Basement structure under the sediments accumulated in the ridge-top depression and landslide-dammed lake around Mt. Tsuenomine, Kumano City, Mie Prefecture: Results of integrated analyses by drilling, electrical and seismic survey methods

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Part of the deep-seated gravitational slope deformation features (DGSD) was recently indicated to be precursors of large-scale landslides, whereas part of them has been stable for more than 10,000 years. Discrimination between them is important to mitigate the landslide disasters, but impossible today, because of scarcity in case studies of DGSD. Ridge-top depression and landslide dammed-lake occur in the Tsuenomine area, Kumano City, Mie Prefecture. They are covered with sediments, and their basement structures are unclear. In order to clarify the structures and development history of DGSD and related landslide phenomena we conducted drilling, electrical and seismic surveys of these topographic features. The two cores drilled at the ridge-top depression are 7.5 and 9 m in depth, and are composed of ca. 1 m thick carbonaceous mud at the top, ca. 5 m thick gray to yellowish brown mud in the middle, and mud with clasts probably deposited on the basement in the lowermost part. Three horizons, 0.8, 4.3 and 7.7 m in depth, of tephra are identified as the Aira-Tn (28-30 ka), Kujyu-Daiichi (50 ka), and Kikai-Tozurahara (95 ka) tephra, resptectively. The sediments accumulated in the landslide-dammed lake are cored until ca. 7.5 m deep, but could not reached to the basement. Together with the ca. 2.5 m thick surface exposure, the ca. 10 m thick lake sediments consist of upper massive yellowish brown mud and lower similar mud with basement rock clasts. They yield reworked volcanic glasses derived from Kikai-Akahoya tephra (7.3 ka) at all horizons. The electric and seismic surveys are performed along the two lines perpendicular to the ridge, and one line parallel to the ridge on the ridge-top depression. Same surveys are also conducted along the two lines perpendicular to the river, and one line parallel to the river on the landslide-dammed lake. The results of the both surveys are consistent and indicate that they are effective to discriminate the basement rocks from the landslide deposits, and sediments accumulated in the ridge-top depression and the dammed lake.

Keywords: Mt. Tsuenomine, deep-seated gravitational slope deformation, geophysical survey

Gravitational deformation process in Tokugotoge Pass and Mt Otakiyama, Northern Japan Alps

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Gravitationally deformed landforms in Tokugotoge Pass and Mt Otakiyama area, in the southeast of Kamikochi, Northern Japan Alps are examined on the precise topographical maps by the airbone LIDAR data.Continuous double ridges which are aligned 100-300 m in distance are the feature in the area. Ridge top depressions-double ridges do not necessarily correspond with the ENE-SWS geologic trend of the Mino Belt but accord with the existent topography, which shows that the gravitational deformation started after the formation of main topographic framework in this area. The main ridge is asymmetric, that is the southeast side is steep slope and northwest side is gentle. In the middle of the slopes, micro landforms such as uphill-facing scarplets, middle-slope small breaks, and vague downhill-facing scarplets are recognized, which suggest gravitational deformation. They develop in the limits less than 150 m in southeast side and 300 m in northwest side relative height from the main ridge, which is interpreted that deep-seated gravitational deformation proceeds northwestwards i.e dip direction of strata. Though clear landslide landforms cannot be recognized, arch-like drainage of the characteristic landslide landform and traces of rapid landslide are developed. Landforms in this area indicate the geomorphic process of the beginning of areal gravitational deformation, succeeding localization, and changing to landslides.

