book may serve you as reference material.

The help and guidance received from many individuals and organizations in publishing the book are most gratefully acknowledged.

Toshio Taniguchi
President, Japan Society of Landslide

Edited by

Chief, YAMAGUCHI, Shinichi
SEKIDO, Kenichi
AKIYAMA, Koshi
ANDO, Takeshi
ISOZAKI, Yoshimasa
ITAGAKI, Osamu
OYAGI, Norio
OZAKI, Masaatsu
KIKUCHI, Akira
KURODA, Kazuo
NAKAMURA, Saburo
NAKAMURA, Hiroyuki
NAKAYAMA, Yasushi
YASUNAKA, Toshio
YOSHIOKA, Yoshiro
YOSHIKAWA, Keiya

Published by

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1. Relation between Landslide Disasters and National Life

Seventy percent of the Japanese Archipelago is mountainous. People have lived on rice for several thousand years on the plain (13% of the whole area) and hills. Thus, rice, which yields a heavy crop per cultivated area, was necessary. Paddy fields spread from plain to valley and, finally, hill sides thereby coming to be effected by landslides. In the 12th century a priest on a pilgrimage was buried as a human immolation to check the Sarukuyoji landslide in the Niigata prefecture.

Water for the paddy fields is provided by the rainfall during a rainy spell of *Baiu* in early summer and the melting of snow accumulated in the mountaneous areas in the Central and Northeast Japan in winter. These water sources together with typhoons, are also the main causes of landslide.

An earthquake causes landslides at a convex slope and flows of unconsolidated material such as a pumice-fall deposit on the gentle slope.

Landslides usually have favorable conditions for rice cultivation; rich in spring water resources, natural deep plowing and gentle slopes. Although villages are developed in landslide areas, roads between them followed the ridgelines to avoid damages by landsliding and flooding.

Some types of landslide control have a long history. Piles were given a trial at Sarukuyoji in the 12th century and counterweight fills at Nagano in the 19th century.

It is about one hundred years since Japan began to modernize. Railways and highways were constructed making detours around landslides and other dangerous sites.

One of the postwar problems was how to feed a large number of people in a small national land area. So, land conservation and development were matters of great importance. At first, landslide control works were tried on the basis of such related legistrations on landslides as the erosion control, river improvement, forestry prevention, agricultural land maintenance etc. Epoch-making legislature took place the "1958 Landslide Prevention Law."

The 1960's were a period of intense economic growth in Japan. People came to want and be able to afford more intensive land development. But, besides conventional landslides, disasters triggered by the reservoir water of dams for water resources development, the construction of highways and the reclamation of suburban building land cause many landslide problems. However, recent progress of landslide control technique has made it possible to solve actively those problems.

Legislative measures providing for the government to shoulder the expenses and provide administrational guidance for recovery from natural disasters for which no individuals bear responsibility have been enacted.

These measures provide for dangerous houses being removed; water leaks from irrigation works repaired and such. Not only restoration to the original form, but also preventive improvement will be permitted to check disasters in future.

The Slope Failure Prevention Law enacted in 1969 deals with steep slopes over 30° in inclination, over 5m in height and with 5 houses or more.

Two thirds or half of the cost will be provided by the central government and the rest will be allocated by the prefectural one according to these two laws.

2. General Trend of Landslide Research and Control

Japan has a number of landslides and slope failures caused by typhoons, a heavy rainfall in the rainy season, or spring thaw every year and thus suffers damage to life and property including interruption of road and railway transportation.

With rapid social development and accompanying land development in and after the 1960's, mountainous and hilly sites have come to be more fully utilized thus increasing the chances of various ground disasters occurring.

Further, through development of civil engineering techniques, it has become possible to execute large scale earthworks and constructions recently. Thus, large scale newtown projects and construction of expressways and dams have been carried out at various sites, and such projects have had to be carried out in landslide regions.

Given such a situation, slope disaster control engineering developed to cope with natural disasters in Japan has come to require new slope disaster control techniques in the new field of predicting and estimating landslides.

Remarkable progress, stemming from the outcomes of the investigations, research and control methods during the last decade or so show remarkable progress. Articles and reports presented in the journals "Landslide" of the Japan Society of Landslide (Nos. 1 to 57 since 1964), "Landslide Study" of the National Conference of Landslide Control (Nos. 1 to 23 since 1956) and "Landslide Techniques" of the Japan Association of Landslide Control Engineering numbered more than 250, 105 and 30 respectively, and they are generally excellent works. Additionally, research reports from the related societies and associations and research organizations number in the dozens every year.

Generally, in the field of the ground disaster science, it is of primary concern how to realize the results of research in the actual control work. The government, research institutions and industry have pooled their efforts and are working as one to achieve this end.

Along with the meetings for reporting on research work held every year, meetings of the International Symposium on Landslide Control were held twice, in 1973 and 1978, in Japan, with their outcomes being evaluated highly.

Today, the social significance of the study and control of landslides is coming to be understood more and more. Fundamental study on landslides is carried out mainly by the Japan Society of Landslide, while control techniques and works are investigated largely by the National Conference of Landslide Control and the Japan Association of Landslide Control Engineering, with good results.

Today, the study is finely divided, and research is being carried out in the fields of geology, geomorphology, geophysics, forestry, meteorology, hydrology, erosion control and soil mechanics on the mechanism of generation of landslide, prediction and estimation, control techniques and works and use of the landslide site. For example, in the field of geology, the study is executed from macroscopic to microscopic examination, and inquiry is made into the process of generation and weathering characteristics of the clay along the sliding surface and the role of the system of fault and fracture in the strata as the factors causing landslides. Further, an attempt is made for introduction of bedrock dynamics as a means of clarifying the phenomena.

In the field of topography, topographical features are investigated using the techniques of remote sensing developed recently, together with studying the influences of the Quarternary climatic changes on the landslide topography and ground condition.

In the field of geophysics, efforts are made to obtain a more precise understanding of the landslide phenomena and clarification of the mechanism through development and improvement of high performance measuring instruments, and observation and analysis utilizing such instruments to enhance the level of accuracy of landslide prediction, with good results.

In the field of geochemistry, the mechanism of landslide is being investigated through examination of the distribution characteristics of ground water from the chemical study of the quality of land water and chemical analysis of the clay minerals.

In geotechnical engineering, the knowledge of soil mechanics, having made a great advance in recent years, is used in the clarification of landslide movement or analysis of slope stability, and is thus contributing greatly to the development of control works. Good results are also being produced by the FEM analysis of landslides with the landslide movement taken as a viscoelastic movement and in the development and measurement of special testing machines for examining the shear strength property of the sliding surface.

In the field of civil engineering, with increasing reliability of the structures, a slope stability control work by means of large structures has come to be used in the mountainous regions, while anchor, piling, drain well and other works have come to be used extensively.

Efforts are being vigorously exerted toward more accurate prediction of the degree of danger through close cooperation of researchers and engineers in all fields, and the accumulated outcomes are used effectively at the sites.

3. Geology and Landslides

The Japanese Islands are situated on the border zone between the Eurasian Continent and the Pacific Ocean. They consist of island arcs, generally extending in a direction of northeast to southwest and convexing toward the Ocean, except one running north to south. The former are Kuril, Northeast-Honshu, Southwest-Honshu, and Ryukyu arcs and the latter is Izu-Mariana arc (Fig. 3-3). The Islands also belong to part of the Circum-Pacific Volcanic and Seismic Belts. There are 77 active volcanoes in the Islands inside of the "Volcanic Front" which is about 200 kilometers away from the trenches toward the Continent. The Islands have been also suffered severe damages by earthquakes occurring inside of the trenches. The Islands are geotectonically divided into two parts, Northeast and Southwest Japan, by the Fossa Magna or the Itoigawa-Shizuoka Tectonic Line. They are also divided into the Inner and the Outer Zones by the Median Tectonic Line. The Islands are underlain by various kinds of rocks from pre-Silurian to Holocene time and have repeatedly suffered tectonic movements since Paleozoic time, showing extremely complicated geologic structures. Those geologic constitution and the landslide distribution (Fig. 3-2) lead us to divide the Japanese Islands into eight geologic units for engineering purposes, especially those of landslides (Fig. 3-1).

1) *Geosynclinal zones of Paleozoic and Early Mesozoic ages.* They are characterized by zonal arrangement of metamorphic, in the low pressure and the high pressure types, and non- or weakly metamorphosed belts which are parallel to the longitudinal axis of the Islands, especially to that of Southwest Japan. The rocks in the zones are highly consolidated by diagenesis and metamorphism and consist of clayslate, sandstone, chert, limestone, tuff, tuff-breccia, crystalline schist and gneiss, intruded by several kinds of igneous rocks. Those rocks have been folded and fractured severely to be rich in cleavages, schistosities, joints, faults and shear zones. Those belts constitute mountainous areas of high relief and steep slopes.

Debris creeps or slow debris slides are the most typical landslides in the belts. Those mass movements occur in debris or colluvium on gentle slope derived from weathered crystalline schists, especially pelitic one, and clayslate. Their movement is usually accelerated by rainfalls as the Kubino and Kitano Landslides (p.29) and by human activities such as road contructions. Some slides distribute in sheared zones of non-metamorphic rocks and segments of sheared igneous rocks and serpentinite as the Choja Landslide (p.27).

Rapid bedrock slides can be sometimes observed generally in steep slopes as the Shigeto Landslide of 1972. Those slides, and surficial slides and debris flows have been also caused by heavy rainfalls brought by typhoons and temperate monsoon Baiu-fronts.

2) *Shallow sea or non-marine deposits of Late Mesozoic to Paleogene age.* Those rocks are unconformably underlain by the geosynclinal accumulations and divided clearly into two zones. 2a). The first is the zone of marine

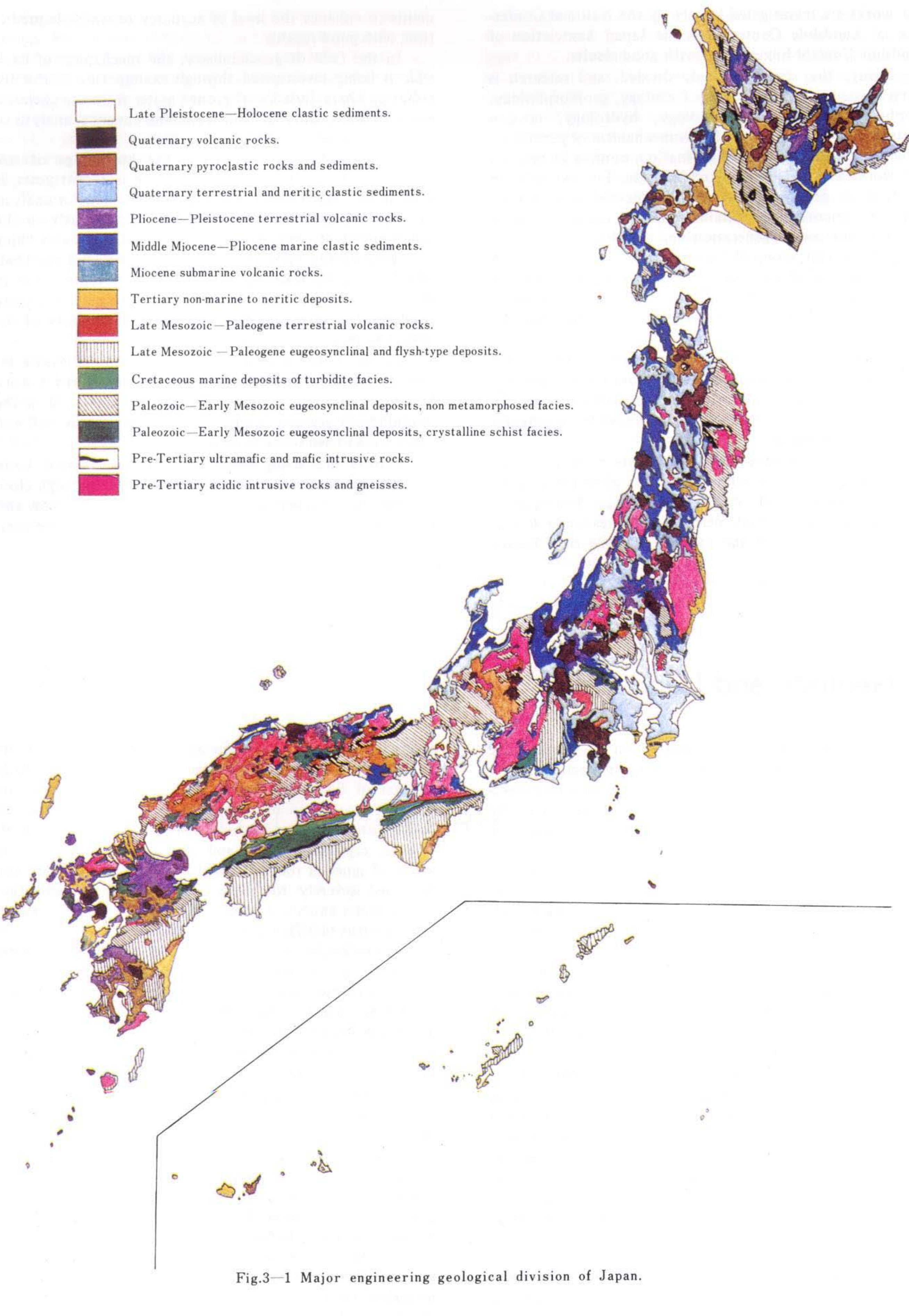


Fig.3—1 Major engineering geological division of Japan.

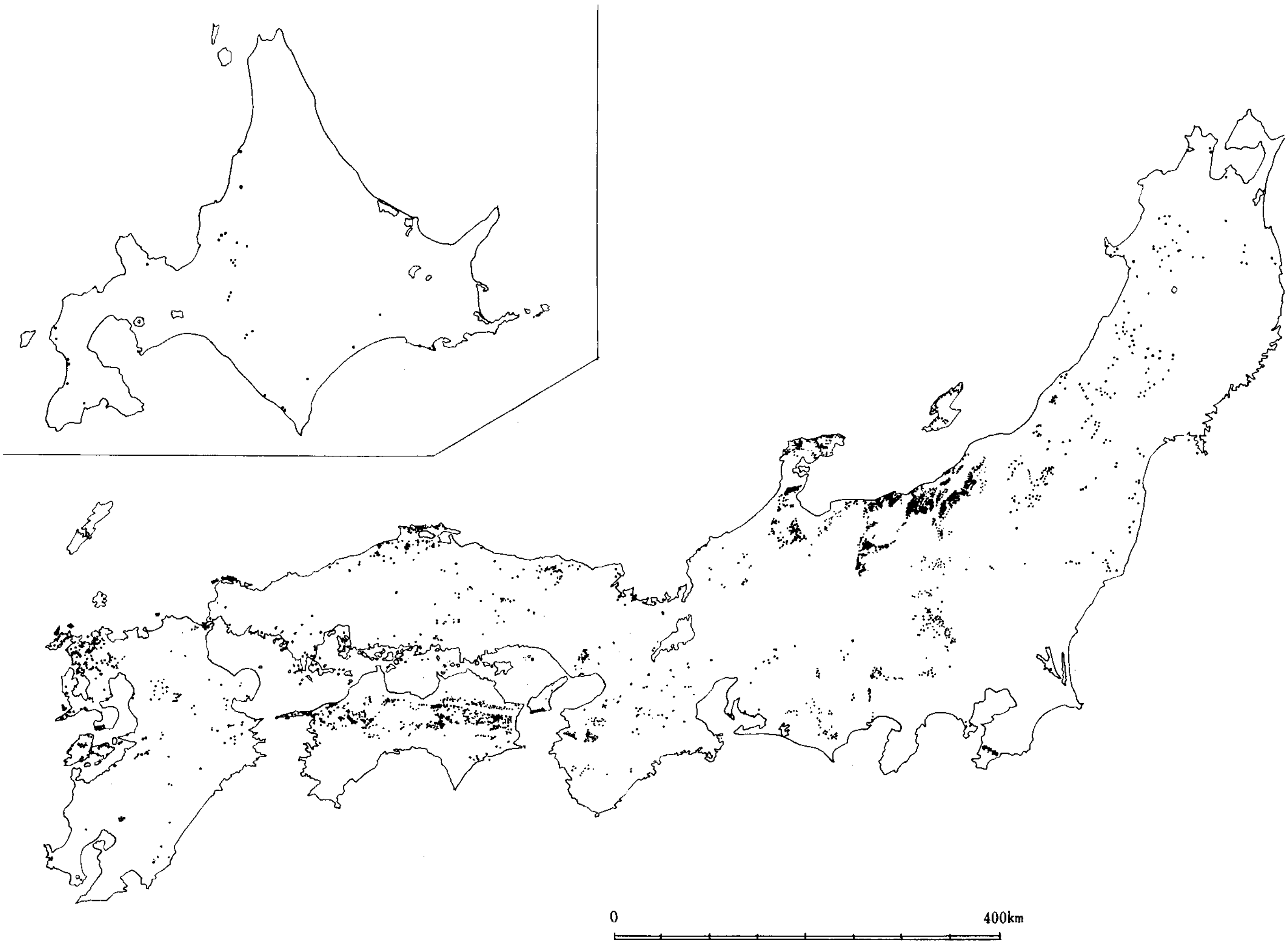


Fig. 3-2 Landslides designated by the government for control works

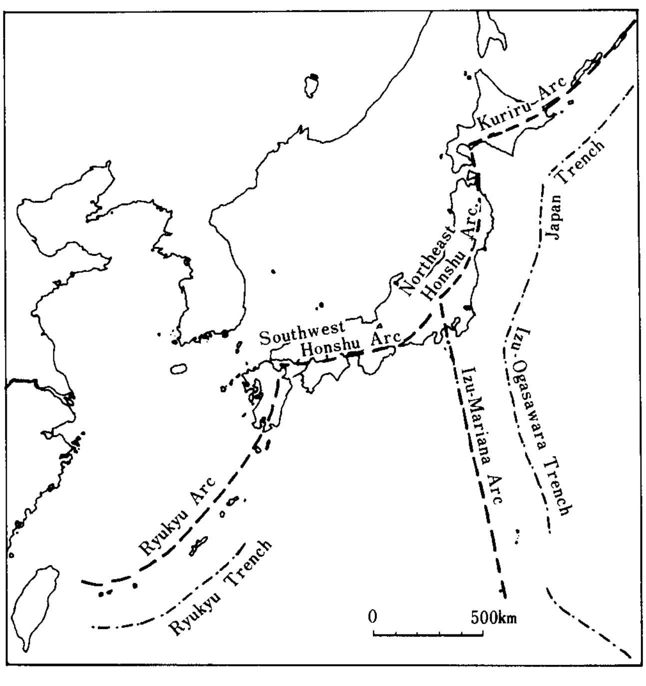


Fig. 3-3 Trenches and island around Japanese Islands

deposits of the Early to Late Cretaceous age, distributed along the Median Tectonic Line in the, south side of the central axis of Southwest Japan. Those of Paleogene age may be included to this zone in the central western Kyushu. The rocks are dominated by turbidite facies.

2b). Eugeosynclinal and flysh type deposits along the southern margin of the Southwest Japan and have been consolidated by diagenesis. The areas underlain by the rocks show sharp ranges of high relief and steep slopes.

Landslides are mainly debris creeps, slow debris slides and bedrock slides in the area in the Cretaceous marine deposits (2a), similar to those in the Paleozoic-Mesozoic accumulations. A heavy rainfall, however, triggers a number of surficial slides and debris slides or flows which cause severe damage to human lives. Futher, rapid debris and bedrock slides occur also in the area of the deposits (2b) by heavy rainfalls.

3) *Terrestrial volcanic and plutonic rocks of Late Mesozoic to Paleogene age.* The older rocks have been covered by the Late mesozoic volcanic rocks of andesite to rhyolite and intruded by granitic rocks of Late Mesozoic to Early Paleogene age in the Inner zone.

The areas of the volcanic rocks are relatively mountainous and of high relief, and fairly stable for landslide phenomena. However, debris and bedrock slides have sometimes occurred along fault sheared zones, as the Ichinomiya Landslide (p.28). On the othrer hand, severe disasters due to surficial slides and debris flows have been caused by heavy rainfalls in the area of the granitic rocks.

4) *Paleogene to Early Neogene non-marine to neritic deposits.* They are sporadically found in the limited basins and composed of alternating beds of sandstone and mudstone, called as a cyclothem type. They bear workable coal seams developed as the most important coal fields in Japan. The mountains are generally gentle in these areas than in those of the Paleozoic accumulations. Those deposits unconformably overlain by Late Neogene basalt lava flows in the Northwest Kyushu.

Landslide occurrence has been sparse in the Paleogene areas. However, landslides have happened in some coal mining sites as the Kita-Ichinosawa Landslide (p.13). In the Northwest Kyushu, large landslides have been densely occurred. This reflects the geologic structure of the area which is the combination of the basalt flow cap rocks and the underlieing Miocene deposits. Examples are the Hirayama and Washiodake Landslides (p.24 and 25).

5) *Marine sequences ranging from Early Neogene to Early Quaternary.* The sequences cover older rocks with distinct unconformity, and trend to be discordant with geotectonical arrangement of the older rocks. The following three characteristic provinces are distinguished owing to the separation of the sedimentary basins. 5a). The province underlain by the Miocene deposits of abundant submarine volcanic rocks, lava and pyroclastics, ranging from mafic to felsic, which are often altered into so-called "Green Tuff". They are intruded by many dikes, sheets and stocks. 5b). The non-volcanic and vigorous depression province, composed of thick marine deposits which consists of thin basal conglomerate, thick black mudstone, siltstone and sandstone. 5c). The non-volcanic and less depressional province underlain by mudstone, silstone and sandstone.

The first province forms mountainous area, but others show relatively gentle hilly lands. Sometimes representing cuesta topography reflecting geologic structure of the gentle folding or monoclinal structures.

Large and gigantic landslides have occurred in the first province (5a), for example the Yui Landslide (p.22). The Kamenose Landslide (p.23) may be included to this province because of similar engineering lithofacies of the geology in Kamenose area with those of "Green Tuff". There are also found medium to small slides of bedrock and debris ones. The former examples are the Handawara Landslide in Narugo dam reservoir and the Iwadonoyama Landslide (p.12 and 36), and the latter are the Yunotai and Makiuchi Landslides (p.14 and 31). The rate of movement is slow to rapid. In the second province of the thick black mudstone (5b), landslides are generally medium to large in scale and occur densely on mountain slopes. The movement is usually slow and the types of landslides are mud or debris creeps to slides as the Matsunoyama, Kamihiramaru, Sarukuyoji, Chausuyama, Shimizudani Landslides (p.15, 18, 19 and 21), etc. However, they often turned into mud or debris flows. In the third province (5c), landslides are densely populated in some areas and relatively rare in other areas.

6) *Quaternary terrestrial or non-marine clastic sediments.* They covers the older rocks with unconformity or distributed in hilly areas around the mountains of older complexes. Their lithofacies are fairly heterogeneous, because their sedimentary basins are small in size and separated each other. The sediments are chiefly semi-consolidated or unconsolidated layers of gravel and sand, with occasional silt and clay intercalating lignite seams. They are covered by weathered volcanic ashes in some areas. Landslides are rather sporadical in the area and small to medium in scale. However, problems may be surficial or shallow slides caused by heavy rainfalls.

7) *Quaternary volcanoes, and their associated lavas and pyroclastic rocks.* There are many active and dormant volcanoes in Japan. Those volcanoes are very dangerous for landslides as well as volcanic eruptions. Some parts of volcanic rocks constituting the steep strato volcanoes have been severely altered into zones by pneumatic and hydrothermal activities. This condition combined with increasing vapor and pore water pressures causes rapid and large landslides which often change into violent debris flows rushing down along valleys and damaging villages. Their recent examples are the Sounzan and Owakudani Landslides (p.34).

8) *Shallow sea or non-marine deposits which filled the valleys of Würm-maximum age and other basins at the same age.* The deposits are usually called "Allvium" in Japan, and their depositional structures form the plains, where the greater part of cities, agricultural fields and industrial districts have been developed. There are few landslide phenomena found except slope failures in artificial fills on the plains. However, ground subsidence is the difficult problems in the plains.

Rencently, earthquake-induced landslides have become one of important landslide problems in Japan. The earthquakes of 1974 and 1978 near the Izu Peninsula triggered many debris and rock slides, and rock falls. Those mass movements caused severe damages with great loss of lives as the Nanamagari and Nashimoto slides (p.32 and 33). Cracks were newly opened and pre-existing fractures were enlarged extensively. Probably, this leads to weaken the stability of slopes. A lot of surficial slides were caused by the heavy rainfalls after the 1978 Near Izu-Oshima earthquake in the central part of the Izu Peninsula (p.33). Many man-made slopes developed by filling the valleys in Sendai City were slid and cracked by the 1978 Off-Miyagi-Prefecture earthquake. Some of those have been abandoned to use.

Reactivation of large or gigantic landslides has been caused by various human activities such as ill planned cuts and fills and by natural agents. This is becoming another problem for landslides and will be more important for future developments of the Islands.

4. Landslide Investigation

Where landslide control is made on a prevention plan of landslide motion or in prediction of landslide occurrence, it is required to conduct an investigation of the landslide area and analyze the data obtained.

Landslide Investigation Methods

The landslide investigation comprises generally of six items according to the object of investigation as shown in Table 4-1.

Table 4-1 Survey items for landslides investigation

Survey items	Objects
(1) Displacement measurement	(a) Grasping the actual condition of the slide on the ground surface.
	(b) Determination of the landslide area (Including the potential landslide area).
(2) Geological survey	(a) Looking into the ground formation and geologic structure.
(3) Sliding surface measurement	(a) Confirming the location and configuration of the sliding surface.
(4) Groundwater survey	(a) Grasping the distribution of groundwater.
	(b) Investigation of the relation between groundwater and slide.
	(c) Clarifying the origin and flow of groundwater.
(5) Soil test	(a) Investigation of physical and dynamic charactersitics of clay along the sliding surface.
(6) Hydrological survey	(a) Investigation of the relation between rainfall or groundwater and slide.

For such items, the methods of investigation usually employed in our country include, in addition to the customary field survey, the following.

Seismic prospecting

Seismic prospecting is for the purpose of determining the ground structure of the landslide area by obtaining the velocity layer of the ground through measurement of the traveling time of a seismic wave, and the P wave-refraction method is used generally for such purpose. In the case of a large landslide area, it is difficult to classify the area into units by field survey. Here, studying the ground structure by this method is effective for unit calssification. Moreover, over the last several years, there have been increasing cases of the S wave-refraction method being used jointly with P wave-prospecting. The S wave is used for the purpose of not only knowing the seismic property of the ground through determination of the modulus of elasticity of the ground constituting the formation of the landslide area in reference to the P wave, but for making classification of the ground by the modulus of elasticity. For the source of S wave, a knocking board method is used.

Further, for the purpose of knowing the detailed distribution of the layers in the landslide area such as, for example, discontinuous surface, a shallow layer reflection method has been developed.

Natural radioactivity prospecting

Radon, thoron and other gases produced upon decay of radioactive elements in the ground rise to the surface through the faults and fissures in the bedrock so that by measuring the gamma ray of radioactive gases at many points on the ground, faults or fissures related to the landslide are prospected.

Drilling survey

Rotary boring is made from the surface to the bedrock and, upon arrival to the bedrock, farther to a depth enough to confirm that it is the bedrock, then the entire core is collected to visually confirm the formation of the layers. In identifying the core, emphasis is placed on classifying into surface soil, colluvium, weathered zone and bedrock in order to determine the layer formation and, at the same time, sliding surface.

The borehole is usually of a size of 66 mm, in diameter but if the hole is used for any other survey, its size is to be determined accordingly.

Electric prospecting

For landslide investigation, a specific resistance method is used upon the assumption that the difference in the value of specific resistance of the ground is based on the difference in the formation. The specific resistance method is classified into horizontal prospecting and vertical prospecting, and for obtaining basic data for the ground water drainage work or investigation of the formation, horizontal prospecting is used.

Electric logging

This is the specific resistance vertical prospecting using a borehole. It represents the relationship between the specific resistance and the formation more correctly than above-ground electric prospecting. This method is effective for investigation of the distribution of ground water.

Displacement measurement by extensometer

The extensometer is an instrument to measure the displacement between two points on the surface, and is installed along the measuring line for the landslide investigation in a direction parallel to that of the landslide. In general, a number of extensometers with self-recording system are installed across the scarp or flanks, and the displacement of sliding mass is recorded with time.

The displacement is taken as a function of the rainfall or groundwater level and is used for analysis of the mechanism of landslide or as a material for choice of control works. Further, from the data of extensometers, the strain and strain rate can be calculated so that the displacement measurement is effective for prediction of the failure of a landslide mass. Further, if the strain rate is predetermined, the displacement can be used in conjunc-

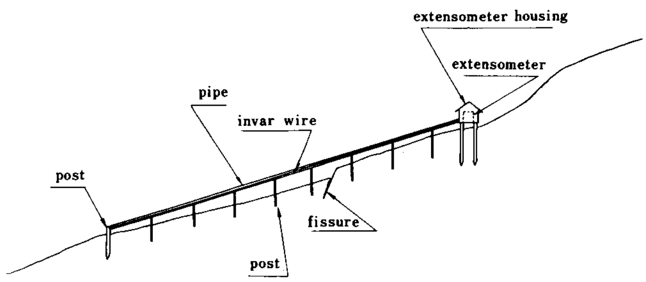


Fig. 4-1 Setting of an extensometer

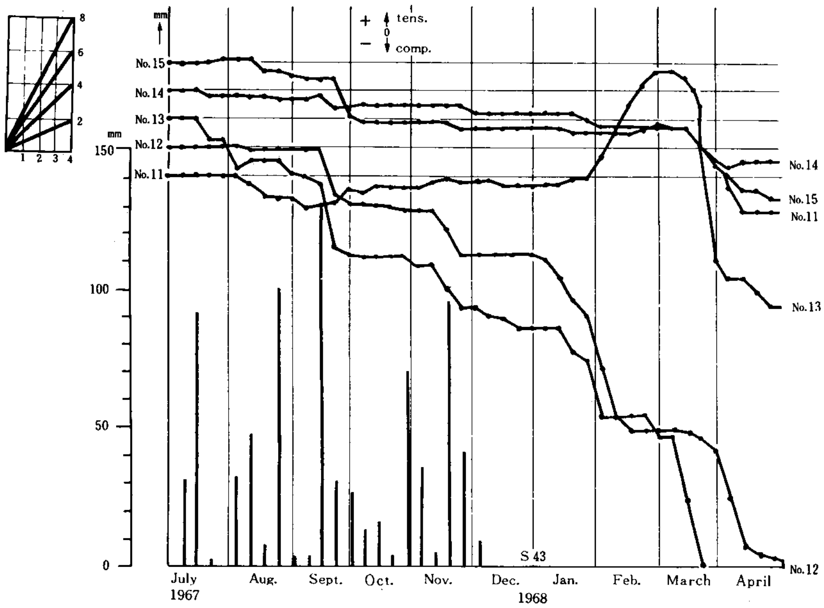


Fig. 4-2 Daily variation of displacement velocity (No. 12-14 point measurement)

tion with a landslide alarm.

Measurement of ground surface fluctuation by tiltmeter

By measuring minute fluctuations on the surface of the sliding mass, determination of the landslide area or prediction of the displacement of a potential landslide is made. The tiltmeter is so installed as to measure the fluctuations in two directions at right angle to each other at one point. It comprises two types, self-recording and manual. But, as it is desired to install as many meters as practicable in the area of investigation, cheap bubble-tube-type tiltmeters have heretofore been used.

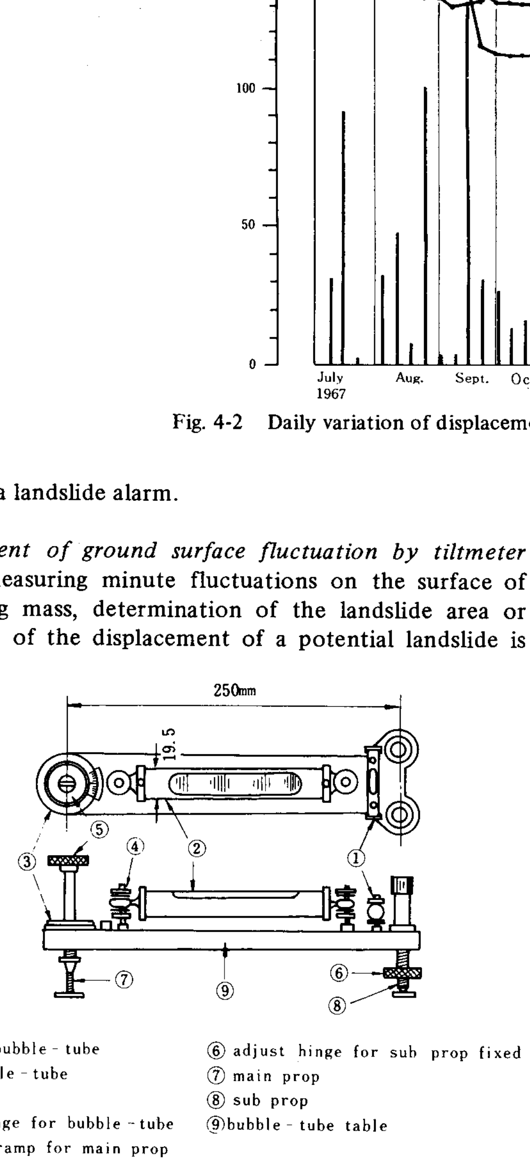


Fig. 4-3 Structure of a bubble-tube type tiltmeter

Measurement of ground surface displacement by surveying

The survey is roughly divided into ground survey and aerial photo survey.

In the ground survey, a method of measuring the displacement of a point provided on the sliding mass by viewing from two points on the stable land on the respective sides of the sliding mass and dropping the perspective line onto the sliding mass is employed, but triangulation or three side interval measurement is also used. The three side measurement has two bench marks fixed on the stable land outside the sliding mass, while a plurality of points are provided on the sliding mass, to measure the distance of three sides by means of a geodimeter.

In the case of a landslide moving greatly, it is possible

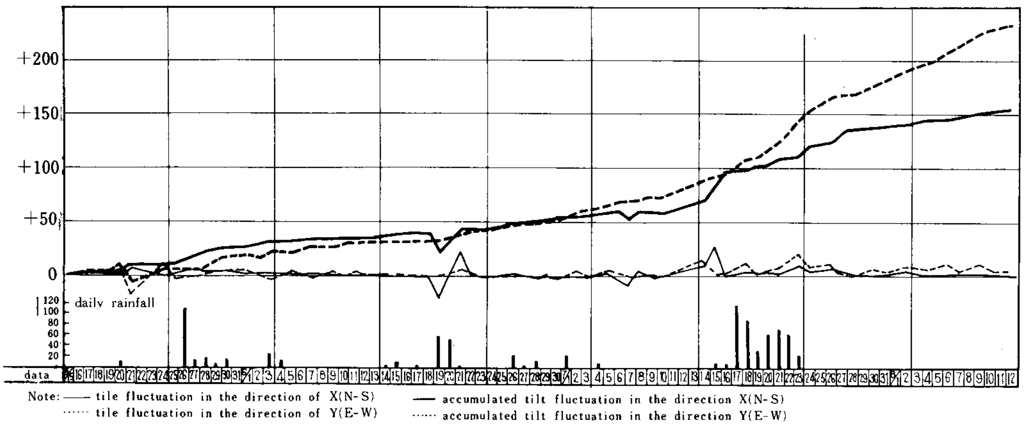


Fig. 4-4 A measurement result of the tiltmeters

to grasp the movement of the points for measurement stations using aerial photos taken periodically. According to some actual cases, a scale of 1/6000 or so permits detection if the movement during the interval of photographing exceeds 5 cm.

Measurement of sliding surface by pipe strain gauge

The pipe strain gauge has a pair of completely waterproof paper strain gauges mounted on both sides of a polyvinyl chloride pipe at the respective depths of measurement and is inserted in a borehole with wiring. Displacement of the mass by sliding deforms the pipe and, at the same time, changes the electric resistance of the strain gauge so that the values of resistance are measured and adjusted to determine the sliding surface.

Recently, a method of depositing a flexible pipe having a guide rail provided on the inner surface into the borehole and inserting a tiltmeter along the guide rail and thus detecting the sliding surface from the bend of the pipe, has come to be used.

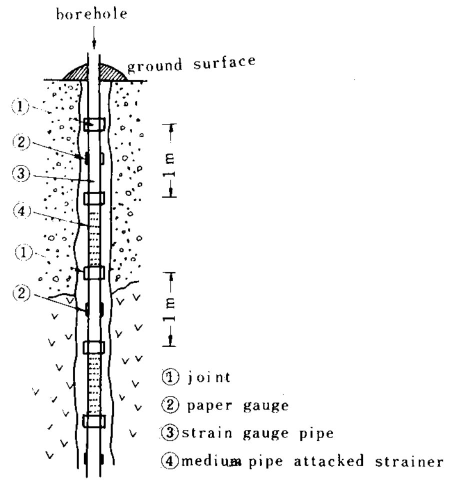


Fig. 4-5 Setting of a pipe strain gauge

Groundwater level survey

For measurement of the level of groundwater, manual detection of the groundwater surface and automatic recording are available, the latter comprising a type utilizing a float and electric contact, both designed for measurement of the level of groundwater in the borehole.

Where measurement of the pore water pressure in the clay along the sliding surface is to be made, it is often substituted with the measurement of the water level, which is comparatively simple.

Groundwater prospecting

This is to detect the location of the flow of groundwater as the electric resistance of solution of electrolyte introduced and stirred in the borehole changes with time as it is diluted.

Groundwater tracing test

This is to investigate the route of groundwater in the landslide area and its surrounding area using the boreholes provided in the area or springs. Prior to tracing the groundwater, a groundwater level survey, groundwater prospecting and examination of the water quality is required. The groundwater investigation is conducted by introducing a reagent into a borehole which is considered to be located at the uppermost part of the route of the groundwater, then measuring the time of elapse until detection of the re-

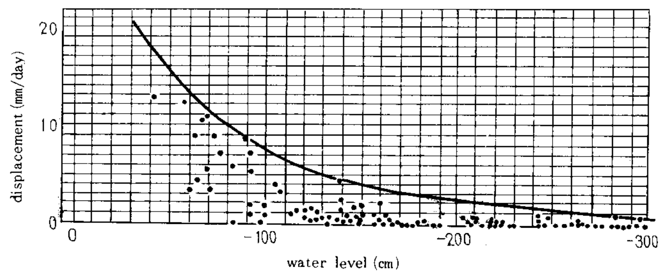


Fig. 4-7 Relationship between displacement velocity and groundwater level at a landslide

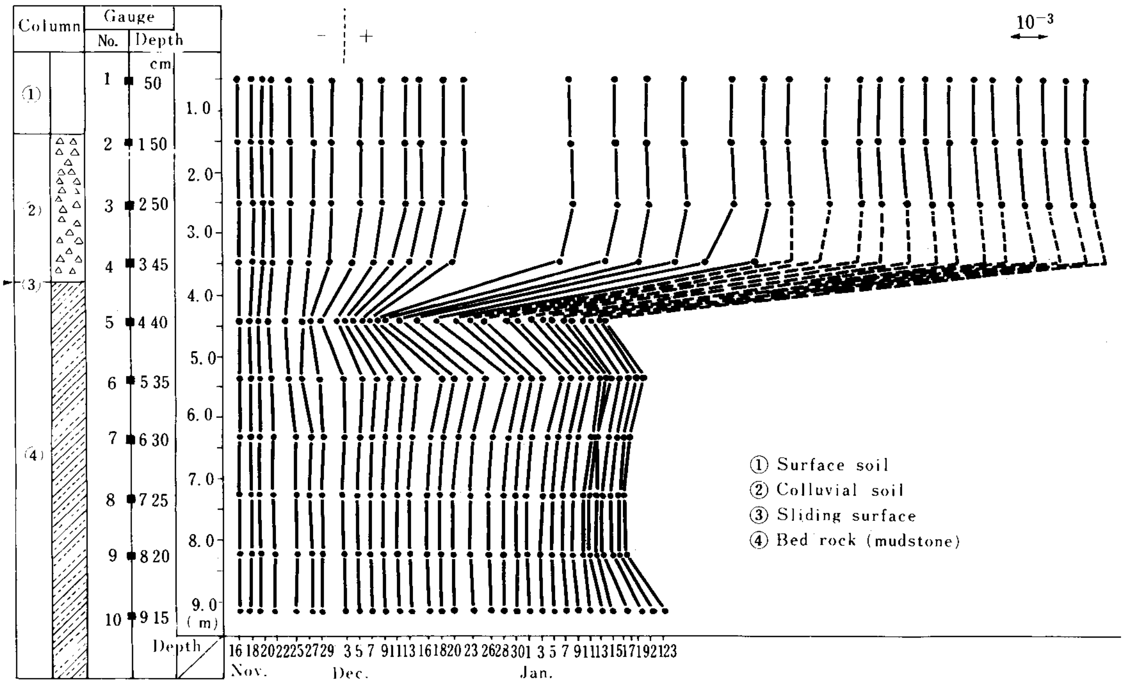


Fig. 4-6 A discription of a measurement result of a pipe strain gauge

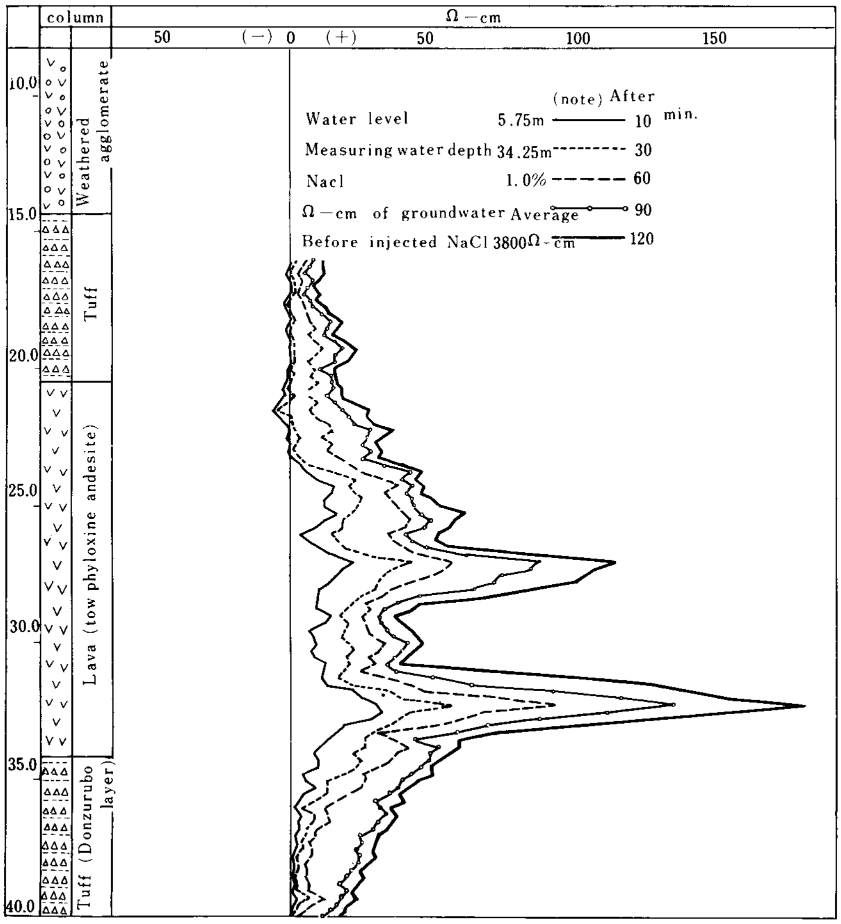


Fig. 4-8 Groundwater prospecting at the Kamenose landslide (No. 4217 borehole)

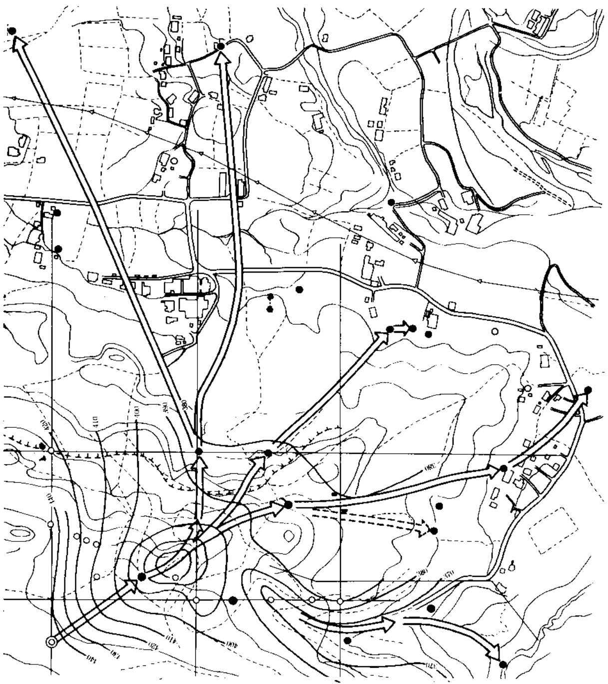
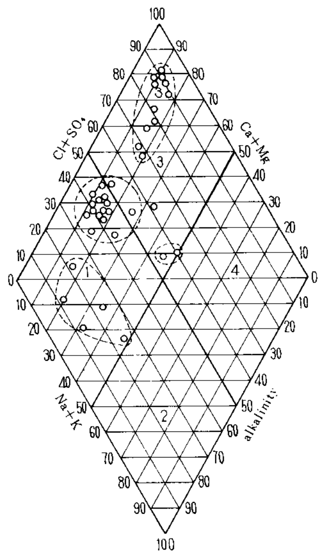


Fig. 4-9 Results of groundwater tracing test



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. 4-10 Rhombic diagram to classify groundwater characters agent at the respective points of detection provided in the area and also the extent of dilution of the reagent, and, then, organizing the data and preparing a groundwater distribution chart.

Groundwater quality survey

This is intended for estimating the origin of the groundwater by the composition. In general, the water temperature, specific inductivity, pH value, pH 4.8 alkalinity, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+ and SiO_2 are determined and are arranged in a rhombic diagram for classification of the characteristics of groundwater.

Pumping test

The test is carried out by a recovery or injection method using a borehole. It is intended primarily for obtaining the coefficients of permeability of the ground layers, but the recovery method is often employed for obtaining data for determination of the volume of drainage. Where it is believed there is a groundwater surface over the sliding surface but the groundwater surface level is not actually measurable because of the water escaping into the borehole, an injection test is carried out to calculate the coefficient of permeability of the ground layer as data for estimating the movement of groundwater.

Soil test

Often, an in-situ shearing test or permeability measurement is carried out using a drainage tunnel or well provided for control works, or samples are taken out for laboratory soil tests. The shearing test method for obtaining the residual strength of the clay along the sliding surface is nearly established.