Keywords: gravitational deformation, LIDAR DEM data, landslides

Oxygen isotopic dendrochronology of a gigantic rock avalanche and its comparison with historical documents -an interim report of the research group on high resolution chronology of large deep-seated landslides

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A lot of huge granitic rock clasts are located on the bank of Dondokosawa River in the east of Mount Ho-ou, the Akaishi Range, central Japan. Radiocarbon ages of tree trunk samples buried in the sediment around the river imply that the giant clasts were originated from a gigantic rock avalanche, and formed natural dams in the ninth century (Kariya, 2012, TJGU, 33: 297-313). In this study, we performed oxygen isotopic dendrochronology analysis in order to reveal the inducement of this ancient rock avalanche and the depositional process of the clasts. The sample for dating (DDK03) was a disk-cut fossil wood log of Japanese cypress (Chamaecyparis obtusa; ca. 50 cm diameter, and ca. 400 years old estimated by counting annual rings) that was found one meter below the surface of the lacustrine sediment in the Dondokosawa natural dam. Cellulose was extracted directly from a thin wood plate (1 mm thick and 1 cm wide) that was sliced parallel to the butt end of the disk. 53 cellulose rings at the outer most part of the disk were dissected out and their oxygen isotope ratios were measured with the combined instrument of a pyrolysis-type elemental analyzer and an isotope ratio mass spectrometer, installed at the Research Institute for Humanity and Nature, Kyoto, Japan. We compared the inter-annual variations in oxygen isotope ratios of cellulose for DDK03 with those of predated master chronologies made for the Kiso-hinoki cypress, and determined that DDK03 died at AD 883+x (1 < x < several years).
On the basis of radiocarbon age of 809-987 CalAD (2-sigma) measured for another tree trunk sample at the same outcrop (DDK-D: Kariya, 2012), four candidates of paleoseismic events can be listed in existing documents (e.g., Usami, et al., 2013, Materials for Comprehensive List of Destructive Earthquakes in Japan, 599-2012, Tokyo University Press), such as earthquakes at AD 841 in Shinano area, AD 841 Izu, AD 878 Kanto resion, and AD 887 Goki-Shichido, if it is assumed that the rock avalanche was induced by strong ground motion from a large earthquake. Oxygen isotopic dendrochronology age of DDK03 (AD 883+x), however, narrows the four candidates down to a single one of the AD 887 Goki-Shichido earthquake. This is consistent with Kariya et al. (2014; JPGU 2014, HDS29-P01); they performed conventional dendrochronology of the same DDK03 sample with the use of the fluctuation pattern of tree ring width and microscopic observation of cell structures of the outer most tree ring, and concluded that DDK03 died in the late summer of AD887 and that slope movement related to the rock avalanche might have been caused by the AD 887 Goki-Shichido earthquake.
This study was partly supported by the 2015 open grant of Japan Society of Erosion Control Engineering.

Keywords: dendrochronology, oxygen isotope ratios, large landslide, Akaishi Range, Gokishichido earthquake

Shinseiko-landslide induced by the great Kanto Earthquake had a sliding surface in the Tokyo Pumice, which is widely distributed in Kanagawa and Tokyo areas

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Numerous numbers of slope movements were induced by the great Kanto Earthquake in the west of Kanagawa prefecture. One of them made a landslide dam and a lake, Shinseiko, which means a lake made by an earthquake. That lake still remains as a part of a park. That landslide was surveyed by Terada and Miyabe (1932) but its internal structure has never been known. We confirmed that the shape of head and frank scarps keeps their original shape and made two ca 30-m long drill holes aligned on a slope line 20 m away from the right frank scarp. The drilling results and the field survey around the landslide strongly suggest that the sliding surface of this landslide is in the Tokyo Pumice (Hk-TP, hereafter TP) about 17 m below the ground surface.
The top of the two drill holes had an 8 m of difference in elevation. The higher one penetrated 17 m of brown volcanic soil from the ground, TP with 1.3 m thickness, then Miura Pumice (Hk-MP, hereafter MP) 1.4 m below it. The lower drill hole penetrated 10 m of black and brown volcanic soil, 7 m of pumice flow (Hk-T(pfl), hereafter TPfl), 1.9 m of TP, then MP. These occurrences draw a geologic profile, in which TP is subparallel to the slope surface and approaches the foot of the head scarp. TP was observed to be involved in the landslide mass in the base of the mass at the downstream face of the deposits on the Ichiki River. Pumice grains of TP and TPfl in the drill cores and in the landslide mass were weathered and weak, while those on the river bed of the Ichiki River were fresh and hard.
High-resolution DEMs obtained by the airborne LiDAR suggest that there are many other remnants of landslide with a planar base, where the materials are all went out. Their sliding surfaces could be along TP, which could have been undercut, judging from the distribution of the TP outcrops.
TP erupted from the Hakone volcano 60 to 65 ka (Machida and Arai, 2003; Kasama and Yamashita, 2008; Machida and Moriyama, 1968) and widely covers Kanagawa and the west of Tokyo areas, forming slope-parallel bedding and being covered by thick Younger loam. When those beds are undercut, they could slide catastrophically during a future big earthquake.