Executing the Landslide Investigation

Surveys for the purpose of examining reasonable methods of landslide control are to be made in the order of preliminary and detailed surveys. Sometimes, a general survey is required between the preliminary and detailed surveys.

Preliminary survey

The preliminary survey is carried out for the purpose of planning a detailed survey which is necessary but has no procedural return involved. It includes reference survey, topographic survey and field reconnaissance survey.

In the reference survey, if the landslide area concerned was used for farming or dwelling from ancient tiems, documents representing the history of slide or the geology might be found. But, such is not the general case so that the extent of the literature survey differs from case to case.

What is required first of all for the topographic survey is a topographic map. It is, of course, convenient if a topographic map of a large enough scale to understand the topography of the landslide area is available. If not, however, 1/50,000 and 1/25,000 topographic maps covering the whole country are commercially offered and usable. Aerial photos are useful means for topographic survey. But, aerial photos taken particularly of the site of investigation are not always necessary. It is possible to purchase aerial photos taken periodically by the government for the purpose of grasping the current condition of the national land so that at least such data are available.

In the field reconnaissance survey, the topography, ground objects and changes due to the slide should be observed for estimation and judgement of the mechanism of occurrence and movement of the landslide.

Detailed survey

Upon studying findings of the reconnaissance, the survey items, survey method, locations where the survey is to be conducted and procedure should be determined before the survey is carried out to actually collect data.

General survey

The general survey is carried out where it is difficult to plan a detailed survey at the stage of reconnaissance or it is believed that the cost of the detailed survey will be reduced by carrying out a general survey. For example, if it is desired to roughly grasp the formation of the landslide area extending over a wide area before a drilling survey is conducted, seismic or electric prospecting is employed.

Frequencies of use of the investigation methods

The frequency of use of the respective methods of investigation actually employed in our country for the landslide control areas over 5 hectares is shown in Table 4-2.

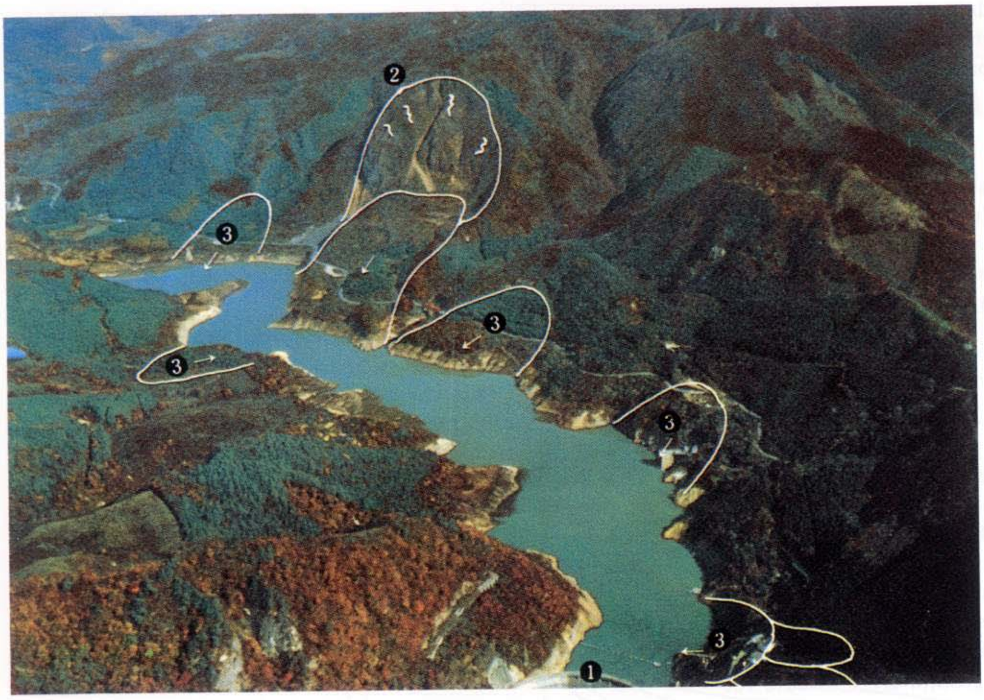
Table 4-2 Investigation methods and their frequency of use

Survey items	Survey methods	Frequency of use
(1) Surface displacement measurement	Offsets survey	C
	Triangulation	C
	Aerial photo survey	C
	Observation by extensometer	B
	Observation by tiltmeter	B
(2) Geological survey	Seismic prospecting	B
	Electric prospecting	C
	Natural radioactivity prospecting	C
	Drilling survey	A
	Electric logging	C
(3) Sliding surface measurement	Boring core identifying	A
	Observation by pipe strain gauge and inclinometer	A
(4) Groundwater survey	Land water quality testing	C
	Groundwater tracing	B
	Groundwater level observation	A
	Groundwater pressure observation	C
	Groundwater prospecting	A
	Pumping test	B
(5) Soil test	Shearing test	C
(6) Hydrological survey	Rainfall observation	B
	Snow observation	B
	Thaw observation	C

Remarks: A – Used at almost all sites.
B – Used at most sites.
C – Used where required.

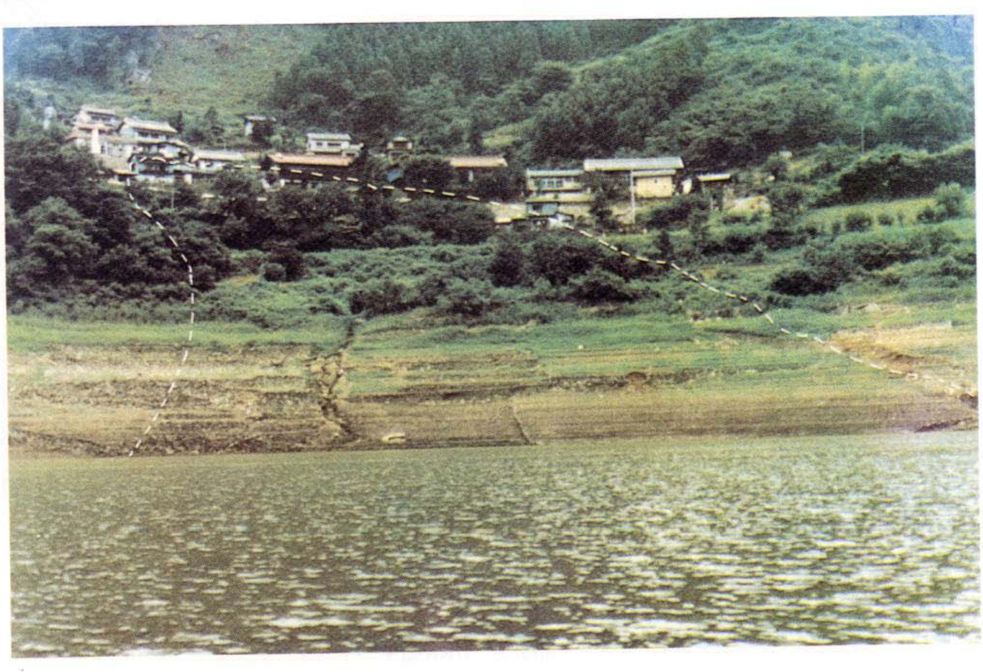
5. Recent Landslides

Landslides Around Narugo Dam Reservoir



Aireal view of the Narugo dam and reservoir (Photo taken in 1978).
① Narugo dam: the first arch dam in Japan
② Handawara landslide
③ Landslides
④ Control office

Location Iwabuchi, Naruko-machi, Miyagi (140°44′E, 38°43′N).
Scale Length, 200–300m; width, 200–300m; area, 4.0–9.0 hectares.
Damage Six landslides occurred during the first impoundment of the reservoir. One of these, the Handawarayama landslide, the mass of 200 000m^3 on which the road collapsed for 100m, slipped into the reservoir.
Subsequently, cracks appeared on the piedmont and the terrace slopes around the reservoir. Then, as the water level was drawing down, the slide increased in the rate of movement to form a clear scraps. Damage occurred in a part of the building of the dam control office, and on a road and a bridge.
Geology, Mechanism and Type The area is underlain by alternating layers of Miocene green tuff and shale in which faults and fracture zones developed. Hydrothermal alteration is prevailed at many places. A talus deposits have thickly deposited on gentle slopes.
Control Works Pile work, crib work, etc.
Present Condition Some landslides without control works have been still in active.
Miscellaneous The Narugo Dam, the first arch dam in Japan, was completed in April 1957. It has a height of 94.5m and a total capacity of about 5×10^7 m^3.
In addition to the Narugo Dam, there are considerable cases of landslide occurrences at dam construction sites and reservoirs. At the Shimokubo Dam*, landslides occurred in the Godo and Numanokubo areas by the first drawing down of water level at a rate of 2 m/day in 1968.
*Takenodaira, Kamiizumi-mura, Kodama-gun, Gunma.



Godo landslide along the coast of Shimokubo dam reservoir, Gunma Prefecture (Photo taken in 1979).
( ) Slid area.

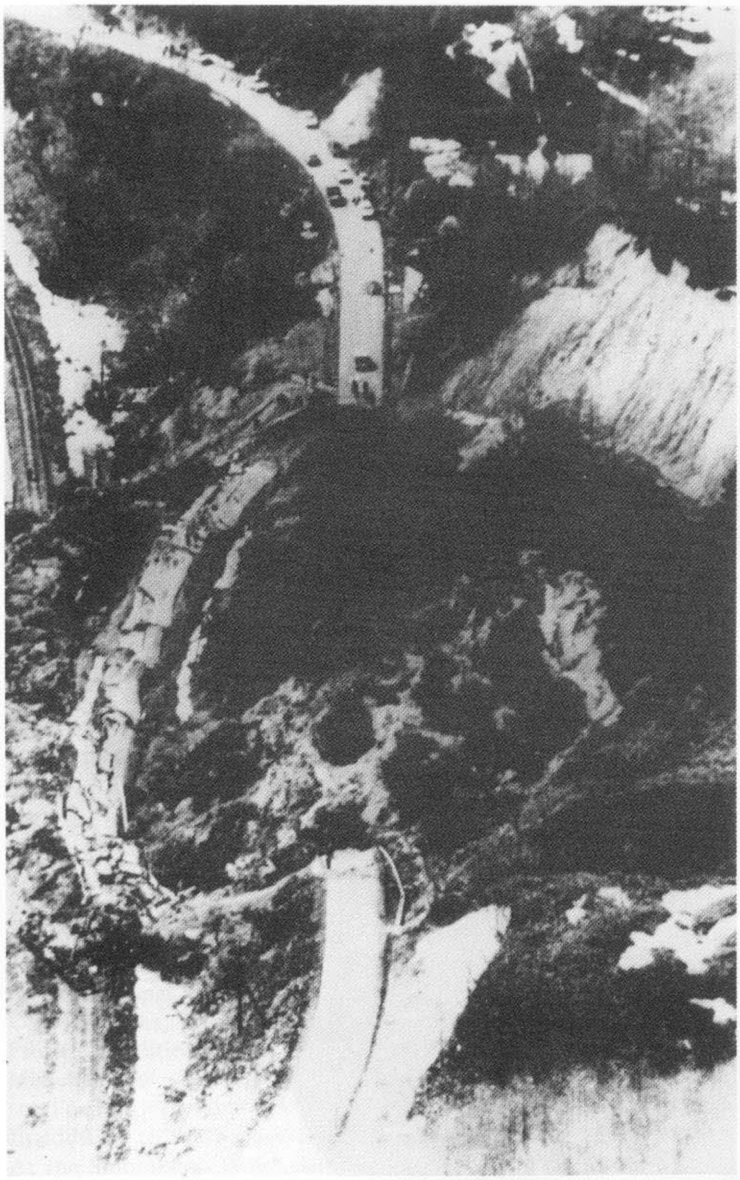
Kita-Ichinosawa Landslide

General view of Kita-Ichinosawa landslide just after the disaster.
① Main slid mass ② Road ③ Coal mine waste-damps ④ Stable area

After the remidial works (Photo taken in 1975).

Location Bibai-shi, Hokkaido (142°00′E, 43°20′N).
Scale The landslide is 450m in length, 300m in width and 15m in mean depth, with the volume of 2 000 000m^3
Damage The landslide movements occurred in 1961 and 1969 in this area. The 1969 slide particularly caused serious damage including 6 dwelling houses destroyed totally or partially, a river buried for 500m and a road collapsed for 500m.
Geology, Mechanism and Type This landslide occurred as the result of the spring thaw water soaking into the soil. The area is underlain by Tertiary mudstone, sandstone and their alternation, colluvium and surface soils. The main sliding surface is thus assumed to be the boundary between the mudstone and the colluvium in the shallow part or t be the lower surface of the remarkably weathered zone in the mudstone and the sandstone in deep part of the landslide.
Control Works Following drainage works have been executed in this area to control the seepage of thaw and rainwater: surface drain, horizontal drilling, drainage tunnels and wells.
Present Condition Subsequent to the damage of the landslide in 1969, countermeasures were seriously taken. It was found that the ground water level had been appreciably dropped in the movement unit with the highest possibility of danger in and after 1971, and that the landslide was tentatively stable.

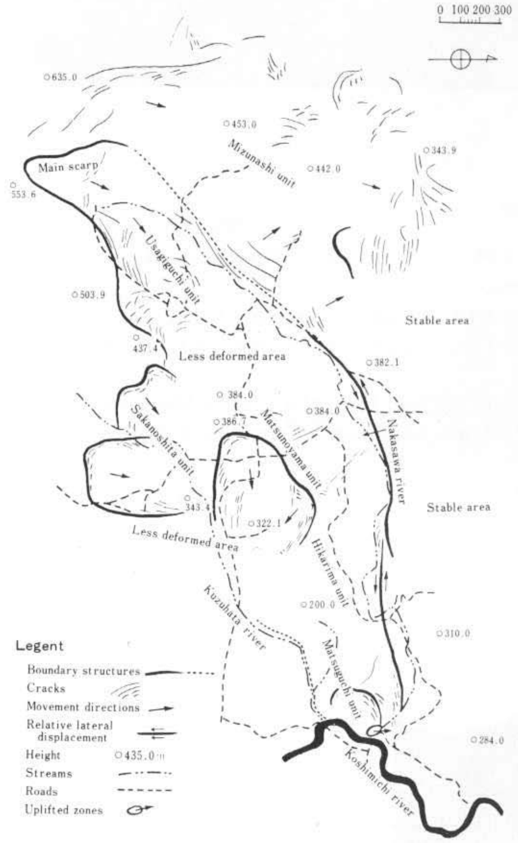
Yunotai Landslide



Location Kaminokuni-machi, Hokkaido (140°14′E, 41°45′N).
Scale Length, 100m; and width, 130m.
Damage The landslide occurred in spring 1975, and damaged a road and a JNL line for 150m in width.
Geology, Mechanism and Type Geology of the area is of the Neogene Yakumo Formation underlained by the Neogene volcanic rocks, and further underlained by the Carboniferous sediments. The Yakumo Formation consists mainly of mudstone. The slip surface shows a circular profile with a maximum depth of 30m. The type of the landslide is a debris slide.
Control Works Following control works were carried out in 1975: soil removal of the deposited mass on the railway, road and river relocation, drainage well, drain, pile and surface drain works. Thereafter, hillside and drainage tunnel works were executed.
Present Condition Little slide movement is presently observed owing to those control works.

Mastunoyama Landslide

A deformed road across the Matsunoyama unit.



Surface structure map of Matsunoyama Landslide.

The graben zone in the Usagiguchi unit.

Location Matsunoyama-cho, Niigata (138°40'E, 37°04'N).
Scale Length, 3600m; width, 2400m.
Damage Paddy field, 349.9 hectares; school buildings, 4; prefectural road, 5.4km; dry field, 78.0 hectares; public buildings, 15; municipal road, 14.8km; dwelling houses, 371; and other buildings, 98.
Geology, Mechanism and Type The area is underlain by the Miocene sediments mainly consisting of tuff and mudstone, and situated at the south-eastern part of the Matsunoyama dome or anticline. Those sediments covered by antient landslide deposits and colluvium. Activity in sliding occurred in spring of 1962, and continued until autumn of the same year. It is thought that the first slide occurred at Usagiguchi in the upper part of the whole landslide area due to the action of seepage water from thaw. This activated neighboring slide units, especially those in the lower slope, Matsunoyama area, owing to large amount of groundwater supply.

In the upper area, a graben has been produced along the boundary of the landslide, at the terminal end by which a disturbed zone is formed. The housing area at the middle part was disturbed by an uneven settlement with the relative subsedence of 2m and flowed to result in bending and displacing a road for more than 20m. In the lower part, an upheaval is noticeable with the check dams raised about 5m.
Control Works Pile work, 2 324 piles; drainage wells, 44; open ditchs with drains, 4 790m; and channel work, 262m.
Present Condition In a state of lull.

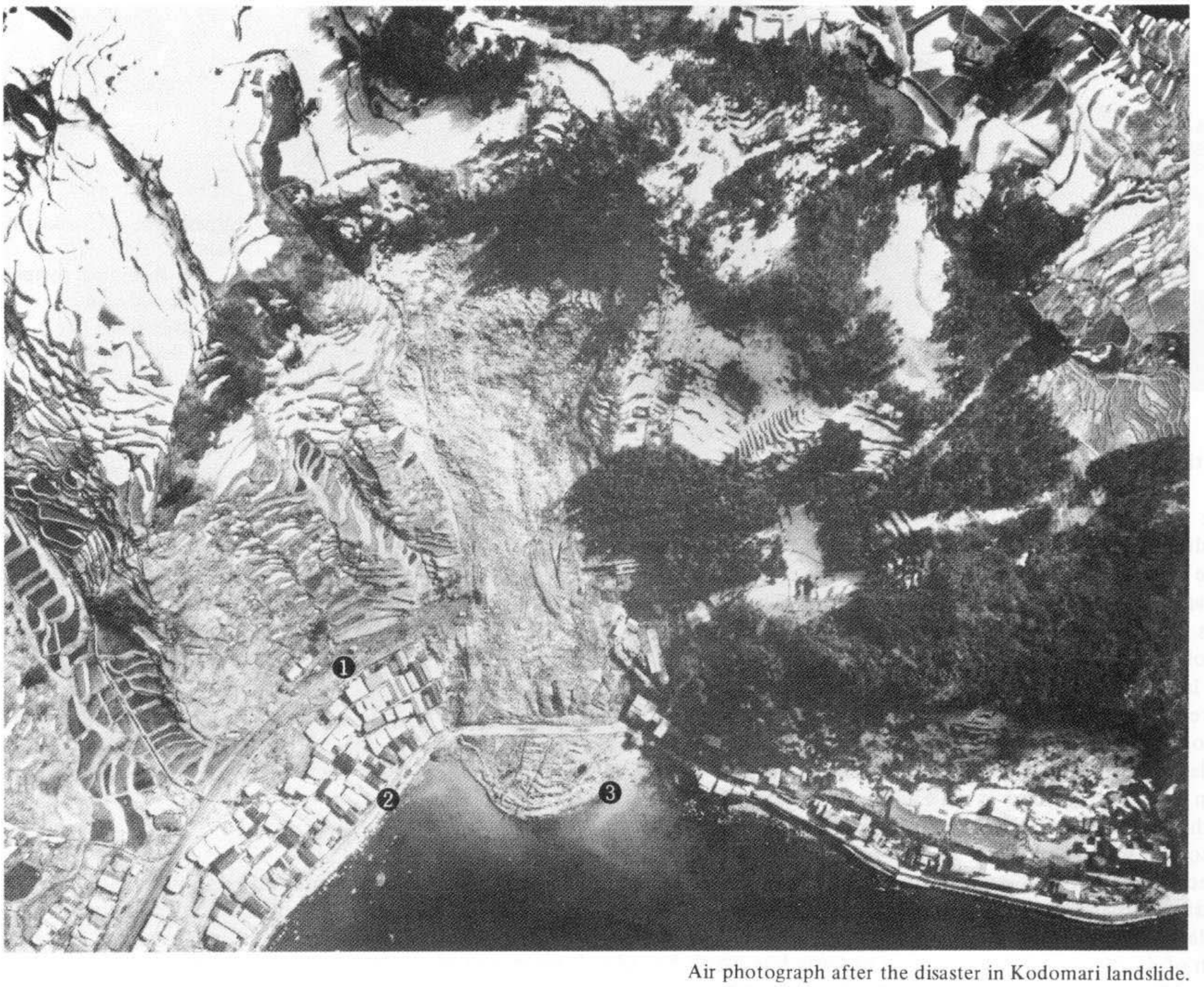
Kamihiramaru Landslide

Main area of Kamihiramaru landslide (Photo taken in 1970).

Location Kamihiramaru; Arai-shi, Niigata (138° 19′E, 36° 56′N).
Scale Slope length, 1100m; width, 600m; area, 60 hectares.
Damage Landslide disasters repeatedly occurred in 1962, 1964, 1969, 1970, 1974, 1978 and 1979. The Hiramarugawa river was blocked by a part of the mud flow which was turned from the 1962 slide mass.
Geology, Mechanism and Type The area is underlain by the Miocene Teradomari Formation consisting black and massive mudstone. The slip surfaces are usually developed at the depth of 6.0–12.0m. Slide movements occur vigorously in snowmelt seasons, while creep movements can be observed throughout a year.
Control Works Check dam and crib works were executed to check the mud flows at the foot of the landslide area, while at the lateral slope pile work was done to prevent the slide movement. At the same time, surface drain and drainage well works were carried out.
Present Condition The slopes have been fairly stabilized at the middle part, but are still active locally at the upper part.

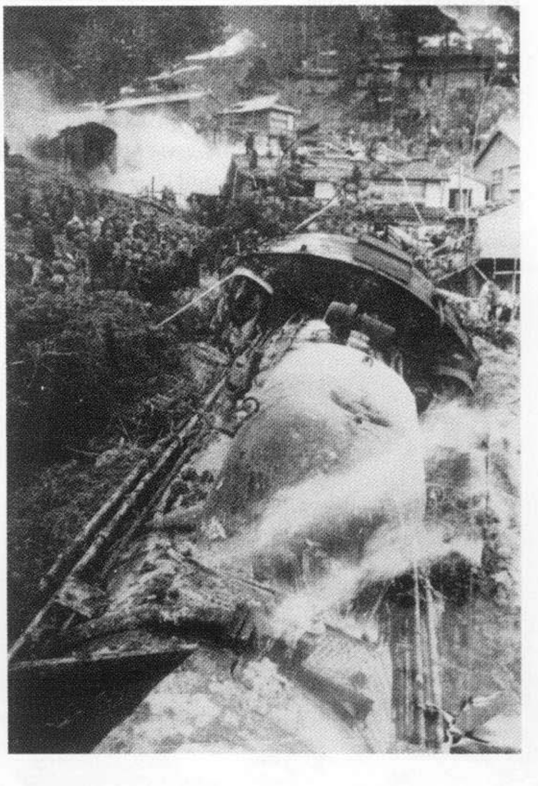
General view of the landslide (Photo taken in 1979).

Kodomari Landslide



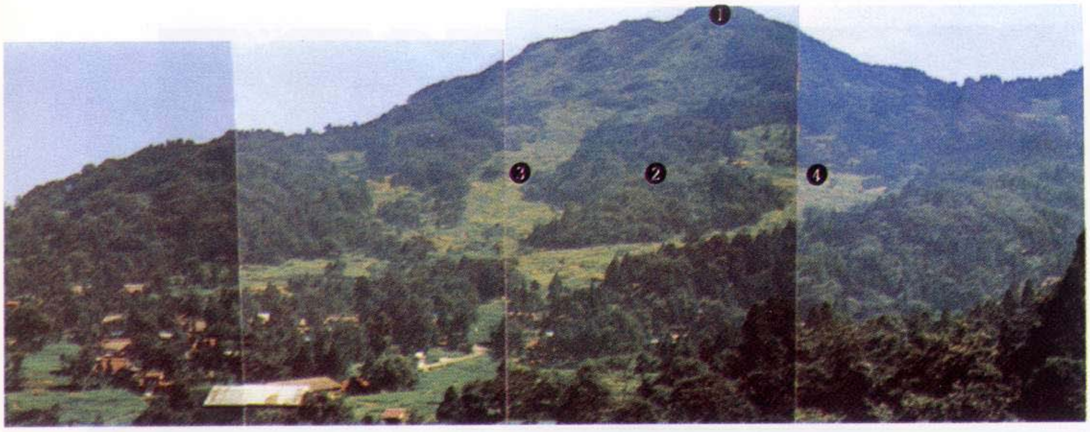
Air photograph after the disaster in Kodomari landslide.
① Hokuriku line, Japan National Railway.
② National road
③ Steam locomotive swept away by the landslide.

Location Nou-cho, Niigata (138°01'E, 37°07'N).
Scale Length, about 370m; width, 100–170m; area, 4.5 hectares.
Damage The landslide struck a freight train that happened to be passing the site and swept the locomotive away for about 170m on 16 March 1963. On account of the landslide, the traffic of the railway and road was interrupted for a long time. The slid mass swept 28 houses into the Japan Sea.
Geology, Mechanism and Type The region between Itoigawa and Naoetsu along the Hokuriku Line of the National Railway is known as an area of a high density in landslides. The Kodomari landslide is one of such landslides, of which geology is composed of the Miocene mudstone and alternation of sandstone, mudstone and tuff.
Control Works The National Railway Line was shifted far from the coast of Japan Sea, with a number of tunnels constructed newly in this area.

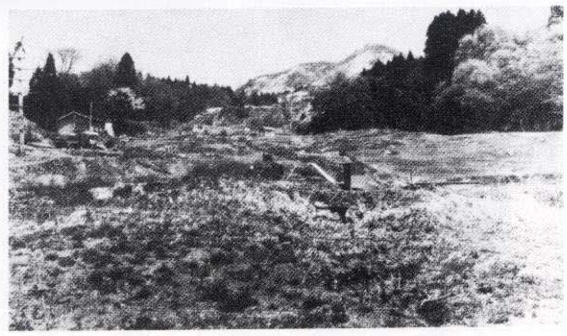


Steam locomotive moved and pertially buried by the slid mass (Courtesy of the Niigatanippo).

Sarukuyoji Landslide



Upper slope of Sarukuyoji landslide.
① Mt. Jogayama composed of andesitic rock
② Stable area
③④ Test field of Public Works Research Institute

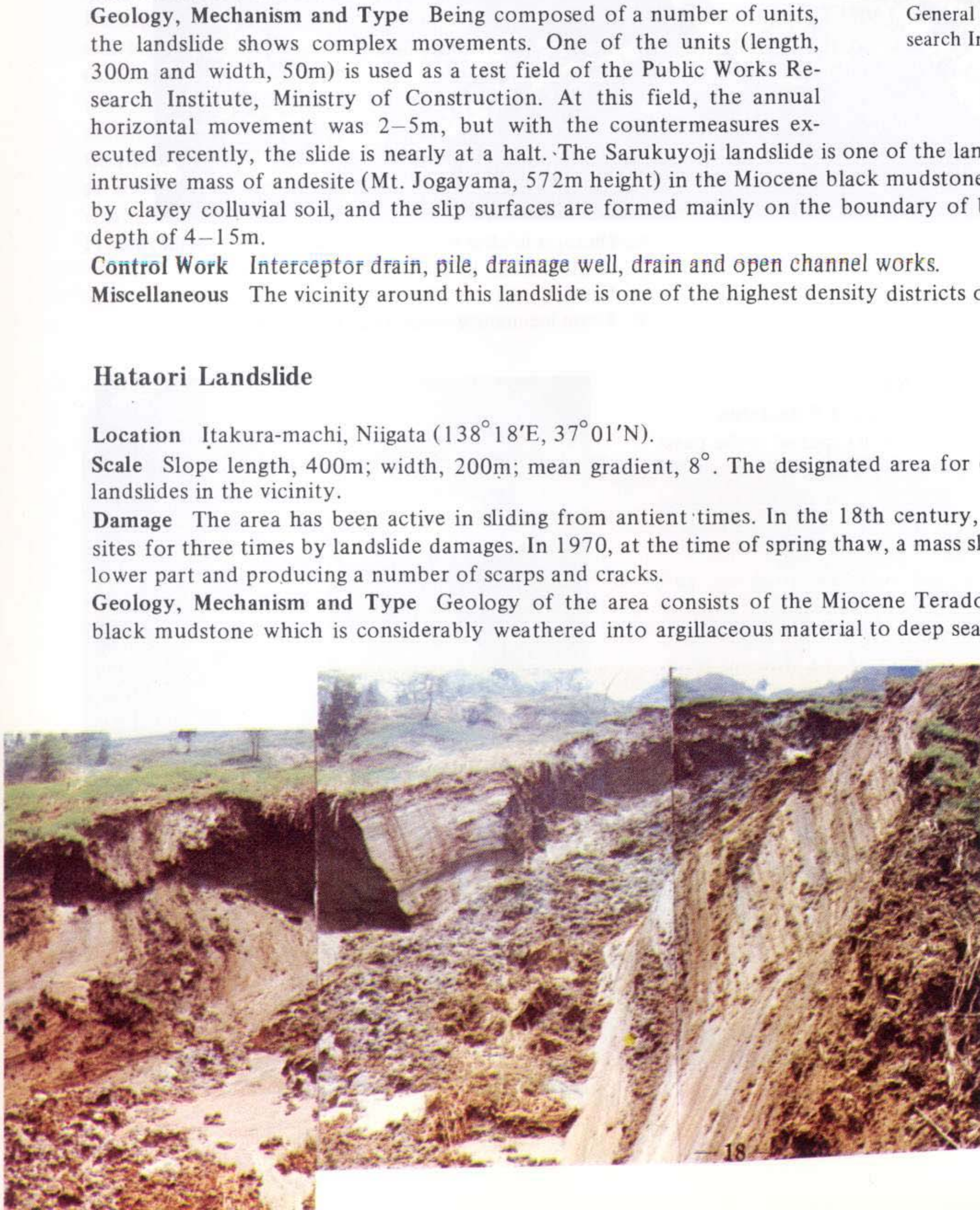


General view of the test field of Public Works Research Institute, Ministry of Construction.

Location Itakura-machi, Nakakubiki-gun, Niigata (138°18'E, 37°01'N).
Scale Length, 1 800m; width, 500m; and area, about 44 hectares. The landslide is composed of a number of landslide units, with a stable area at the center.
Damage It is believed that landslide has been active from ancient times. According to a folk tale, a traveling priest was buried alive as an immolation or a scapegoat to pacify the landslide about 800 years ago. The landslide site is used largely for paddy field, but the units of marked activity are left in a state of wasteland.
Geology, Mechanism and Type Being composed of a number of units, the landslide shows complex movements. One of the units (length, 300m and width, 50m) is used as a test field of the Public Works Research Institute, Ministry of Construction. At this field, the annual horizontal movement was 2–5m, but with the countermeasures executed recently, the slide is nearly at a halt. The Sarukuyoji landslide is one of the landslides distributed radially around the intrusive mass of andesite (Mt. Jogayama, 572m height) in the Miocene black mudstone. The bedrock of mudstone is covered by clayey colluvial soil, and the slip surfaces are formed mainly on the boundary of bedrock and colluvium. They are at a depth of 4–15m.
Control Work Interceptor drain, pile, drainage well, drain and open channel works.
Miscellaneous The vicinity around this landslide is one of the highest density districts of landslides in Japan.

Hataori Landslide

Location Itakura-machi, Niigata (138°18'E, 37°01'N).
Scale Slope length, 400m; width, 200m; mean gradient, 8°. The designated area for control works is 41 hectares, involving landslides in the vicinity.
Damage The area has been active in sliding from antient times. In the 18th century, a village had been forced to move its sites for three times by landslide damages. In 1970, at the time of spring thaw, a mass slid with high velocity excavating in the lower part and producing a number of scarps and cracks.
Geology, Mechanism and Type Geology of the area consists of the Miocene Teradomari Formation mainly composed of black mudstone which is considerably weathered into argillaceous material to deep seated layers. The movement of the landslide is slow in rate and a creep type. It is particularly active in snowmelt seasons. The slip surface is at a depth of 7.0–15.0m.
Control Works A check dam was constructed in the stream near the foot of the slope, while the toe of the landslide was covered by crib works, and the middle slope was protected by steel pile works. As the result, the movement was completely stopped.



Lower part of Hataori landslide.
Fine slickensides developed along both sides of flanks in the lower part of the landslide.

Chausuyama Landslide

General view of Chausuyama landslide (Photo taken in 1975).
① Natural Botanical Garden ② Stable area or "island" ③ Mt. Chausuyama

Location Shinonoi, Nagano-shi (138°10′E, 36°40′N).
Scale Length, 2 000m; width, 130–430m; area, 46 hectares; volume, 9 000 000m^3.
Damage A mass of soil on the upper part of the mountain slowly slid down and crushed a vast area of farm land.
Geology, Machanism and Type The area is underlain by Miocene sedimentary rocks consisting of the Susobana tuff, Nobusato sandstone and younger tuff breccia in ascending order, which is partially covered by the antient landslide deposits. The movement was initiated by the 1847 Zenkoji earthquake and has continued. The type of the slide is a bedrock and debris creep-slide on a gentle slope.
Control Works Drainage works of groundwater was carried out in the upper part of the slide. Deep wells were made at the first step, and then, as the second step, drain drilling and surface drain works were conducted. The main works are piling, interceptor drain wall and surface drain works.
Present Condition As the upper part of the landslide was stabilized, the "Chausuyama Natural Zoo and Botanical Garden" were planed in 1976 for the new landuse of the landslide site by the Nagano Municipal Authorities. The former was completed in 1978. The lower part of the slide is still unstable. Thus, further investigations and control works are urgently called for.

Looking the upper part of the landslide from the Natural Botanical Garden (Photo taken in June, 1979).
① Mt. Chausuyama ② Location of the old summit before the slide ③ Drainage well ④ Surface drain

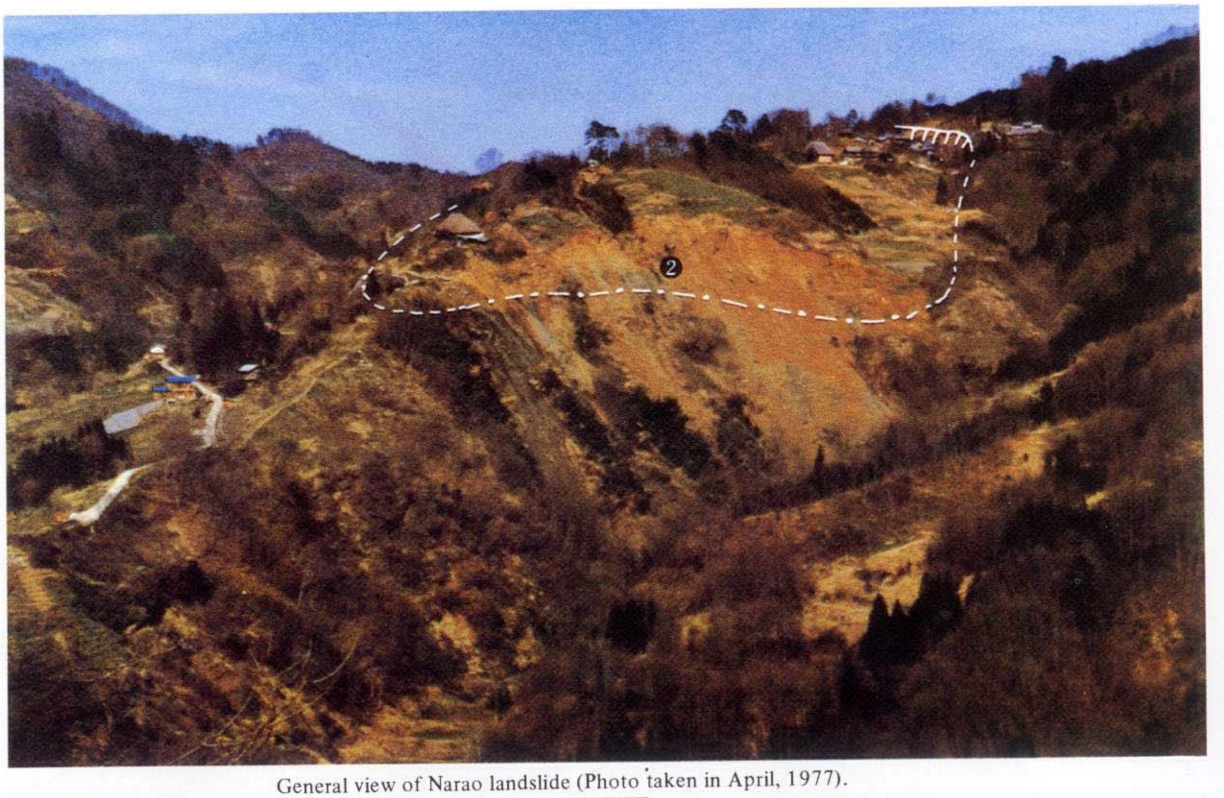
Narao Landslide

Location Shinshu Shinmachi, Nagano (137°57.30′E, 36°36.22′N).
Scale Length, 700m; width, 100–200m; area, 7.6 hectares; volume, 2 800 000m^3.
Damage The landslide was first noticed when cracks were observed in the yards of dwelling houses on 6 October 1976. At first, the slide was as large as 30–40cm a day, but, now, it is about 5mm a day. In this landslide, 14 of the 15 houses of the Narao village were damaged.
Geology, Mechanism and Type The area is underlain by Miocene sandstone and mudstone with subordinate conglomerate. The landslide occurred in a ridge extending northwest of the Mt. Iizunayama (866m). It may be the partial reactivation of an antient and large landslide mass on the Miocene bedrocks. The slip surface is 20–70m deep.
Control Works Because of the difficulty of control works inside of the landslide area due to the active movement and the depth of the sliding mass, four drainage wells and a drainage tunnel were constructed along the boundary of the sliding mass to reduce the rate of sliding at first. Then secondly three drainage wells and steel pipe pilings were executed in the sliding mass.
Present Condition The mass movement produced a clear and steep toe scarp, from which 300 000m^3 of the sliding mass has slipped down. Thus, the lower part of the landslide is forming a narrow ridge. There is no other way available for controlling the slipping down site but to drain the groundwater for reducing the movement.

Damaged house and road. (Narao landslide).

Shimizuyama Landslide

Location Otari-mura, Nagano (137°55.5′E, 36°49.5′N).
Scale Length, 2 000m; width, 400–600m; and area, 100 hectares.
Damage The landslide has a long history, and so far as the record is concerned, the oldest one occurred 718 years ago. Thereafter, movement of the landslide has continued to date, and the land form has changed gradually during the period, while a lot of houses and extensive farm land have suffered much damage.
Geology, Mechanism and Type The area is underlained by Miocene mudstone and sandstone intruded by rhyolites. However, bedrocks have been considerably sheared because of the tectonic movement along the Itoigawa-Shizuoka Tectonic Line. Topographically, the site is generally of gentle slope except for a sharp slope at the central part. The landslide is repeating a intermittent-slow movement.
Control Works Control works were begun in 1956 consisting of drainage works with horizintal drilling, open channel, piling, tunnel and interceptor drain works.
Present Condition Displacement of the landslide is fairly decreased recently due to the control works. Today, the works are carried out mainly by drainage works.



General view of Narao landslide (Photo taken in April, 1977).
① Main scarp
② Foot scarp
③ Sliding surface —·—·—·—
④ Boundary of the landslide - - - - - - - - - - -

General view of Simizuyama landslide (Photo taken in 1979).
Boundary of the sliding areas

Yui Landslide

General view of Yui landslide area (Photo taken in 1978).
① The area of the 1961 slide after the completion of control works
② The area of the 1974 slide under control works.

Location Yui-machi, Shizuoka (138°35′E, 35°07′N).
Scale A lot of landslides can be found in the Yui landslide area, of which the total is 242 hectares with 1 000m in length and 3 000m in width.
Damage Activities in sliding have been recorded since mid-1800's in the area. Lately, those in 1961 and 1974 were severe in damage.
Geology, Mechanism and Type The area is situated to the east of the Itoigawa-Shizuoka Tectonic Line and southwest part of the Fossa Magna. The geology of the area with the Iriyama Thrust running south to north is composed of the Ogochi Group of Miocene age, which is unconformably covered by the Hamaishidake Formation of Pliocene in age. Type of landslides in the area can be identified with debris slides, flows and rock slides.
Control Works Control works have been excuted here since 1948, and involve excavation, drainage tunnel, surface drain, drain, drainage well and piling works. Total cost was about ¥3 800 000 000.
Present Condition A five-year project has been carried out from 1977 to 1981 at a cost of about ¥7 000 000 000.
Miscellaneous This area is a pivotal point for land transportation between the east and west of Japan. Surveys are being done by such organizations as the National Land Agency, Ministry of Construction, Ministry of Transport and Forestry Agency with respect to the possibility of occurrence of landslides by a Tokai-oki earthquake which is anticipated to take place in the near future.

Kamenose Landslide

Aireal view of Kamenose landslide.

① Shimizudani unit
② Toge unit
③ Yamatogawa river
④ National road
⑤ Kansai line, Japan National Railway
⑥ Main scarp where excavation works are carried out
⑦ Foot of the Toge unit

Location Kamenose, Kashiwara-shi, Osaka (135°39′E, 34°35′N).

Scale and Damage In 1931–1932, a slide unit, called Toge, of about 32 hectares began to slide in the Kamenose landslide area. It blocked the Yamatogawa river and caused severe damage to the upstream basin by inundation. The maximum horizontal displacement was as large as 32m at that time.

In 1967, the Shimizudani unit of 800m in length, 200–300m in width and 15 hectares in area became active.

Geology and Mechanism The geology of the area is mainly composed of Miocene volcanic rocks, consisting of basal conglomerate, lower andesite lava, andesitic tuffbreccia, thin clayly sandstone, and upper andesite lava, in ascending order. The main slip surface is found at the thin clay layer between the upper andesite and the tuff breccia.

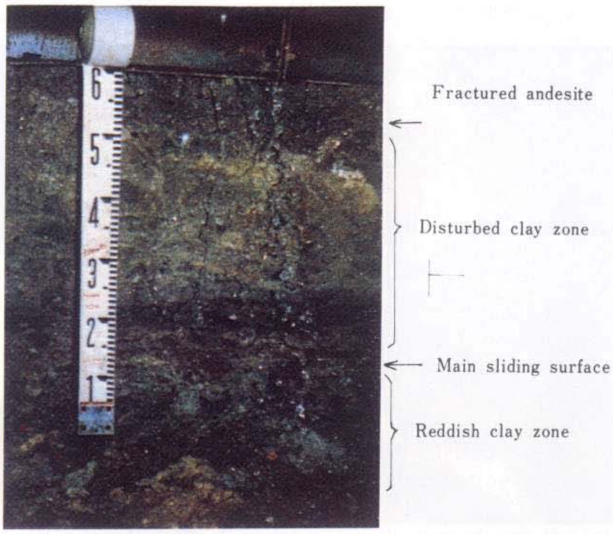
The maximum depth of the slip surface is about 80m.

Control Works Excavation work are carried in the head of the Shimizudani unit. Drainage works were done mainly by drainage tunnels connected with drainage wells. Cast-in-place pile works are now going on in the Toge area for permanent stabilization.

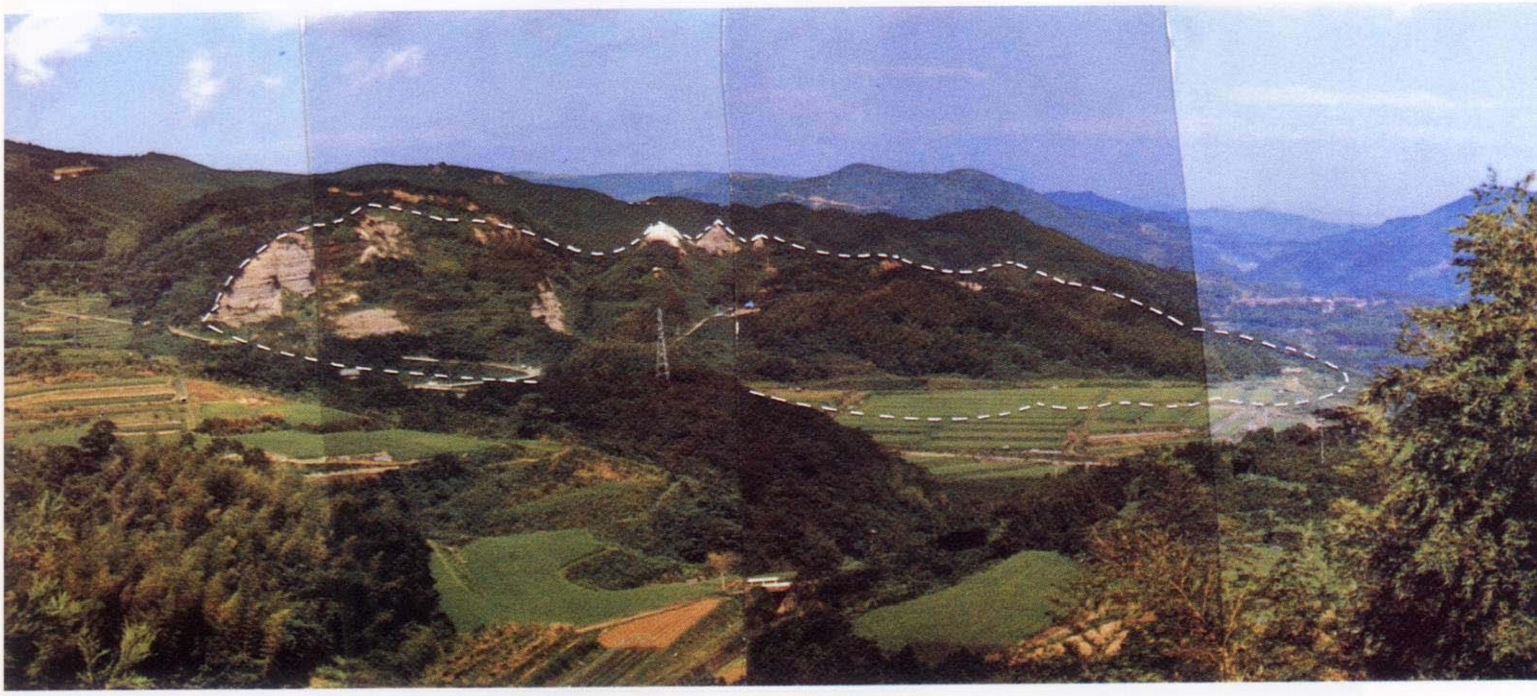
Present Condition The Shimizudani unit is almost stabilized by the control works.

The Toge unit involves the problem of the discharge revision of the Yamato river which proposes the river channel excavation at the foot of the landslide. The present control works are intended to such a purpose.