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Keywords: Pyroclastic fall deposits, Earthquake, Landslide, Tokyo Pumice

Characteristics of tephra thickness distribution in steep regions of Aso Volcano and their origin

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Heavy rainfall associated with the seasonal rain front on July 2012 triggered huge number of shallow landslides on steep, tephra-mantled slopes, resulting severe sediment disasters in northern part of Aso Volcano. Rainfall-triggered landslides repeatedly occurred almost every decade (1990, 2001, and 2012 in the last 30 years) in this region. To avoid and mitigate such disasters in steep regions close to active volcano(s), it is important to know thickness distributions of accumulated tephra layers as potential source of landslide materials.
By using a spline interpolation method, we estimated thickness distribution of accumulated tephra layers, which include ash, scoria, and loam/kuroboku soil layers overlying Ojodake scoria (OjS; 3.6 ka) layer, from an isopach map of Aso Volcano developed by Miyabuchi et al. (2004). We compared the estimated thickness with actual thickness measured in following two sites: Takadake area, which is located on the northeastern side of central cones, and Saishigahana area, which is located on eastern part of the caldera rim. We also analyzed relationships between tephra thickness and slope topography (i.e., slope angle and curvature), then discussed characteristics of present tephra thickness distribution in steep regions of Aso Volcano and their origin.
By assuming tephra thickness estimated from the isopach map is equal to total amount of tephra fallout after the eruption producing OjS, ratio of measured and estimated thickness means residual ratio for total amount of tephra fallout during the last 3,600 years. Residual ratios ranged from 0.25 to 0.31 (25-31%) in Takadake area, and from 0.12 to 0.22 (12-22%) in Saishigahana area, respectively (Fig. 1). As shown in Fig. 2, the residual ratios had significant negative correlation with curvature (correlation coefficient r: -0.60, p-value: 0.05), while no significant correlation was found with slope angle (correlation coefficient r: -0.35, p-value: 0.29).
Averaged residual ratio (±S.D.) was estimated to 0.22±0.06 (22±6%), thus, about 70 to 90 % of tephra fallout had already eroded in steep regions of Aso Volcano. In addition, the residual ratios had declined as slope curvature increase, suggesting tephra layers at convex slopes more prone to erode. From our outcrop observations, following features of tephra stratigraphy were observed: (i) OjS layers were most found as disturbed block deposits, (ii) Nakadake N2 scoria (N2S; 1.5 ka) was found as well-preserved layers, (iii) loam/kuroboku soil layers above and below N2S layers were found as thin and discontinuous layers. Therefore, the present thickness distribution of accumulated tephra layers can be attributed to the shallow landslide occurrences just after the eruption producing OjS, in the middle to latter term between 3,600 and 1,500 years ago, and from after the eruption producing N2S until the present time.

Keywords: Aso Volocano, tephra-mantled slope, isopach map, thickness distribution, shallow landslide

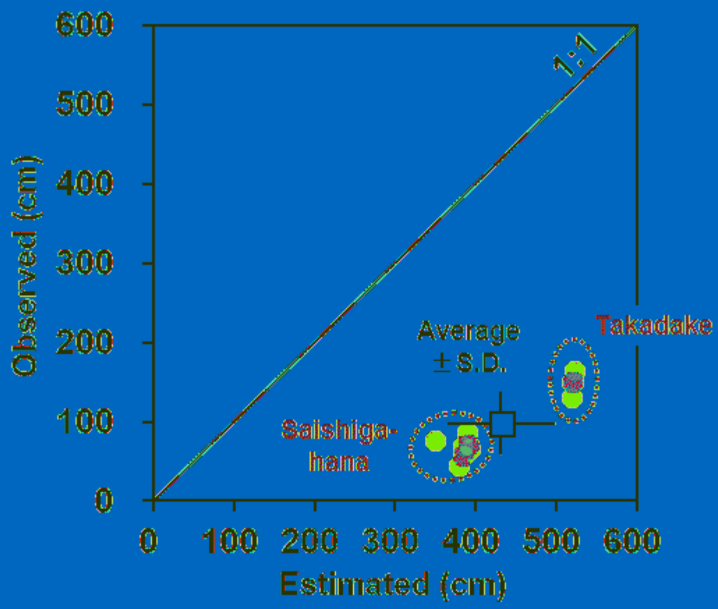

Fig. 1 Comparison between estimated and measured thickness.

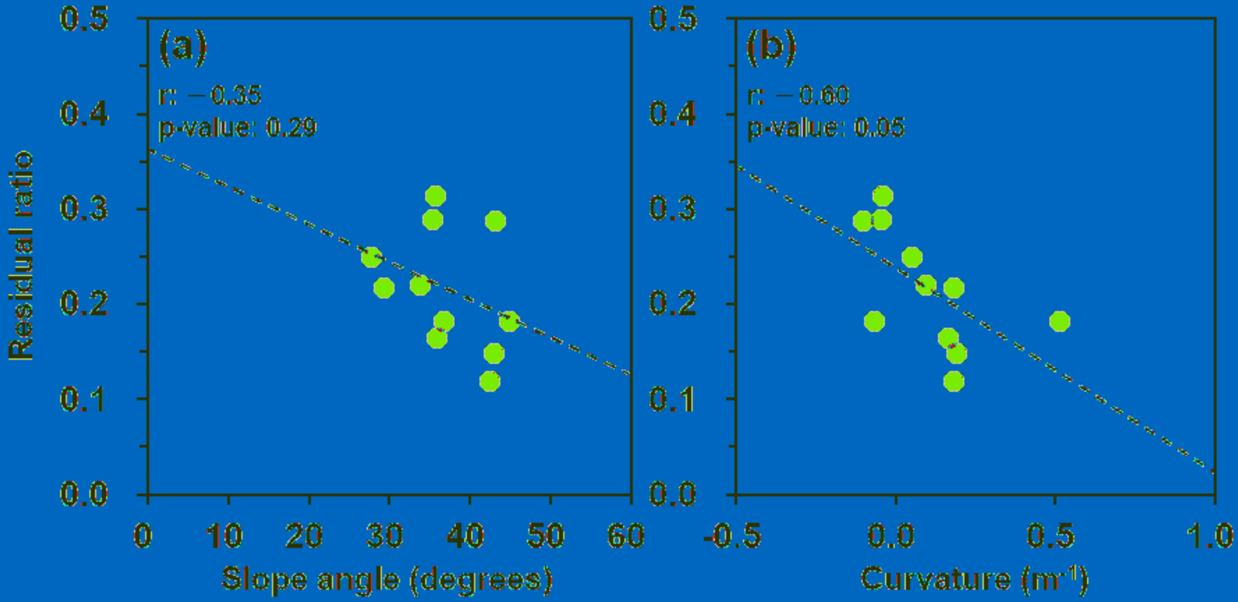

Fig. 2 Correlations of measured thickness with (a) slope angle and (b) curvature.

Slope disaster along Bhote Kosi River, induce by Nepal-Gorkha earthquake in 2015

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Nepal-Gurkha earthquake 2015 induced innumerable landslides in mountfooe area of the Great Himalayas. Most of them are shallow slope failures. They are mainly distributed just below breaks of slopes along troughs of major rivers incising the Great Himalayas. This study reports the detail distribution of landslides and discusses geomorphological and geological characteristics of the landslides' sites.