Miscellaneous The control works have been done as a direct project of the state, because of the importance of the landslide location, scale of the slide and the necessity of high level techniques for control works.



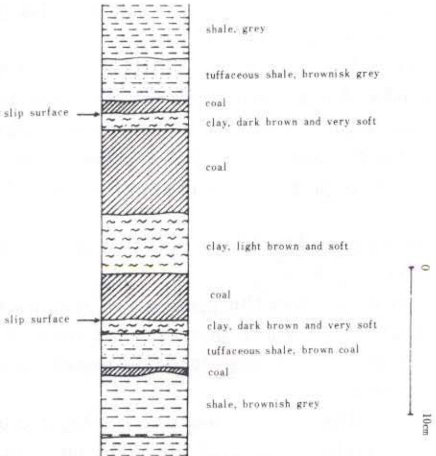
Sliding surface of Toge unit, observed in an investigation well of a depth of 60m.



General view of Hirayama landslide (Photo taken in 1979).
Boundary of the landslide

General view of Washiodake landslide (Photo taken in 1979).
Boundary of the landslide

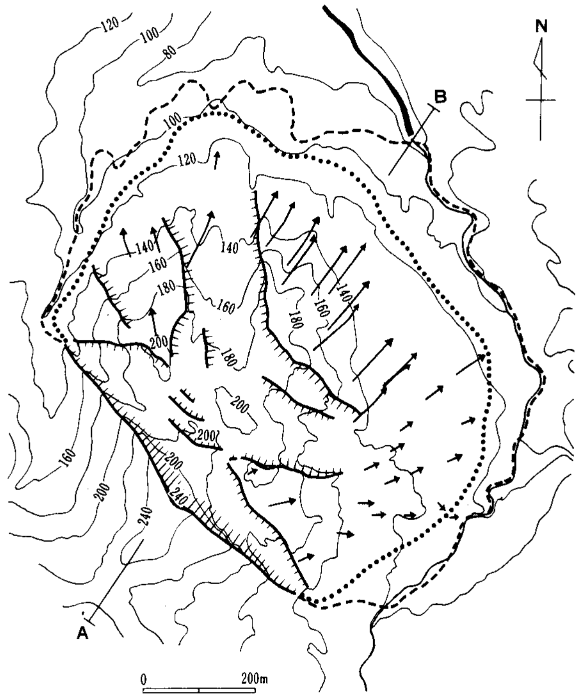
Slip surface and measurement of the displacement of the slide in the observation well (Washiodake landslide).



Detail geologic column of the main slip zone (Washiodake landslide).

Hirayama Landslide

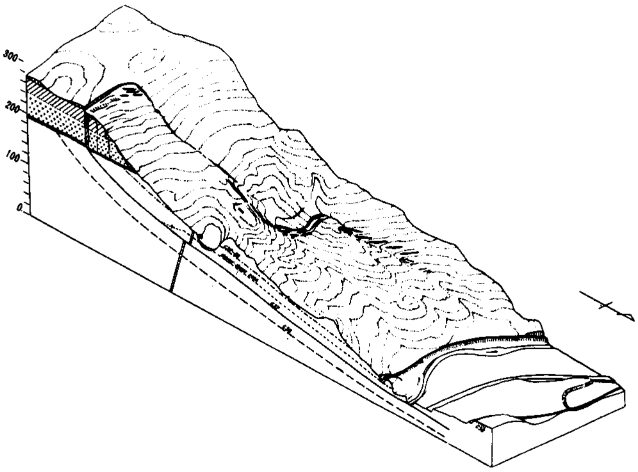
Location Hirayama, Yoshii-cho, Nagasaki (129°41'E, 33°15'N).
Scale Length, 670m; width, 800m; area, 56 hectares; volume, 19 000 000 m^3.
Damage The landslide destroyed 22 houses, roads, paddy field and forest. Inhabitants were forced to move to outside of the landslide area.
Geology, Mechanism and Type The area is composed of Miocene cyclothem sediments, Pliocene gravel, and Pliocene basalts in ascending order. The Miocene sediments consist of sandstone, mudstone, tuff and coal seams, two of which had been worked under the landslide area. The underground coal mine might affect the initiation of the sliding movement which started in 1963. Mt. Atago (273m) was crossed by a subsiding belt 80m in width, of which the south wall had developed into the main scarp of the landslide. The subsiding belt and the main sliding mass looked like large wedges. The former moved downward and the latter slid nearly horizontally. The type of landslide is a bedrock slide. The total horizontal movement is about 100m from 1963.
Control Works Drainage works were conducted mainly with drainage tunnels constructed under the slip surface and connected by drain shafts crossing the slip surface. Several upward boreholes were also drilled from the tunnels to drain water near the slip surface.
Present Condition The movement is recently 30cm a year in the root area. The surrounding area affected by debris flows was rehabilitated for paddy field.



→200m Horizontal displacement
Horizontal movement of Hirayama Landslide (Geographical Survey Institute, 1970)

Wasiodake Landslide.

Location Emukae-cho, Nagasaki (129°40'E, 33°17'N).
Scale Length, about 1 000m; width, 240m–450m; area, about 32.5 hectares. Volume, about 12 500 000m^3. (Designated area for prevention, 69.0 hectares).
Damage In or about 1950, fissuring occurred in the mountain side, followed by a main scarp produced at the crown about 300m long and a throw of 15m or more at present. Thereafter, toward 1957, significant movement was observed along the Matsuura Line of the National Railway and the Emukae river bank which are located at the foot of the landslide, causing damage to paddy field and dwelling houses in the vicinity. Total displacement of the sliding mass is about 11m from 1950 to 1979.
Geology, Mechanism and Type Geologically, the area is mainly composed of the Miocene Sasebo Group and the Pliocene Kitamatsuura basalt of the Neogene period. The Sasebo Group shows cyclothems which consist of regular cyclic sediments from sandstone to mudstone of which the upper part is interculated with coal seams sandwiching a clay layer of tuff origin. Such coal seams commonly form the sliding surfaces.
In the landslide, the main slip surface is formed in the C37c coal seam called the Hedamono layer. The landslide is a bedrock slide extending for about 1 000m in length. The depth of the sliding surface depends on the topography and geologic structure and is from 3 to 4m at the foot in which the bedding surface dips about 7° and to 80m, averaging 50–60m at the head of the landslide in which the surface dips about 25°.



Block diagram of Washiodake landslide (Oyagi, Oishi and Uchida, 1970).

Control Works Drainage works were carried out as the control works because of a large sliding mass.
Horizontal drain 1957–1964.
Improvement of open channels with drains.
Construction of drainage tunnels from 1965:

Washio Tunnel	1965–68	L = 730m.
Kanenosaka Tunnel	1967–70	L = 949m.
Sarugatake Tunnel	1971–73	L = 732m.
Eboshi Tunnel	1975–77	L = 263m.

Present Condition With improvement of the efficiency of drainage through the series of control works, the annual slide decreased from 90cm/year during 1956 to 1964 to less than 6cm/year in 1969 after the practical completion of drainage tunnels.
The movement of the landslide recently turned into the intermittent slips only in abnormal rainfalls.

Ikadani Landslide

Location Ikadani, Himi-shi, Toyama (136°55′E, 36°55′N).

Scale The sliding mass spreaded for about 1 200m in length and 200–350m in width with the maximum displacement of 100m. The landslide is a typical bedrock slide with the sliding surface as deep as 60m.

Damage In mid-March 1977, several cracks of a width of 10cm and a length of about 20m were found in paddy field after the snowmelt. They expanded gradually. In the morning of March 29, the houses began to rattle, and a minor failure took place. At 10:45 am, the houses began to topple, and the small sliding units along the river began to slip successively. This movement finally came to a stop at about one o'clock in the afternoon of the day.

The damage extended over an area of 40 hectares; paddy field 7 hectares, dry field 7 hectares and forest, etc. 26 hectares

Failures occurred in reservoirs at 4 places, water channel for 1 800m, agricultural road for 1 600m, prefectural road for about 1 000m and 23 buildings.

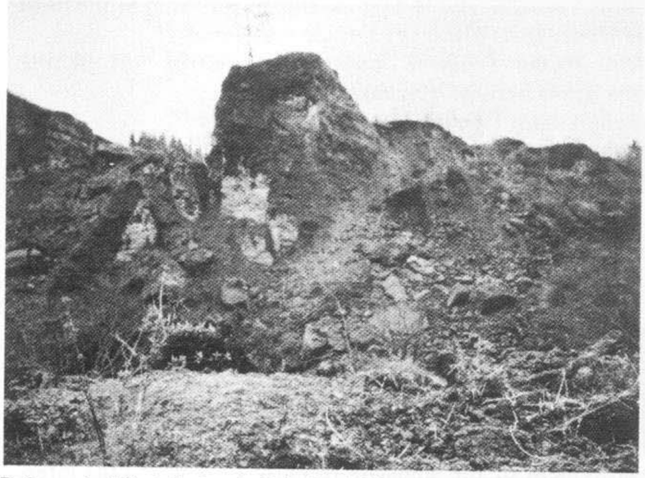
Geology, Mechanism and Type The area is composed mainly of dark grayish mudstone of the Neogene period including tuffaceous coarse sandstone and tuff. The stratum shows a monoclinic structure inclined southeastward at 10–22°, and obviously forms a cuesta topography. In the area, there are several lineaments running in the northwest-southeast direction; the main direction of sliding. The landslide is identified as a bedrock and dip slide due to the structural control of the bedding surface and a group of faults. It was induced mainly by the thawing water permeation owing to sharp rise of the temperature early in March.

Control Works The control works were carried out mainly for drainage; drainage wells, 15; and drain drilling, 3 000m and more. In addition, drain, crib and dam works were carried out to stabilize the movement.

Present Condition Since the occurrence of the landslide, three years have elapsed, with control works carried out to a considerable extent, so that the movement is scarcely observed presently.

Miscellaneous The landslide is noteworthy in the scale and morphology as a bedrock slide.

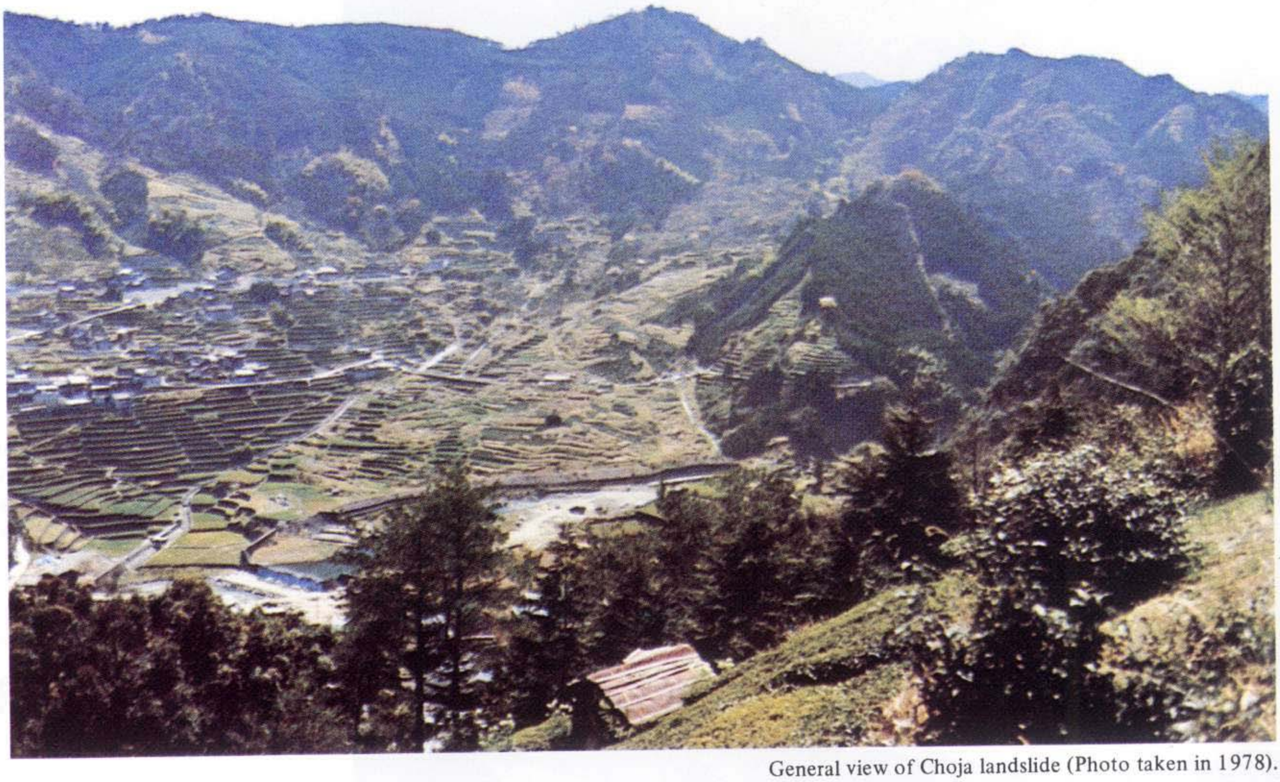
←
Oblique aireal photograph of Ikadani landslide just after the disaster in 1977.



Deformed cliff at the head of the landslide.

Right flank and middle part of the landslide.

Choja Landslide

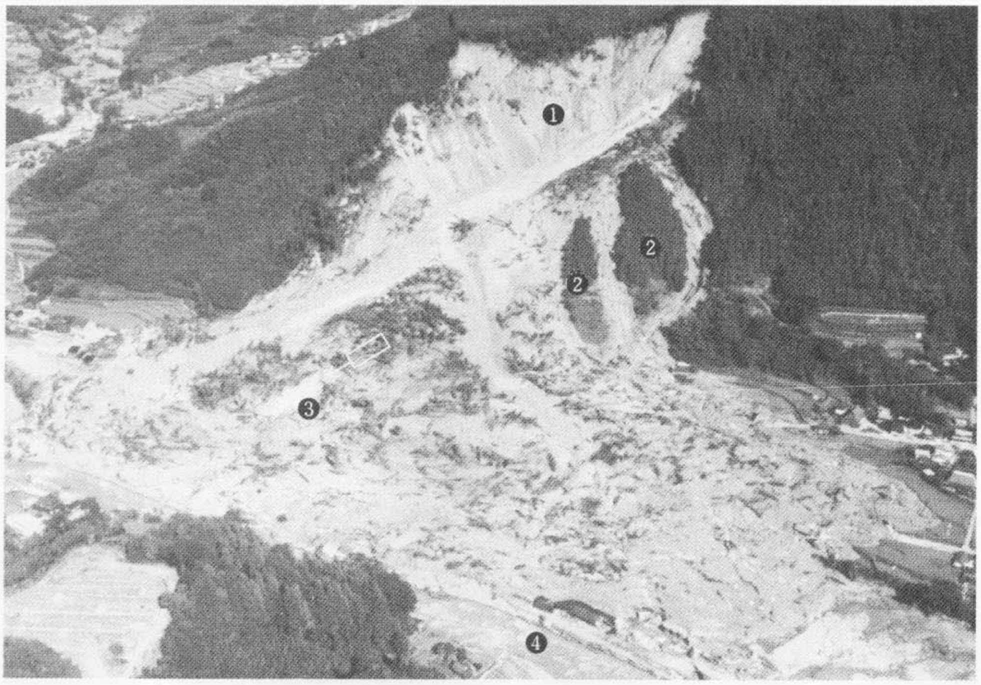


General view of Choja landslide (Photo taken in 1978).

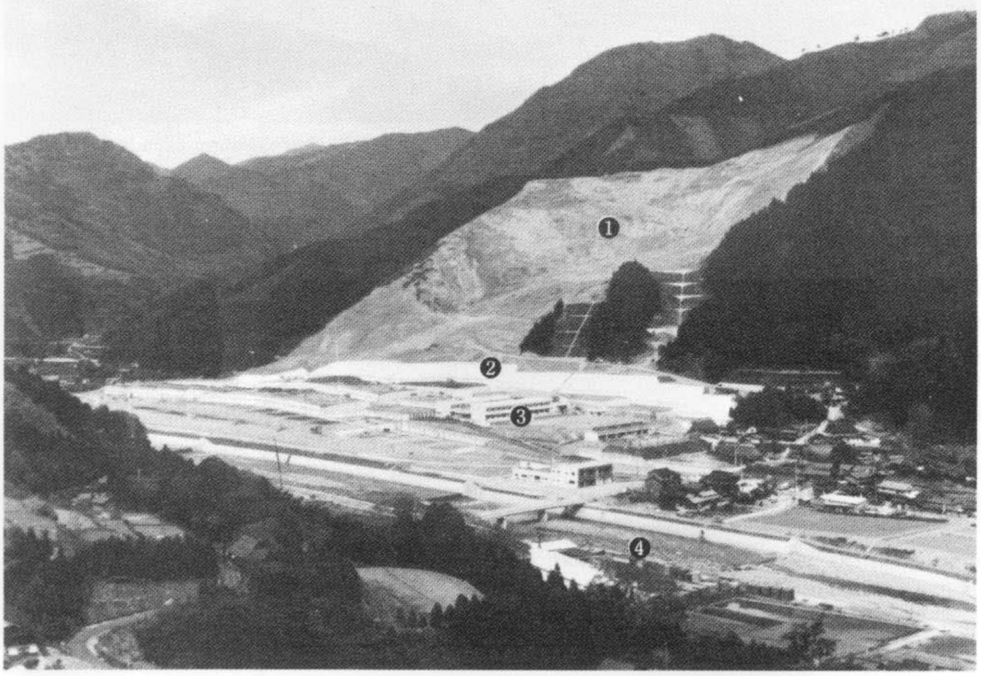
Location Choja, Niyodo-mura, Kochi (133°08′E, 33°31′N).
Scale The landslide covers an area of 68.4 hectares including 51.6 hectares of farm land, with a length of 900m and a width of 150–300m.
Geology, Mechanism and Type The area is composed of slate, serpentinite, schalstein and Mitaki igneous rocks belonging to the Permian series, Paleozoic system of the Chichibu terrain and has a number of fault sheared zones developed. It is a typical landslide zone in sheared zones in Japan.
Type of the landslide is a debris slide. Movement of the landslide was caused by the heavy rainfalls due to the typhoons of 1886 and 1890. Recently, the embankment of the Chojagawa river situated at the toe of the landslide was washed away during the heavy rainfall of 835mm at the time of the Typhoon No. 9, 1963, resulting in more intensive landslide activity.
Control Works Drain drilling, drainage well, channel, check dam works and revetment work of the Chojagawa river.
Present Condition The landslide is moving toward the Chojagawa river at a rate of 20–30cm/year, and, at the toe, the ground is repeatedly experiencing upheaval at the bed of the Chojagawa river.
The landslide movement once settled has become remarkable recently and is now watched with care.

Uplifted crib work at the toe of the landslide (Photo taken in 1979).

Ichinomiya Landslide



General view of Ichinomiya landslide just after the disaster (Photo taken in 1976).
① Root area
② Stable area
③ School
④ Ibogawa river



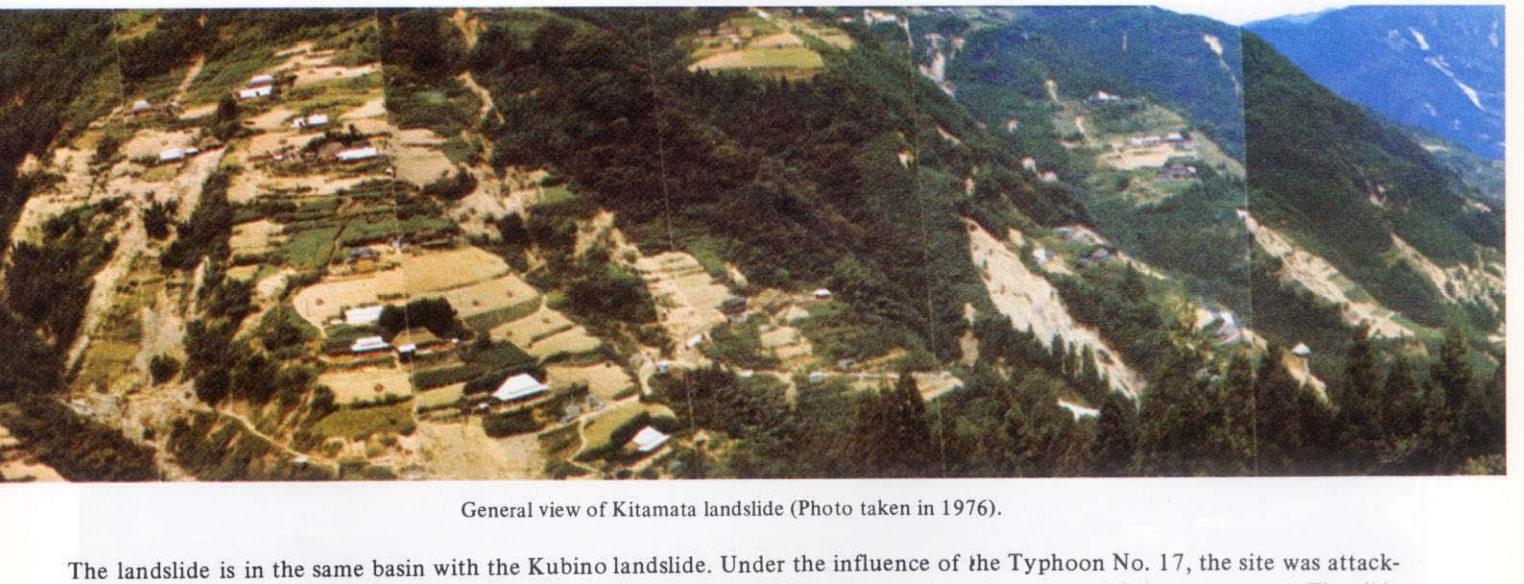
Ichinomiya landslide area after the completion of control works (Photo taken in 1979).
① Excavation work
② Crib work
③ Newly constructed school
④ Ibogawa river reformed

Location Fukuchi, Ichinomiya-cho, Hyogo (134°37'E, 35°09'N).
Scale The landslide root area: width, 300m; depth, 30m; and volume, 600 000m^3.
The landslide deposit area: width, 600m; length, 250m; and deposited volume, 810 000m^3.
Damage The landslide occurred on September 13, 1976 and killed 3 persons and injured 3 persons, destroyed 52 houses, and 17 public buildings. It damaged river banks, 991m along the left and 810m along the right ones, and roads, 540m of prefectural and 768m of municipal roads including a bridge.
Geology, Mechanism and Type The area is composed of Triassic sediments, Cretaceous volcanic rocks (andesitic to rhyolitic) and quartz diorite. It is situated at the southern part of the Maizuru Tectonic Zone and also in the mineralization zone of Tertiary age. Therefore, geologic structure is mosaic and bedrocks are highly altered and weathered. The root area of landslide showed topographically an antient slide. The 1976 slide occurred 12 hours after the final peak of heavy rainfalls brought by the Typhoon No. 17. It is thought that the trigger might be the pressure of underground water from the rainfall. The type of the landslide is a bedrock and debris slide which was turned into debris flows.
Control Works Following control works were done: retaining wall, crib, interceptor drain, surface drain, drain, drainage well, drainage tunnel and piling works.
Present Condition Those control works were completed and leveling of the ground was carried out in the landslide deposit area.