Keywords: Nepal-Gorkha earthquake 2015, slope disasters, break of slope

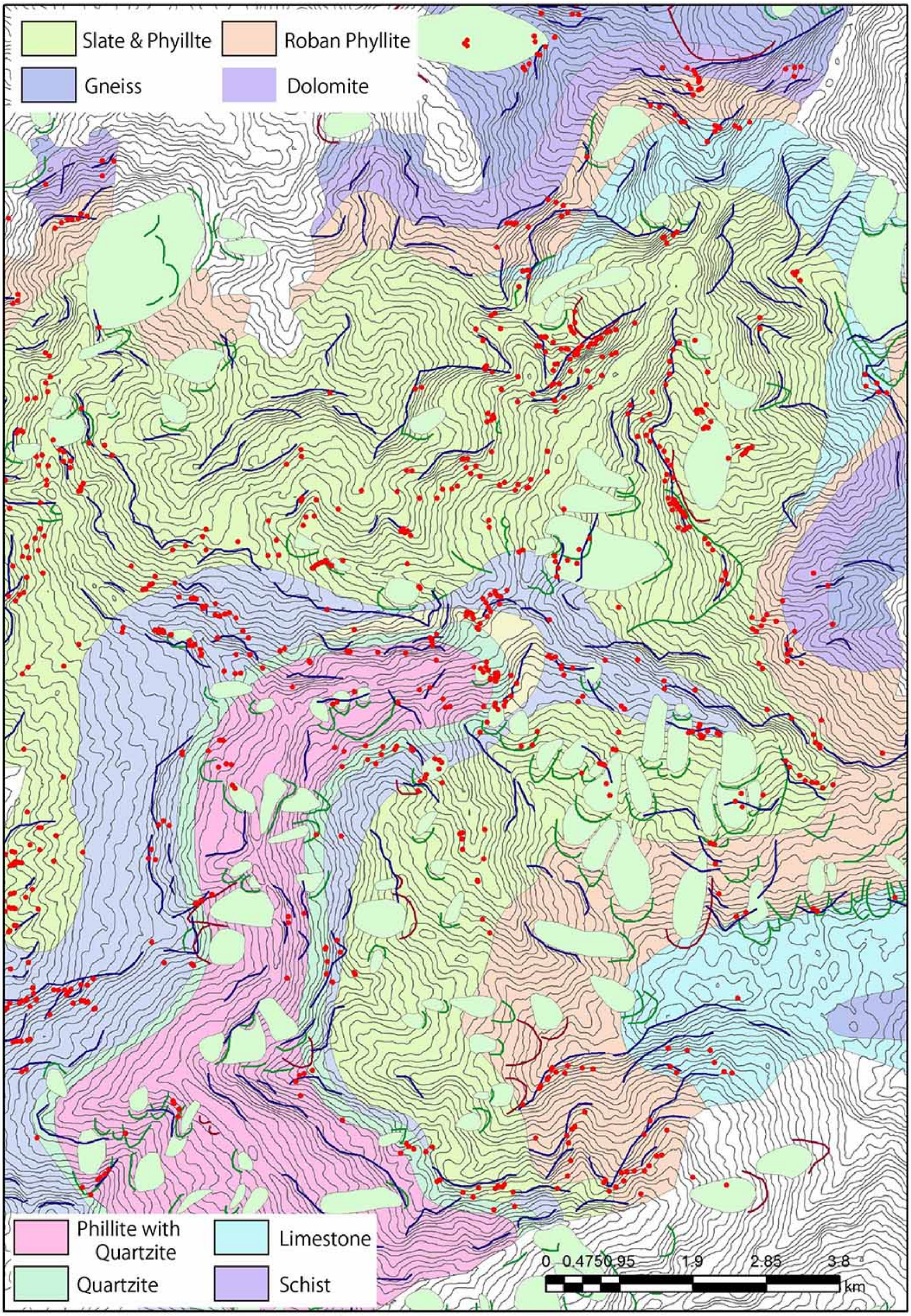

Fig.1 Distribution of landslides, geology and break of slope

Detection of Landslide Displacement from SAR Interferometry of ALOS-2/PALSAR-2 data