Kubino Landslide

General view of Kubino landslide (Photo taken in 1976).
At the center of the picture is seen the penstock deformed by the landslide.
Cracks produced by landslide.
Failure sites

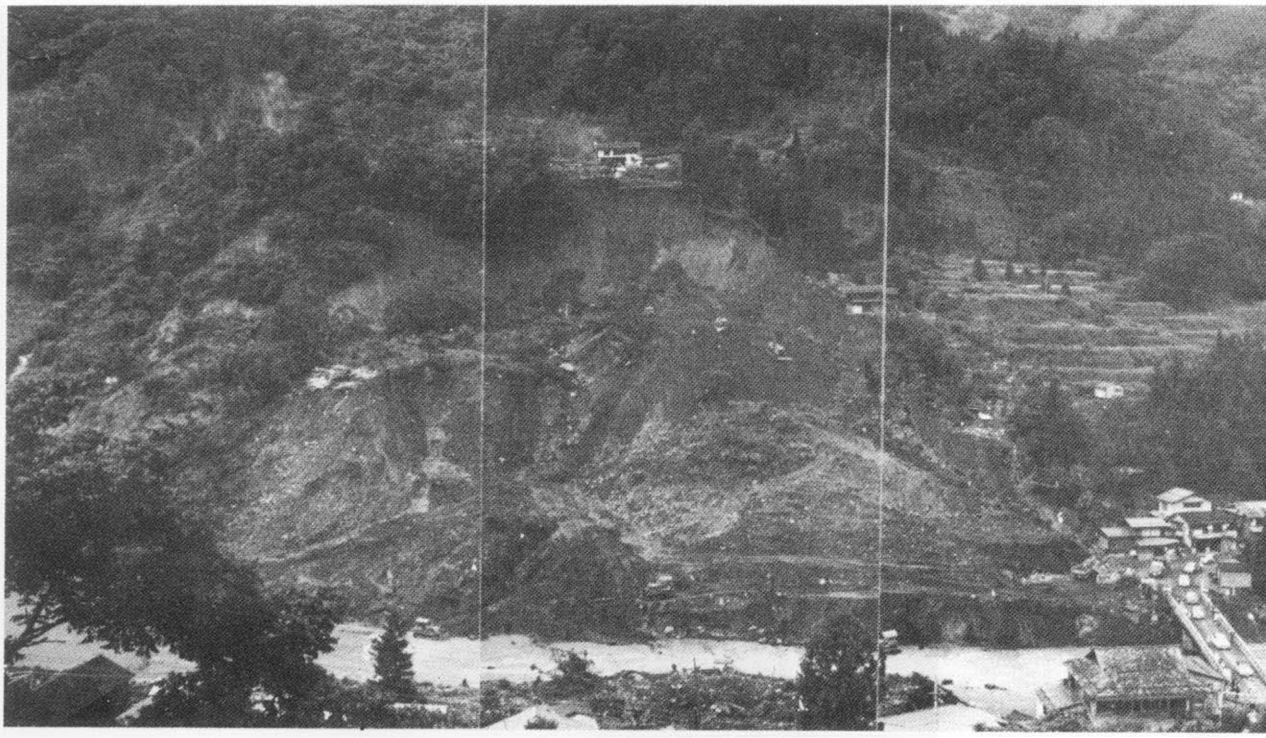
Location Kuchiyama, Anabuki-cho, Tokushima (134°10'E, 34°01'N).
Scale Length, 250m; width, 400m; depth, 10–15m; area, 10 hectares.
Damage The landslide completely destroyed an electric house, and damaged four dwelling houses and roads.
Geology, Mechanism and Type On September 8–13, 1976, the Tokushima district was struck by a heavy rainfall brought by the Typhoon No. 17. A lot of landslides and debris flows were triggered by the rainfall and caused severe damage. Particularly, in the basin of the Anabukigawa river where the damage was heavy, total amount of the rainfall exceeded 1 000mm and, at another place, the continuous rainfall in five days exceeded 2 700mm.
Activation due to such heavy rainfall was observed on landslides of debris creep type which extensively distribute in the crystalline schist zone in this basin. The Kubino landslide is a typical example of those landslides. The slid mass consists mainly of the debris or colluvial soil covering the bedrock of pelitic schist, and the horizontal displacement was 6m at the maximum.
Control Works Groundwater drainage works such as drainage wells and horizontal drain drillings, surface drainage channel and pile works.



General view of Kitamata landslide (Photo taken in 1976).

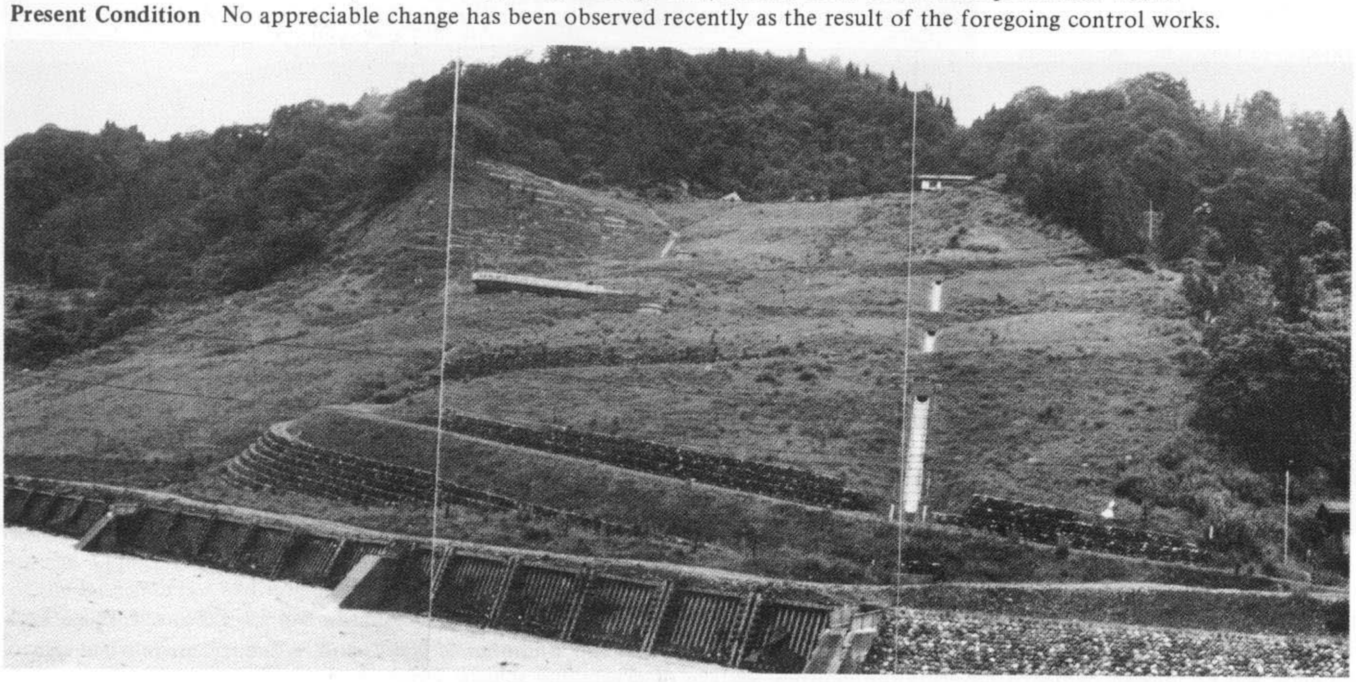
The landslide is in the same basin with the Kubino landslide. Under the influence of the Typhoon No. 17, the site was attacked by a torrential rainfall of 1 000mm from September 8 to 13, 1976 and a number of cracks and failures occurred. The sliding mass was composed of debris covering the bedrock surface of crystalline schists. Drainage works for surface and ground water were carried out.

Ozuchiyama Landslide



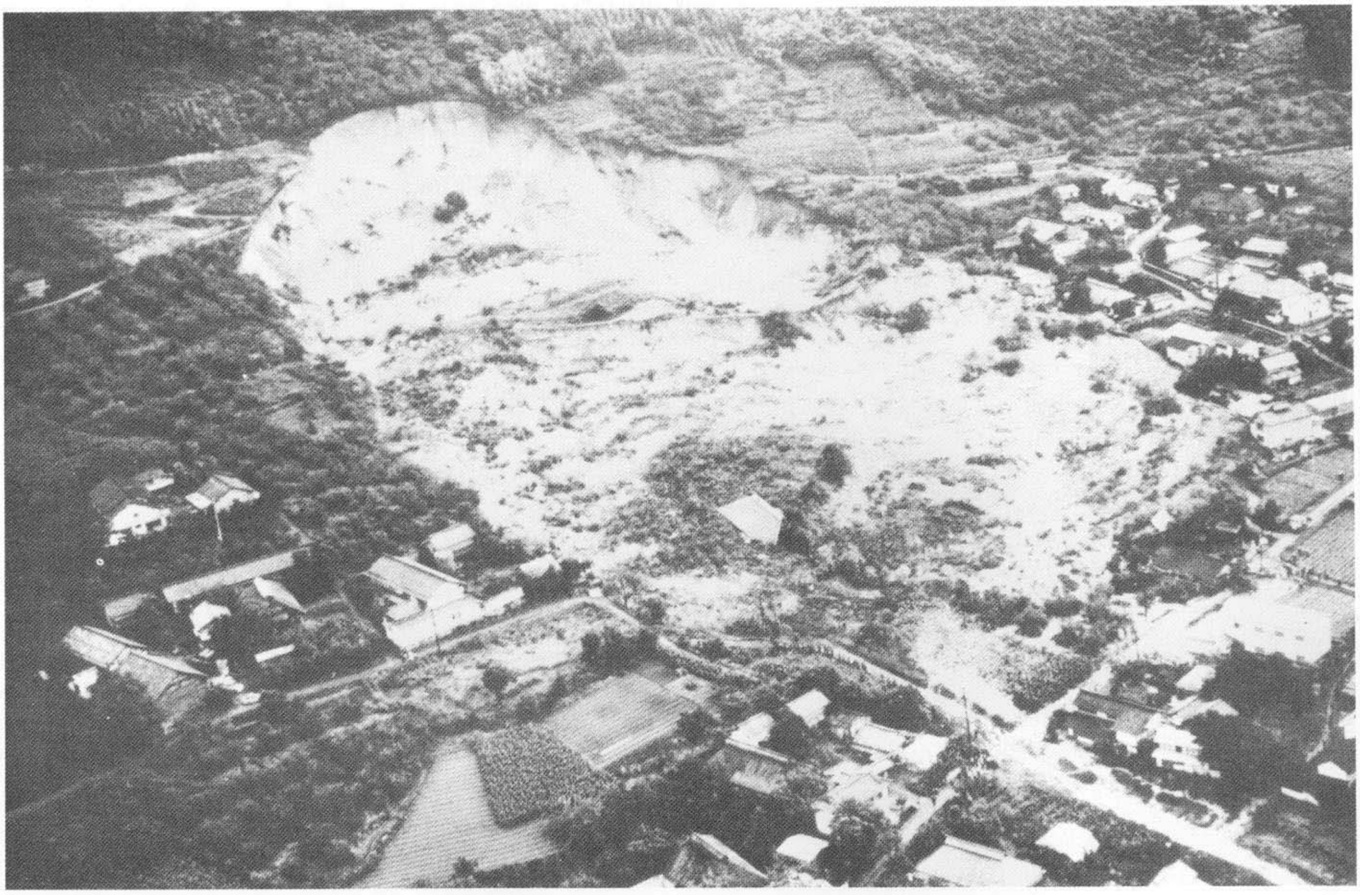
General view of Ozuchiyama landslide (Photo taken in 1971).

Location Otari-mura, Nagano (137°55'E, 36°46'N).
Scale Length 180m, width 200m and depth 20m, with the volume of 300 000m^3.
Damage The landslide occurred in July 1971. The sliding mass flowed into the Himekawa river and blocked the river so that the overflowed muddy water ran over a national highway and a village, resulting in the destruction of 15 houses and some public buildings, and the interruption of the highway and the National Railway line by inundation. Total damage was about ¥700 000 000.
Geology, Mechanism and Type The landslide is a reactivated one in the frequently repeated landslide. The area is located along the western boundary of the Fossa Magna and is transversed by the Himekawa Fault with a clayey-sheared and altered zone of 10m wide. The Miocene strata of welded tuff, mudstone and sandstone are considerably altered and weathered to result in weakening in strength. The trigger of the movement is thought to be the groundwater from a heavy rainfall blocked by the fault shear zone.
Control Works The restoration works for the Himekawa river were conducted at the lower part of the landslide. The main part of the slide was stabilized by excavation, piling, drainage well, surface drain and surface protection works.
Present Condition No appreciable change has been observed recently as the result of the foregoing control works.



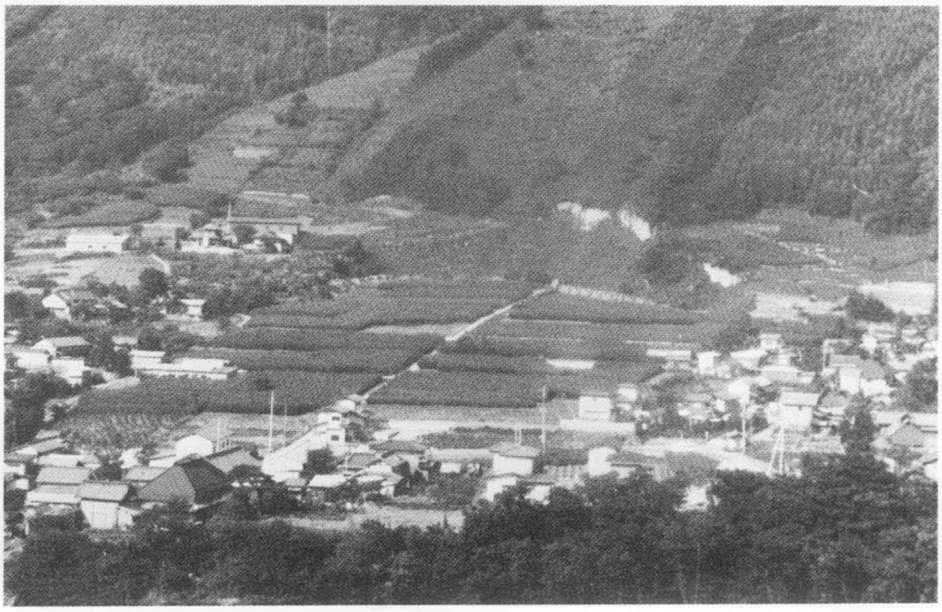
General view of Ozuchiyama landslide after the completion of control works (Photo taken in 1979).

Makiuchi Landslide



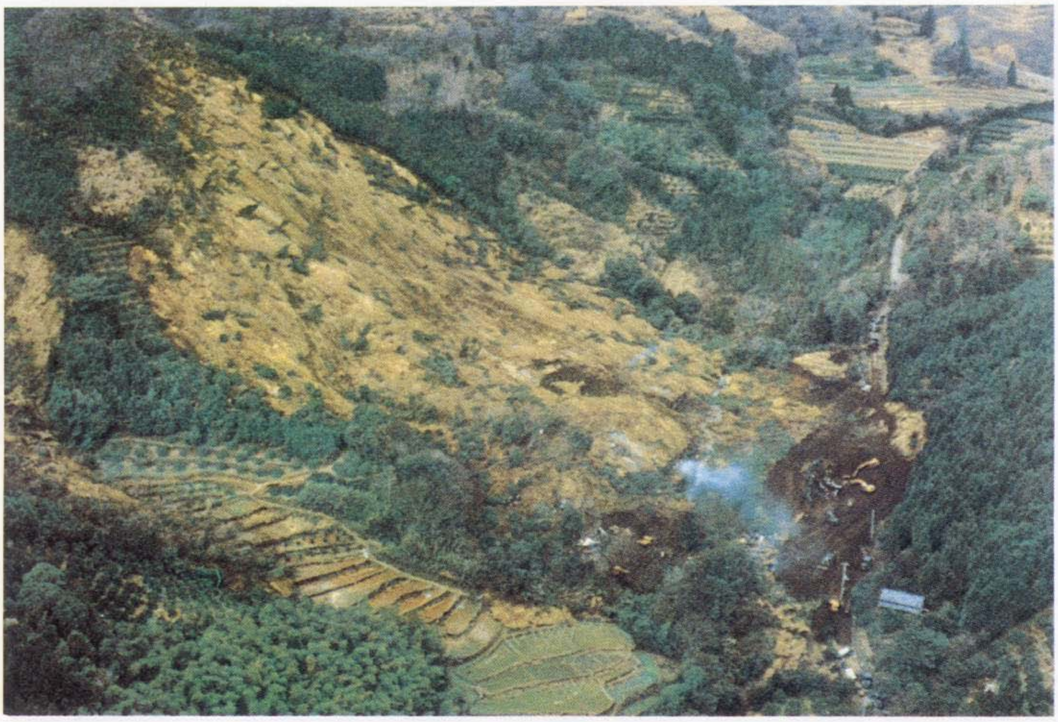
General view of Makiuchi landslide just after the disaster (Photo taken in 1966).

Location Makiuchi, Matsushiro-cho, Nagano (138°10′E, 36°33′N).
Scale Length, 250m; width, 150m; and volume, 200 000m^3.
Damage Eleven houses and farm land were destroyed.
Geology, Mechanism and Type The landslide occurred with seepage of a great amount of groundwater due to the ground deformation during the Matsushiro earthquake swarm which began on August 3, 1965.
The bedrock is composed of Miocene sedimentary rocks and volcanic rocks.
The type of the landslide is a debris slide.
Control Works The control was made mainly by the drain drilling, with crib and surface drain works jointly executed.
Present Condition The swarm earthquakes tended to cease in and after 1978, while the control works proved to be effective. Thus, the site is stable and calm, with the farm land expanded and dwelling houses built thereon.



Makiuchi landslide after the completion of control works.

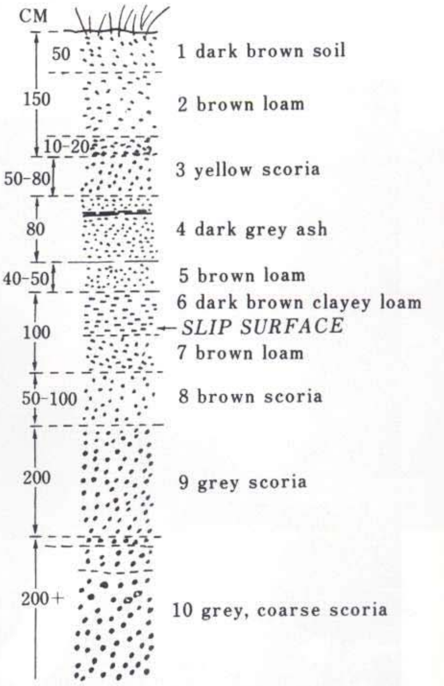
Nanamagari Landslide



General view of Nanamagari landslide (Photo taken in 1978).

Landslides triggered by the 1978 near the Izu-Oshima earthquake are the northwest of Nashimoto, Kawazucho, Shizuoka Prefecture. (Air photograph taken on January 15, 1978)

Location Iriya, Kawazu-cho, Shizuoka (139°02'E, 34°46'N).
Scale Length, 300m; width, 200m; root area 13 000m^2 and moved volume, about 60 000m^3.
Damage Four houses buried, and seven persons killed by being buried under the slid mass.
Geology, Mechanism and Type At 12:24 on January 14, 1978, an earthquake of magnitude 7.0 occurred in the sea near the Izu Oshima Island. This caused a number of landslides and slope failures along roads, large and small, at about 600 places in the Izu Peninsula about 20km distant from the epicenter. The largest was the Nanamagari landslide. The slid mass was composed of the scoria layers covering an older loam layer. It slid down over the loam layer by the earthquake shaking and turned into a dry grain flow at a high speed for about 200m. The mass slid down on a slope of about 24°.
The thickness of the slid mass is about 3m.

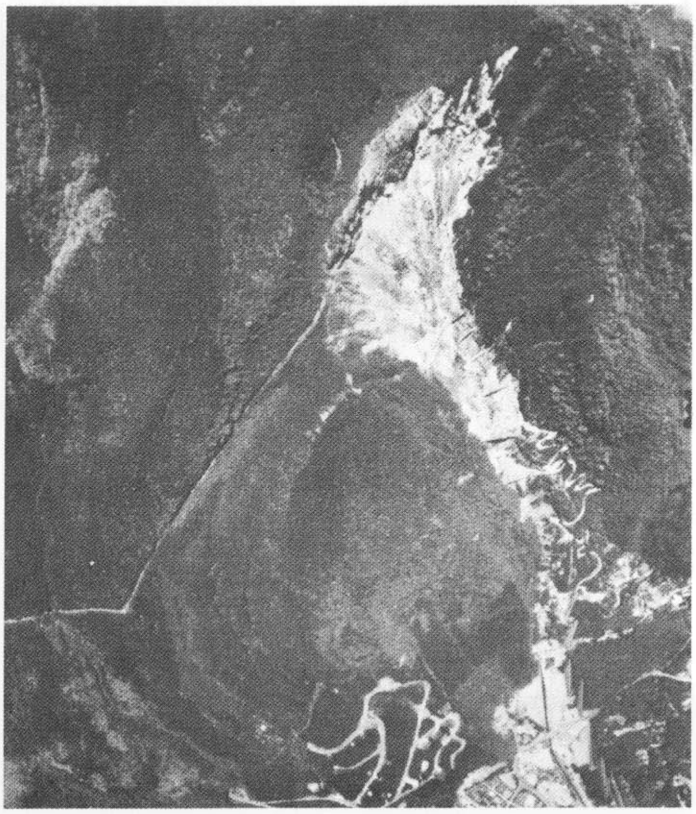


Geological columner section of Nanamagari Landslide area.

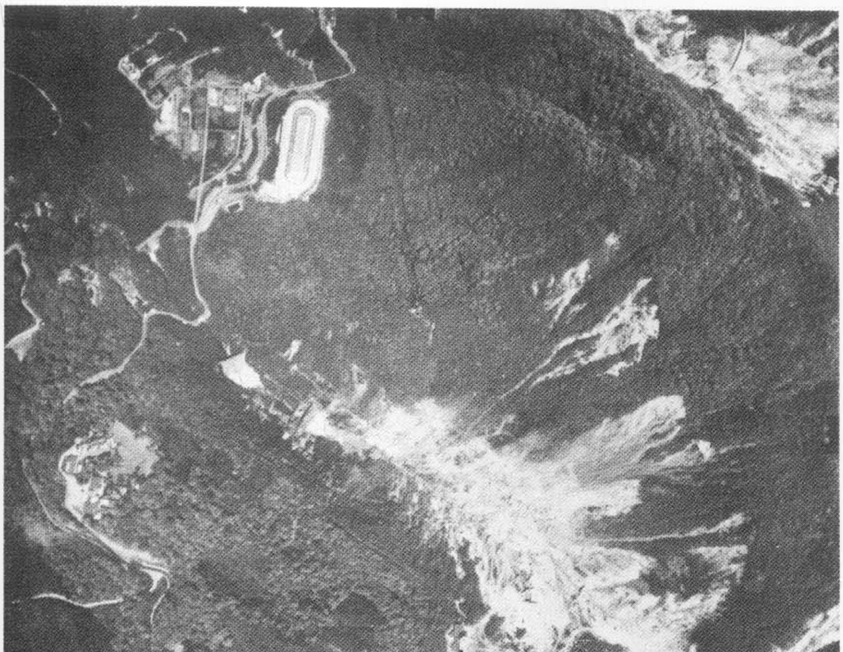
Surficial slides by heavy rainfalls after the earthquake in the same area as the photograph shown in the left page. (Air photograph taken on August 5, 1978)

Owakudani and Sounzan Landslides

The 1953 slide in the Sounzan landslide area.
x: A destroyed temple.



The Souzan landslide area (Photo taken in 1979).



The Owakudani landslide area (Photo taken in 1979).

Location Hakone-cho, Kanagawa (130°02'E, 35° 14'N).

Scale Owakudani: Length, about 800m; width, 400m; and Sounzan: Length, 1 200m; and width, 100m.

Damage Owakudani: Major slidings in 1910, 1921, 1935, 1948 and 1950. Particularly, in 1910, a debris flow blocked the Hayakawa River, causing a great damage to the hot spring town in the lower stream.

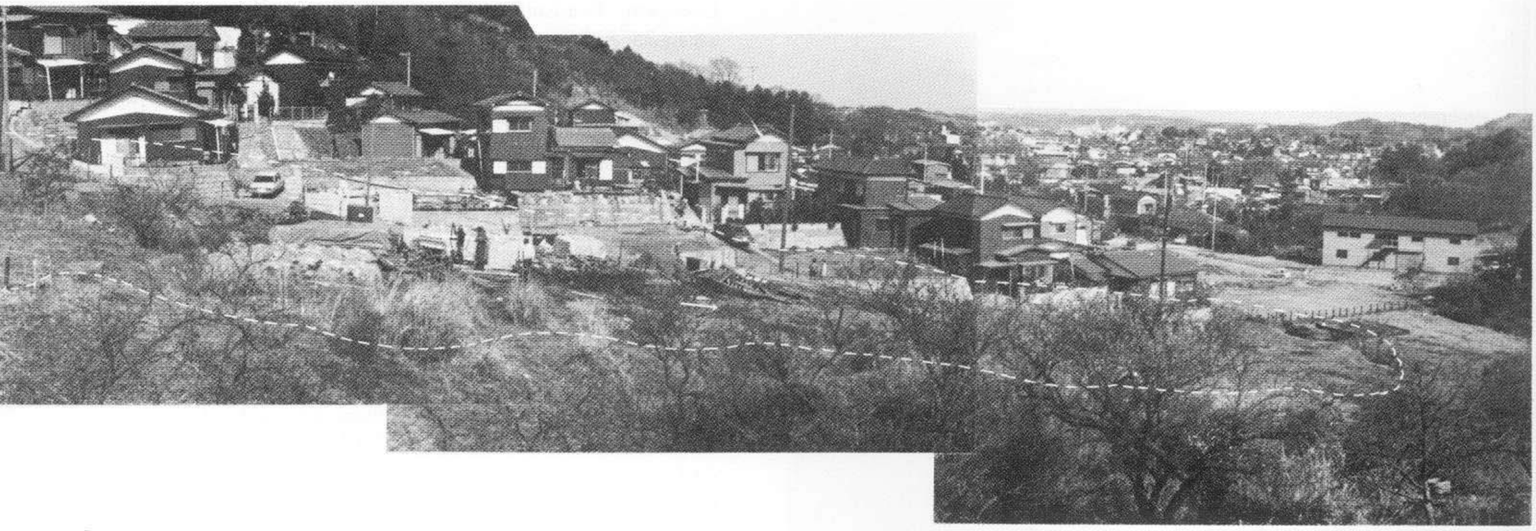
Sounzan: In July 1953, the landslide buried a temple, 17 dams and 7 hectares of forest with 10 persons killed and 15 persons injured in a moment.

Geology, Mechanism and Type This is a typical landslide in hydrothermal alteration areas. The area is underlain by andesitic lava flows and tuff breccia layers. Such bedrocks have been altered by the hydrothermal and fumaloric activity into clayey zones. Landslides are caused in such clayey zones by heavy rainfalls, swarm earthquakes and stream explosions.

Control Works Erosion control, surface drain, banking, hillside and gas exhaust drilling works.

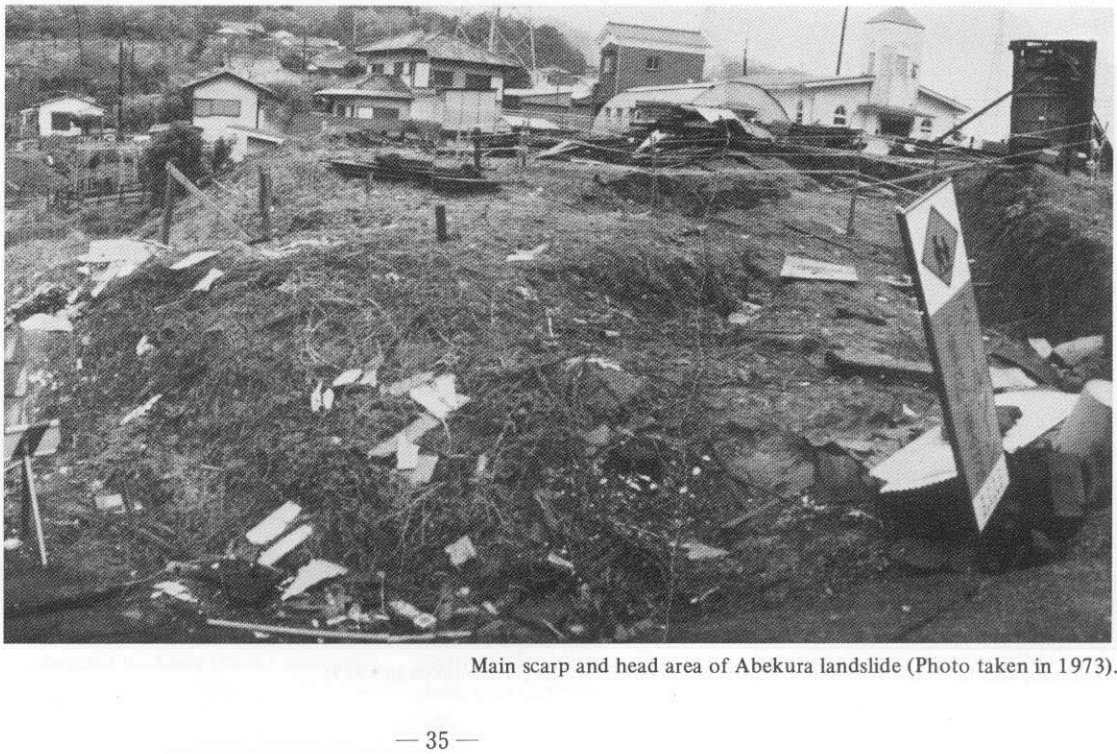
Present Condition The highly geothermal field at the uppermost part of the Owakudani moved upward with repeated failures. In the Sounzan area, no appreciable change is noted in these years.

Abekura Landslide



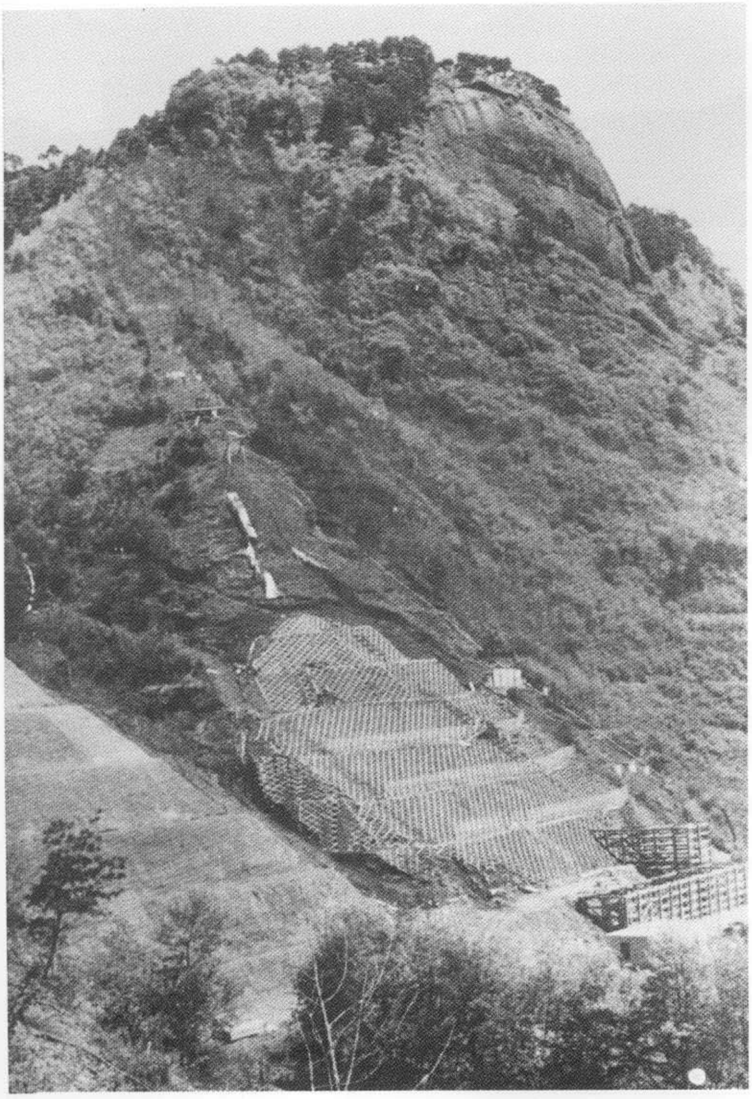
General view of Abekura landslide (Photo taken in 1974).
Sliding area

Location Abekura area, Yokosuka-shi, Kanagawa (139°18'E, 35°15'N).
Scale The landslide is of a relatively small scale about 80m in length, about 50m in width and 10m in depth.
The slope gradient was gentle (ca. 10 degrees), and the head of the landslide was located at the ridge of a small hill.
Damage This area is a residential quarter developed from a forest in 1969.
Around November 1973: Movement of the slide first appeared.
March 1974: The rate of the movement came to 6mm/hour, and the relative height at the main scarp increased to nearly 2m. The landslide occurred mainly in the field and wasteland areas. However, the cracks at the right side of the landslide crossed the buildings of a kindergarden and those at the left side damaged many houses. Four houses were demolished, and the inhabitants of seven houses temporarily evacuated.
Geology, Mechanism and Type The area is composed of mudstone of the Hayama formation of Miocene age. The landslide is considered to be caused by disturbance of groundwater system due to an urban development.
Topographically, there are a number of small landslides around the Abekura landslide. The housing land was made by developers ignorant of such landslides.
Control Works Counterweight fill and excavation works were carried out, as a temporary measures to control the landslide movement. Then a drainage well, drain drilling and piling works were conducted as permanent countermeasures.
Present Condition Little slide movement has been detected.
Miscellaneous The landslide disaster is in a result of the impact of a recent urban development to landslide prone areas.



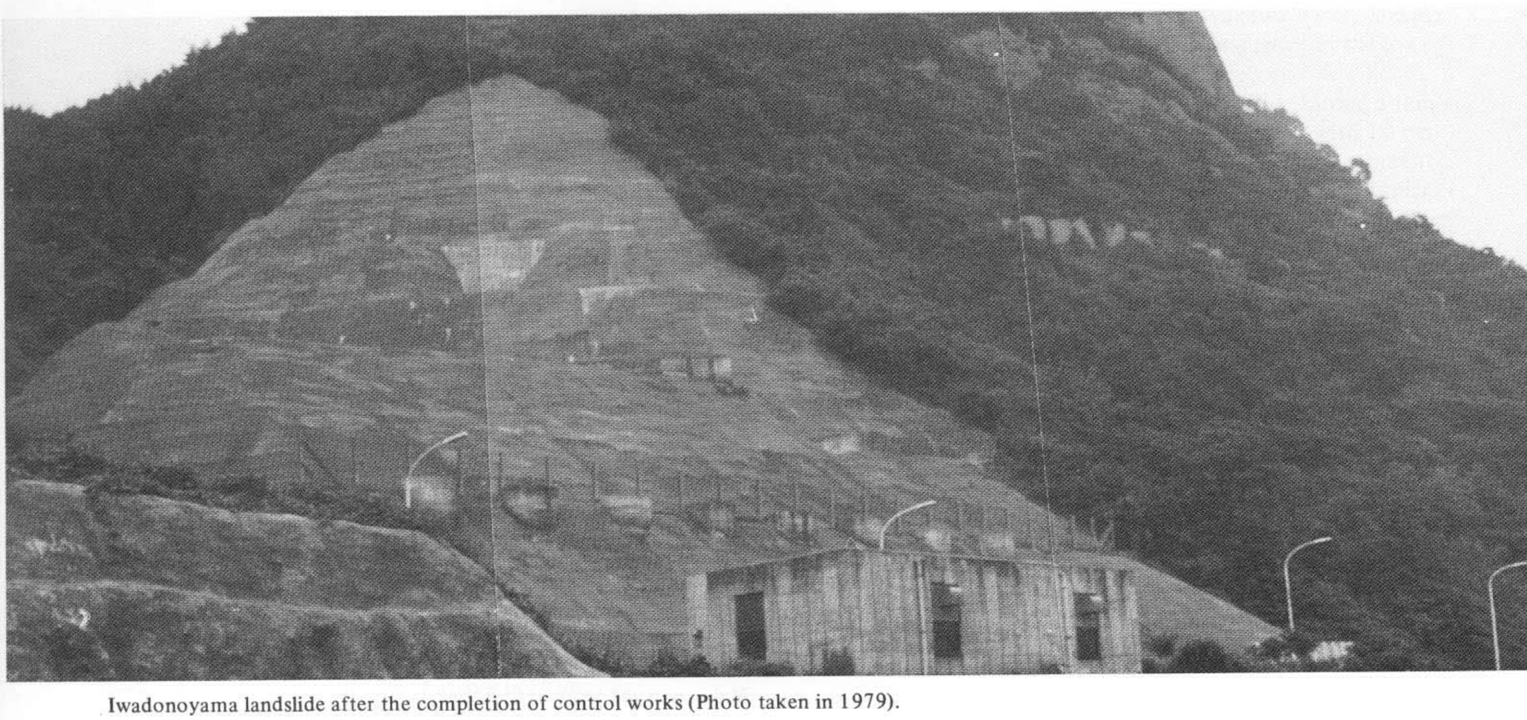
Main scarp and head area of Abekura landslide (Photo taken in 1973).

Iwadonoyama Landslide



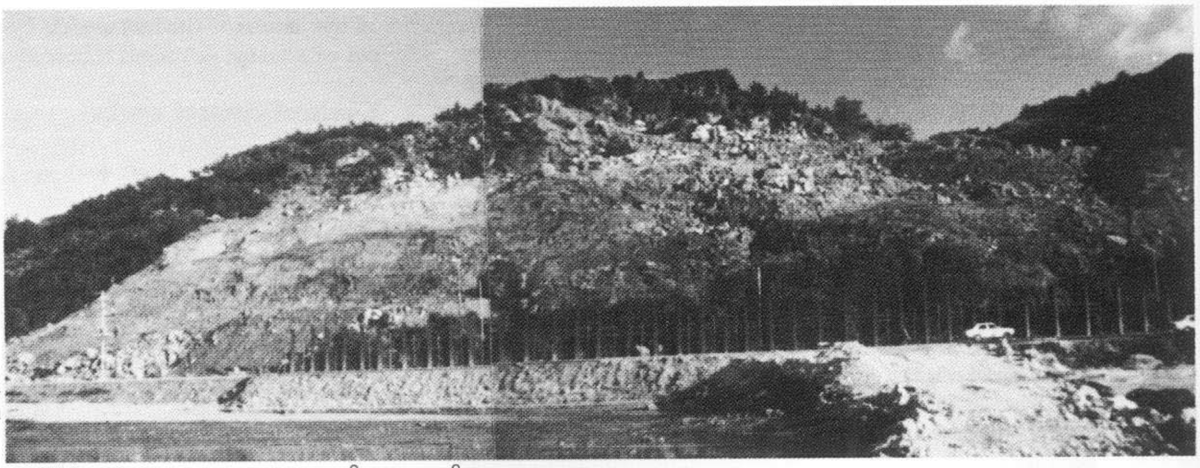
General view of Iwadonoyama landslide during the movement (Photo taken in 1972).

Location Iwadonoyama area, Otsuki-shi, Yamanashi (138° 58'E, 35°37'N).
Scale The landslide is about 100m in length and about 80m in width with a sliding surface at a depth of 15–20m, presenting a ridge configuration of very sharp slope with a gradient averaging 35 degrees.
Damage The Chuo Expressway serving as an artery of transportation between Tokyo and Kofu districts had to be closed for more than three months only three years after opening for service.
February 1972: Fissuring observed in a mountain path on a slope.
21 March 1972: The sliding mass moving at a speed of 3mm/hr.
29 March 1972: The movement at 13mm/hr; the expressway closed; evacuation of inhabitants in four houses located far from about 100m beneath the Expressway.
Geology, Mechanism and Type The material is composed of alternation of shale, tuff and tuffbreccia, and andesite of Misaka Formation, Miocene age. Those rocks are sheared by fault movement.
Although the bedrocks were apparently observed as fresh ones in the time of excavation of the ridge, they were rapidly weakened by weathering through the seepage of water and the unloading.
The sliding surface developed through the weathering of bedrock to result the occurrence of a rock slide.
Control Works To control the movement of sliding mass, a temporary counterweight fill was made at the foot of the slide on the Expressway.
After the sliding mass ceased to move, permanent control works such as excavation at the head of the sliding mass, cast-in-place piles and steel piles were conducted. Then, upon completion of such works, the counterweight fill was removed.
Present Condition After the preventive works, extensometers were installed on the slope to observe any change in the condition of the slope. To date, no movement has been observed.



Iwadonoyama landslide after the completion of control works (Photo taken in 1979).

Yamada Landslide



General view of Yamada landslide (Photo taken in 1975).

Location Yamada Spa area, Onna-mura, Okinawa (127°45′E, 26°26′N).
Scale The landslide is about 250m long about 150m wide and 10–15m deep. It is differenciated into several units. The slope gradient is about 20 degrees.
Damage and Mechanism The area has a deep layer of colluvial soil distributed over Paleozoic slate and black shist. The head of the landslide is constrained by a tectonic line.
The landslide occurred after cutting the foot of the slope for the construction of a bypass for the National Highway No. 58 and heavy-subsequent rainfalls of 250mm in 3 days late in May, 1975 and of 300mm in 2 days in early June.
Control Works For the stabilization of the landslide, a temporary counterweight fill was made on the highway, and the soil at the top of the slope removed. The highway was leading to the site of the Okinawa Marine Exhibition in 1975 to be opened two months later so that cast-in-place pile works were executed to replace the counterweight fill on the highway for the security of traffics.
Thereafter, drainage well works were executed for insuring the stability of the slope.
Present Condition No landslide movement has been observed after the control works.

Takabayama Landslide

General view of Takabayama landslide (Photo taken in 1970).

Location Kawai, Ojiya-shi, Niigata (138°49′E, 37°15′N).
Scale The landslide is about 100m in length and 60m in width with a slip surface at 20m in depth and occurred at a ridge of the steep slope with an average gradient of 35°.
Damage Deformation of the tunnel having been observed since the completion, countermeasures were taken for the prevention of collapses and reinforcement of the tunnel body. After a heavy rainfall in August 1969, the deformation of the tunnel increased, and additional countermeasures for the landslide were taken, but the failure of the landslide occurred on January 22, 1970 and about one-half of the tunnel was completely destroyed.
Geology, Mechanism and Type The area is underlain by Neogene sediments including shale and alternating layers of mudstone and sandstone. The slip surface developed along the boundary between the shale and the alternation layers. The landslide was caused by the river erosion at the foot of the slope, groundwater, water permeation through a heavy rainfall and snow melting, and loosening due to excavation of the tunnel. The tunnel was situated at a position crossing the landslide slope at a right angle with the direction of the movement and cutting the slip surface at the central part of the landslide.
Control Works Protection from the river erosion on the surface at the foot of the slope and prevention of rainwater permeation were performed. Reinforcement of the support and concrete lining were conducted for the tunnel body. However, the deformation of the sliding mass proceeded further so that drain drillings were conducted in the landslide area, but the final failure of the landslide occurred.
Present Condition The tunnel was constructed with the route changed farther to the back of the slope in order to keep out of the landslide site. To date, no deformation of the new tunnel has been observed.
Miscellaneous It was possible to conduct minute observations from generation of the landslide to failure. As a result, the forecasting of collapses by using extensometers was possible and, thus, was improved greatly.

6. Control Works

Concepts

"The control works actually carried out in the landslide areas in Japan are based on the following concepts."

With primary importance placed on the respect of human life, the control works are performed for evacuation of the inhabitants from the dangerous landslide zone to a safety zone, relocation of the dwelling houses, prevention of river flooding and securing road traffic.

Where damage is caused to private and public buildings or there is a possibility of damage to such buildings, counter measures are considered with primary importance given to the protection of buildings.

Where public structures are damaged (e.g., road damage, bridge collapse, breakage of river embankment, damage to a dam, damage to rails and destruction of a tunnel or bridge in the case of railway, breakage of an irrigation channel and damage to a school yard and a hospital or a public square) and if left unrepaired cause trouble for many people, corrective measures are carried out even if considerable amount of expense is required.

Where the damage is not great on a one-time basis but occurs successively every year or continuously or intermittently and if it accumulates and results in serious damage, the control works are considered in alignment with the movement of the whole landslide region.

Where a public work is carried out, it is considered in such a way as to maximize the investment function of the work generally. In the case of a landslide control work, its scale is considered commensurate with the extent of its public benifit.

Where a landslide is present along a railway line or road, the route of the railway or road may be changed if landslide damage can be avoided by doing so and if the expense required for such change is far cheaper than that of the landslide control works. For such a change of route, use of a bridge or tunnel is conceivable.

Kinds of control works

- Surface drain. (Figs. 6–1, 6–2, 6–3)
- Drain work. (Fig. 6–2)
- Interceptor drain work. (Fig. 6–18)
- Interceptor wall work. (Fig. 6–4)
- Groundwater drain works.
  - Horizontal drain drilling. (Figs. 6–5, 6–6)
  - Oblique drain drilling. (Fig. 6–7)
  - Drainage wells of liner plates. (Figs. 6–8, 6–9, 6–11)
  - Drainage wells of ferroconcrete. (Figs. 6–9, 6–10, 6–11)
  - Drainage tunnels. (Fig. 6–12)
- Pile works.
  - Steel piles. (Fig. 6–14, 6–17)
  - I-steel piles.
  - PS-piles.
- Cast-in-place pile work. (Figs. 6–13, 6–16)
- Anchor work. (Fig. 6–19)
- Excavation work. (Fig. 6–15)
- Counterweight fill work. (Figs. 6–21, 6–22)
- Retaining wall works. (Fig. 6–21)
  - concrete retaining wall.
  - crib. (Fig. 6–20)
  - gabion.
  - tied-back wall by combination of steel piles and steel sheets.
- River structure works.
  - Consolidation dams. (Fig. 6–23)
  - Revetment.
  - Groin.

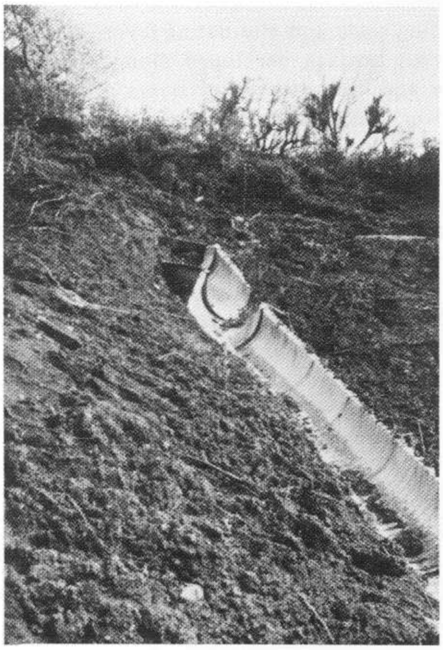


Fig. 6–1. Surface drain of the corregated pipes.