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The types of landslide are various, and it is important to monitor the spatio-temporal landslide movement for understanding the landslide mechanism. GNSS survey and ground-based observations are generally used for landslide monitoring, but it is impossible to monitor the spatial distribution of landslide. InSAR (SAR Interferometry) is developed originally for a technique to detect the ground surface displacement spatially. Now InSAR becomes a monitoring tool for the deformation with glacier, landslide and subsidence.
In this study, we estimated landslide displacement from InSAR analysis and studied the characteristic of landslide movement with ground-based observation in the Noto Peninsula, central Japan. We analyzed SAR (synthetic aperture radar) images acquired by ALOS-2/PALSAR-2, and used GNSS and borehole extensometers as the groud-based observation.
InSAR analysis reveals landslide displacement in the area of 300 m ×500 m. The magnitude and direction of landslide displacement is coincident with the ground-based monitoring results. In this study, we present a relationship between the landslide displacement detected by InSAR, the ground monitoring and cumulative rainfall, and discuss the spatio-temporal landslide movement.
Acknowledgement: PALSAR-2 data are shared among PIXEL (PALSAR Interferometry Consortium to Study our Evolving Land surface), and provided from JAXA (Japan Aerospace Exploration Agency) under a cooperative research contract with ERI (Earthquake Research Institute, University of Tokyo). The ownership of PALSAR data belongs to METI (Ministry of Economy, Trade and Industry) and JAXA. We used RINC (coded by Dr. Taku Ozawa), DEM (GSI of Japan), GMT [Wessel,P. and W.H.F.Smith, 1998], and QGIS.

Keywords: Landslide displacement, ALOS-2, InSAR, GNSS, Noto Peninsula

Detection of landslides using InSAR analysis all over Japan

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In Interferometric SAR (InSAR), two observations are performed for the same site, using a SAR sensor onboard a satellite. The data obtained from both observations is transformed into an image through an interferometric processing to obtain phase differences. InSAR is Effective method for Monitoring of the landslide, because the SAR can observe the place where there is no ground observation equipment, and there are some reports about detection the landslide by InSAR.
The Geospatial Information Authority of Japan (GSI) has approached to monitor ground surface deformation of earthquake, volcanic activity, subsidence and landslide all over Japan by InSAR analysis using ALOS-2 (Daichi-2) /PALSAR-2 data, and succeeded in detecting many phase variation of landslide.
In this presentation, we report the result of comparing between InSAR analysis and field survey.

Keywords: InSAR, landslide, ALOS-2

Self-Potential Approach to Monitor the Ground Water Condition : Electro-kinetic effect and self-potential tomography

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Landslide is one of the most severe natural hazards in the world and there are two types; rainfall-induced landslides and landslides triggered by an earthquake. To understand rainfall-induced landslide process by the self-potential approach, we struggle with the integrated research to clarify the coupling among hydrological, geotechnical, and electromagnetic changes. Our final goal is to develop a simple technology for landslide monitoring/forecasting using self-potential method. The previous laboratory experiments show that the self-potential variation has a relationship with the ground water condition and soil displacements. So, in this paper, we first demonstrate the numerical computations on the self-potential variation by the simulated groundwater flow, and compare the result with those observed by laboratory experiments. In the result, the simulated self-potential variation is consistent with observed one.
Then, we developed self-potential tomography to estimate the ground water condition. And we also characterize the pressure from the self-potential data, and compare the result with observed pressure head that is measured by pore-pressure gauge and found that the inverted pressure head is consistent with observed one. In addition, we apply the self-potential data observed by the flume test. The estimated pressure head from observed self-potential data shows the consistency with observed pressure head. And estimated pressure head also show the characteristic distribution before the landslide occurred. These facts are highly suggestive in effectiveness of the self-potential tomography to monitor groundwater changes associated with landslide. The details will be given in our presentation.