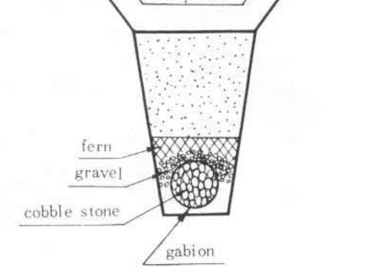


Fig. 6–2. Surface drain with a drain.

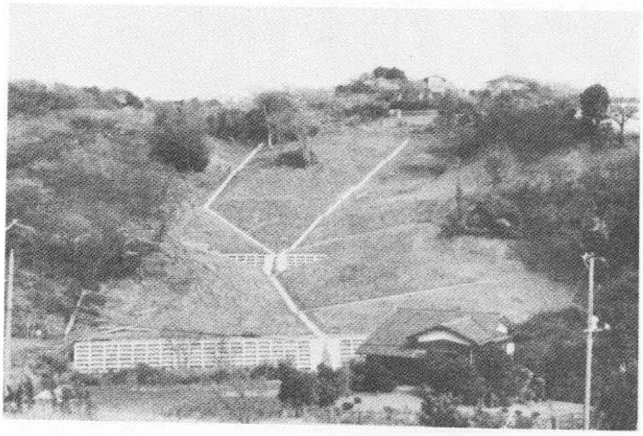


Fig. 6-3. A surface drain system and crib works.

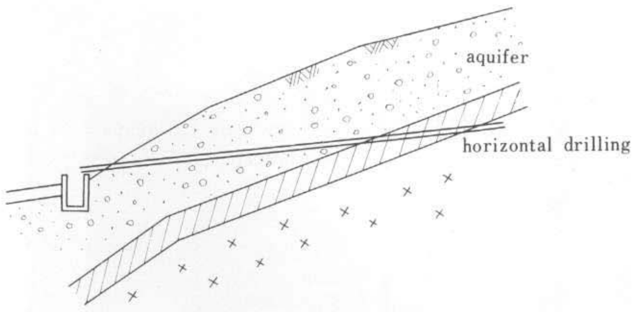


Fig. 6-6. Section of horizontal drilling.

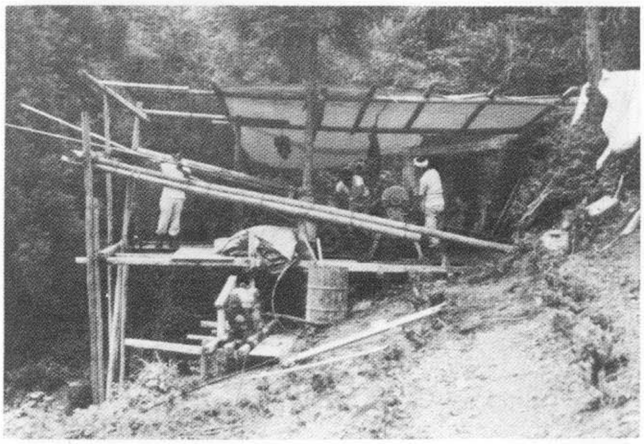


Fig. 6-7. Oblique drain drilling.

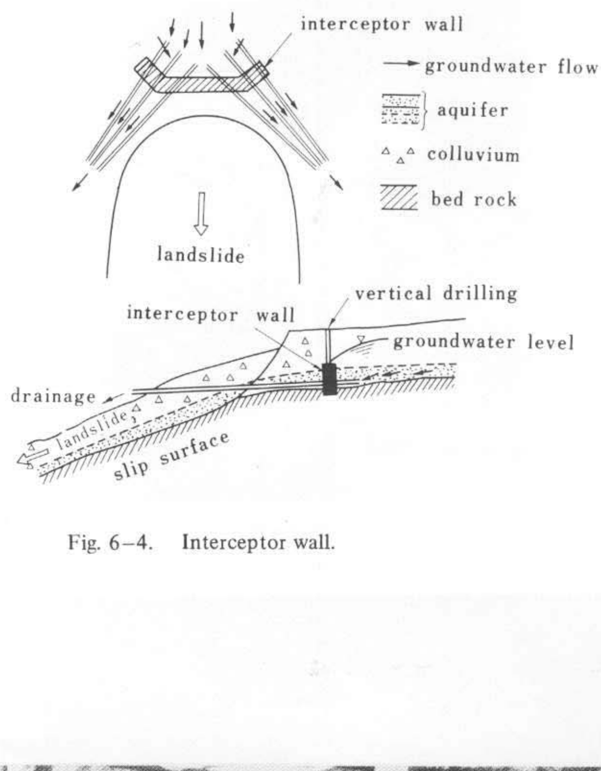


Fig. 6-4. Interceptor wall.

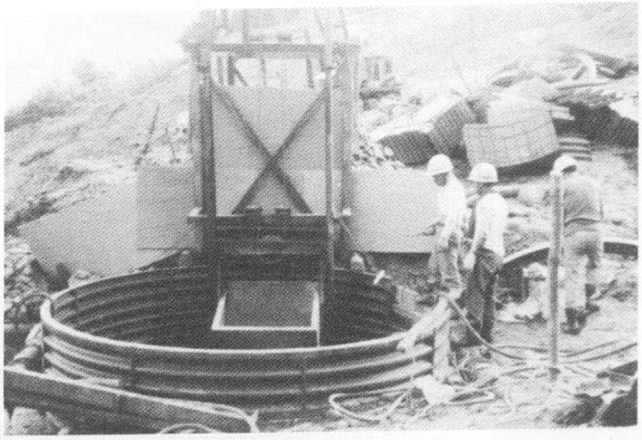


Fig. 6-8. Under construction of a drainage well of the liner plates.

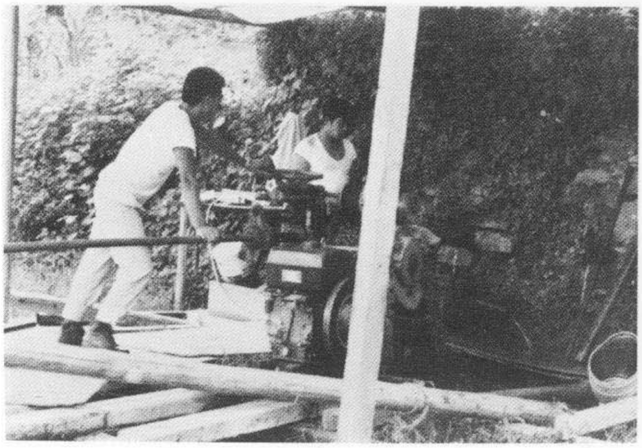


Fig. 6-5. Horizontal drain drilling.

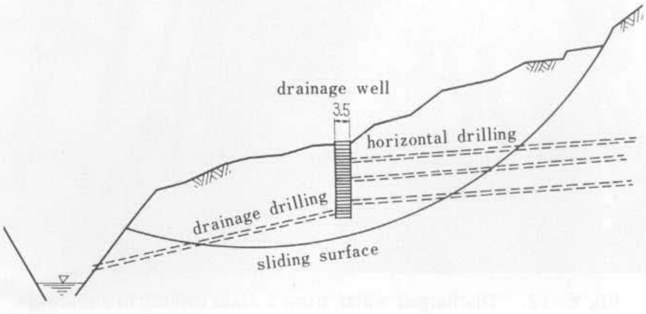


Fig. 6-9. Section of a drainage well.

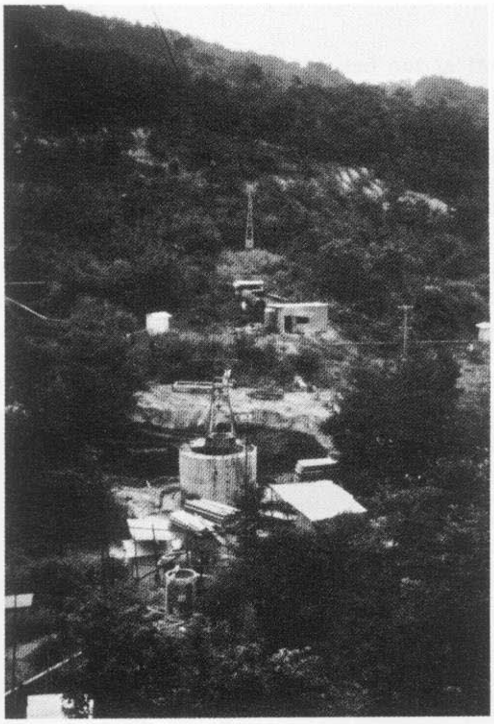


Fig. 6–10. Underconstruction of a ferroconcrete well.

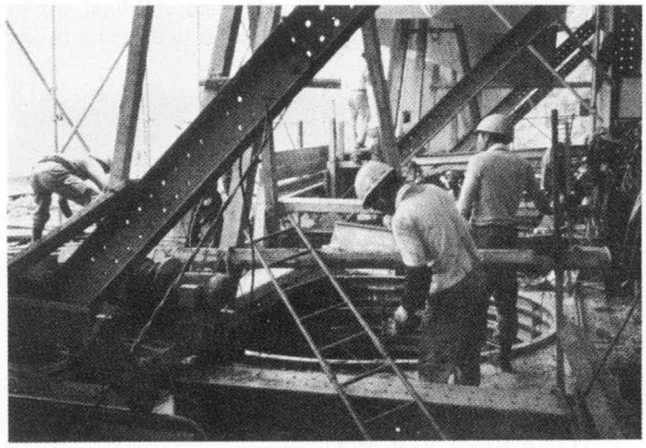


Fig. 6–13. Under construction of a cast-in place pile.

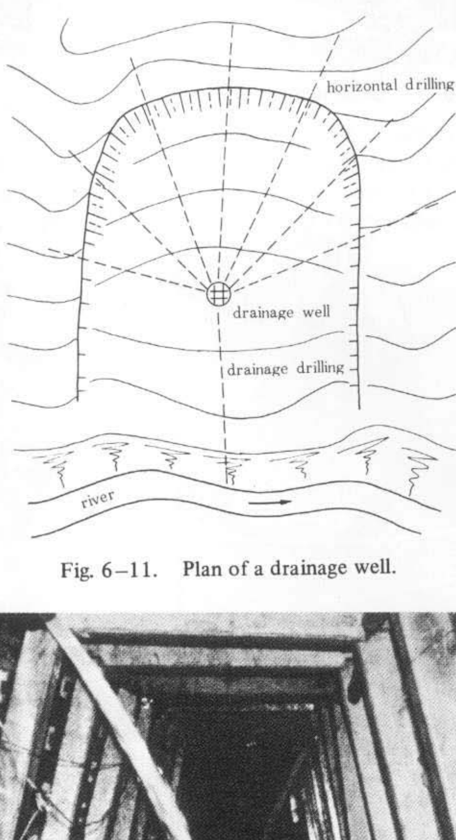


Fig. 6–11. Plan of a drainage well.

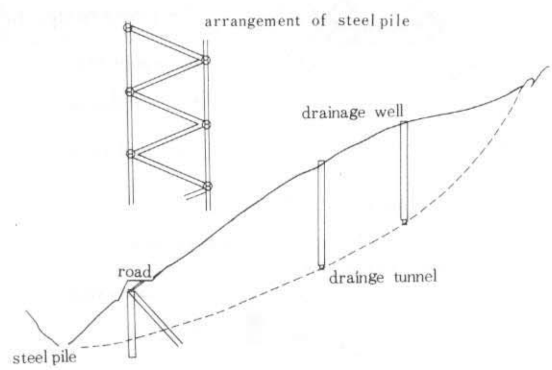


Fig. 6–14. Pilling works.

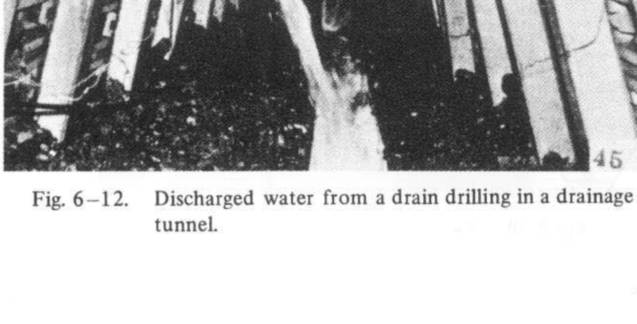


Fig. 6–12. Discharged water from a drain drilling in a drainage tunnel.

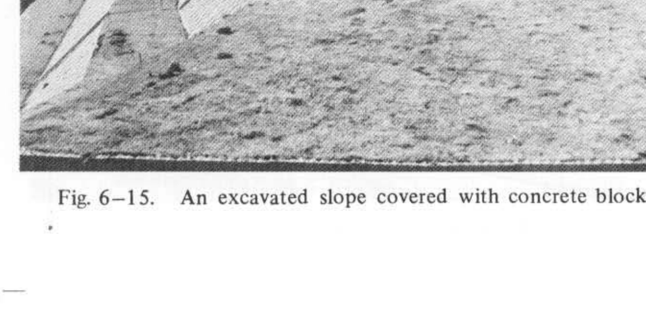


Fig. 6–15. An excavated slope covered with concrete blocks.

Fig. 6-16. An example of a landslide stabilized by cast-in-pile works. (Iwadonoyama landslide)

Fig. 6-18. Under construction of an interceptor drain work.

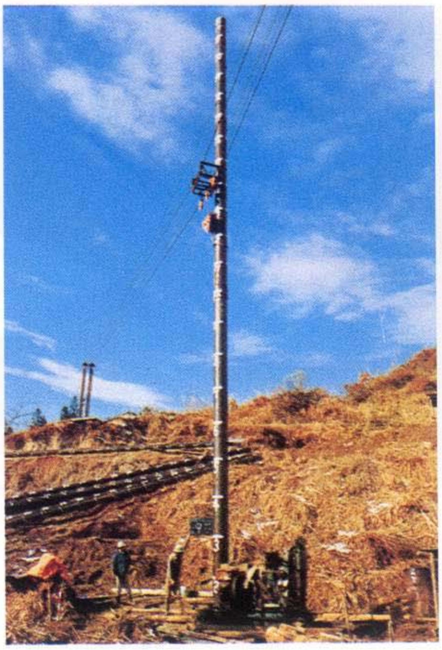


Fig. 6-17. Inserting of a steel pile

Fig. 6-19. Anchoring for a landslide control. (Odo landslide)

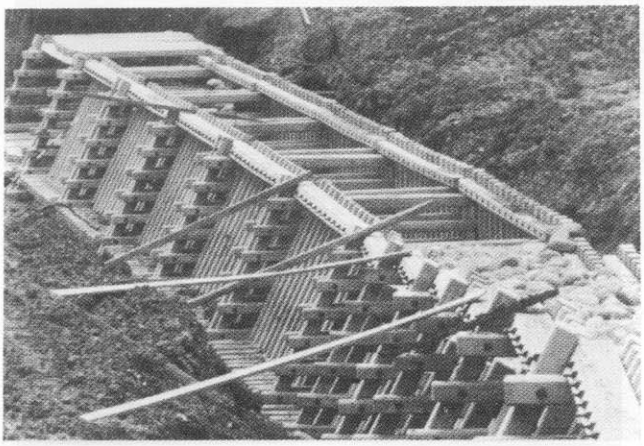


Fig. 6-20. Crib work.

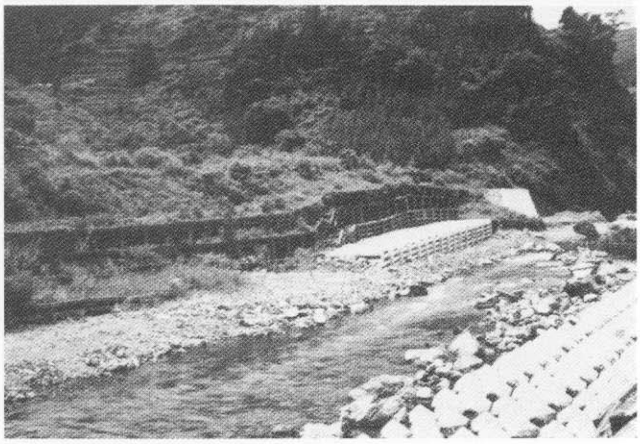


Fig. 6-22. Counterweight by the concrete blocks and cribs.

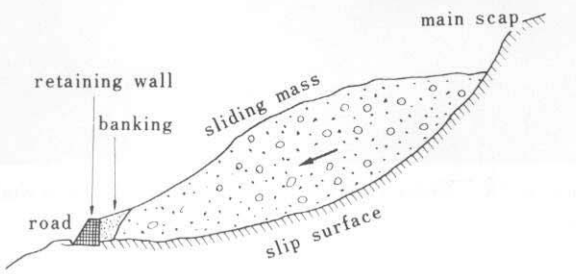


Fig. 6-21. A retaining wall for counterweight fills.

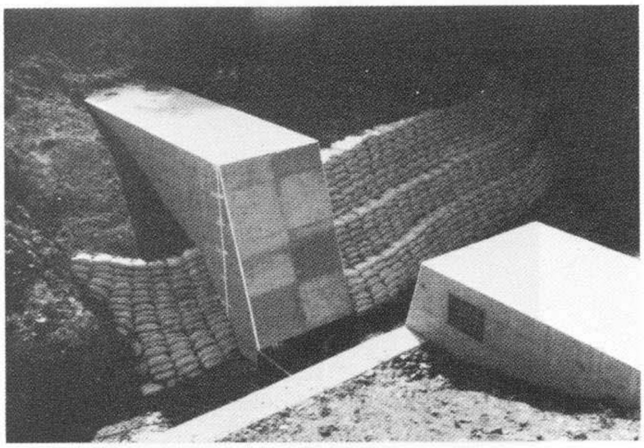


Fig. 6-23. A consolidated dam work.

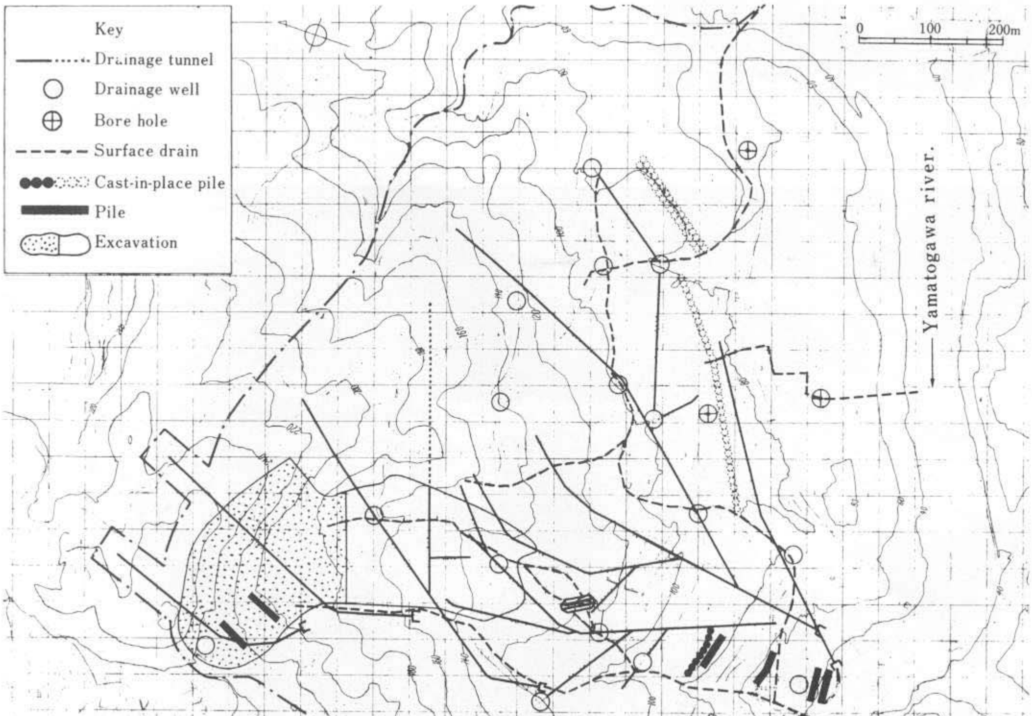


Fig. 6-24. General plan for control works at the Kamenose landslide area.

7. Prediction and Estimation

When cutting, filing, piling or other work is performed on a slope or the lower part of a slope is dammed up, prediction of whatever change the slope will undergo is dependent on the formula of safety factor in the case of long term prediction. Safety in the case of elevation of the groundwater level in the rainy season or spring thaw is also examined by the formula of safety factor. Indefiniteness of the values of cohesion and frictional coefficient in the formula of safety factor is averted by taking the current value of safety factor as unity and calculating how it is changed by the work or change in the water level.

Further, a double check system is often employed in carrying out the work by installing extensometers and tiltmeters and confirming that there is no change in the meter indications.

For short term prediction, a formula proposed by Dr. Saito for estimating the failure time by extensometer is used extensively. Sometimes, estimation is made by means of electric tiltmeter or other instrument.

Estimation of the range of damage is made statistically with reference to past cases.

For the regional forecasting, the relationship between the total amount of rainfall and intensity of rainfall and the percentage of failure occurrence probability in the past is taken statistically, and when the specified conditions are exceeded, the road is often closed.

For the debris flow, estimation of the dangerous region is made to complete the evacuation system.

8. Organizations Concerned with Landslide Study and Control

The Japan Society of Landslide

The Society was established in 1964. It has about 1500 members composed mainly 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. It issues a quarterly journal and holds symposiums and seminars for information on the results of studies on the landslide phenomena and landslide control techniques and is thus striving for study of the landslides and improvement of the control techniques.

It is also deploying its activities on an international scale through, for example, international symposiums held twice to date concerning the landslides and their control works.

President : Toshio Taniguchi
Address : Ichimura Bldg., 5-7-2, Shinbashi, Minato-ku Tokyo 105

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 Nagano
Address : 692-2, Habashita, Minaminagano, Nagano-shi, Nagano 380

Forestry Conservation Research Association

The Association is designed for improvement of forestry conservation techniques and development of the forestry conservation projects through exchange and reporting of study and information on forestry conservation, with the members composed mainly of engineers concerned with forestry conservation.

President : Director, Forestry Conservation Division
Address : c/o Forestry Conservation Division, Forestry Agency
1-2-1, Kasumigaseki, Chiyoda-ku, Tokyo 100

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 : 5-7-2, Shinbashi, Minato-ku, Tokyo 105

Universities and Colleges

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

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, Sakura-mura, Niihari-gun, Ibaraki 305

b) National Research Institute of Agricultural Engineering
Address: 2-1-2, Kannondai, Yatabe-machi, Tsukuba-gun, Ibaraki 305

c) Forestry and Forest Products Research Institute
Address: Matsunosato-1, Kukisaki-mura, Inashiki-gun, Ibaraki 300-12

d) Geological Survey of Japan
Address: Higashi 1-1-3, Yatabe-machi, Tsukuba-gun, Ibaraki 305

e) Public Works Research Institute
Address: Asahi-1, Toyosato-machi, Tsukuba-gun, Ibaraki 305

f) Geographical Survey Institute
Address: Kitanogo-1, Yatabe-machi, Tsukuba-gun, Ibaraki 305

g) The Railway Technical Research Institute, JNR
Address: 28-38, Hikari-cho, Kokubunji-shi, Tokyo 185

h) Central Research Institute of Electric Power Industry
Address: Abiko 1646, Abiko-shi, Chiba 270-11

Academic Societies

a) The 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

9. Index Map of Landslides Illustrated