Keywords: Self-potential, Landslide, Tomography

Modeling of rainfall-induced shallow landslides by coupling of hydrological processes and hillslope stability analysis: an example from the Hiroshima disaster in 2014

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This study reveals soil layer structure and characteristics of pore-water pressure fluctuation at hillslopes underlain by granite and metamorphic rock in Hiroshima City, southwest Japan, where heavy rainfall triggered numerous shallow landslides on 20 August 2014. We reconstructed processes of shallow landslides using hydro-slope stability analysis and verify the model by inputting the rainfall recorded on the date of the disaster, referring to the timing of landsliding and the depth and slope angle of landslides. Change in mechanical strength of soil seems to control the position of sliding surface in granite hillslopes, whereas hydraulic discontinuity in soil profile affects the formation of slip plane in hillslopes underlain by metamorphic rock. Depth and slope angle of landslides were obtained by airborne laser scanning of land surface before and after the disaster. Shear strength of soil around the sliding surface was measured by direct shear testing using undisturbed specimens. Pore water pressure at potential sliding surface in granite hillslope increased rapidly in cases of a wet condition by preceding precipitation. In hillslopes underlain by metamorphic rock, pore water pressure at a shallow part increased rapidly and a parched groundwater table formed occasionally; pore water pressure at a deeper area increased gently within few hours later from rainfall peaks. Based on these results, we modeled response of pore water pressure to rainfall infiltration and hillslope destabilization to reconstruct processes of landslide initiation.

Keywords: Shallow landslide, Rock control, Soil layer structure, rainfall infiltration, slope stability analysis

Detection of the ground surface deformation by InSAR analysis at Kuchisakamoto landslide

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SAR Interferometry (InSAR) is one of the methods measuring small-scale ground surface deformation such as landslides and land subsidence. However, InSAR is a relatively new technique and factors affecting the accuracy of analysis are not well understood. We conducted accuracy validation of InSAR analysis using ALOS and ALOS2 images by comparing with in-situ GPS observation data in the Kuchisakamoto landslide in Shizuoka prefecture, central Japan. Additionally, we calculate annual average deformation rate by stacking method using interference images with high accuracy. Comparison of InSAR analysis results with GPS observation data showed that 17 in 97 ALOS and 4 in 6 ALOS2 interference images had high accuracy with error ≤20 mm. By comparing errors in the InSAR analysis and SAR observation conditions, four factors likely increased errors in InSAR analysis: (i) baseline decorrelation affected by long perpendicular baseline, (ii) temporal decorrelation affected by long observation period, (iii) noise associated with observation mode conversion, and (iv) phase unwrapping error that sometimes occur when ground deformation is large . Deformation rate map calculated using stacking method showed that some sub-blocks of landslide with large ground surface deformation existed in the main landslide block.

Keywords: landslide, InSAR

Topographical interpretation of landslides using a constant vertical exaggeration stereoscopic map

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This study introduces the method for interpreting landslide topographies with a constant vertical exaggeration stereoscopic (CVES) map. The map created by using digital elevation model (DEM) data shows 3D images of landforms as an anaglyph. We created two types of CVES maps by using the light detection and ranging (LiDAR) digital terrain model (DTM) and the Advanced Land Observing Satellite (ALOS) World 3D (AW3D) digital surface model (DSM) data (observation data from the Japanese satellite ALOS-Daichi) around Mt. Ebiradake in Northern Japanese Alps. We then compared these maps with a landslide distribution map created using air-photo interpretation. As a result, we could clearly identify scarps, which were formed on the landslide body due to secondary landslide activity and were several meters high on the CVES map created using LiDAR DEM data with 5 m resolution. A number of scarps identified on the CVES map were difficult to interpret using the air-photo technique. The CVES map provides very helpful data for creating high-resolution landslide distribution maps. In contrast, it was difficult to detect those scarps on the CVES map that were created from AW3D DSM data with 5 m resolution. However, we could identify landslides more than 200 m width and scarps more than 10-20 m high on the landslide body. The AW3D data cover the entire world, so the CVES map created by using AW3D DSM is useful for areas where LiDAR data and / or air-photos are unavailable for generating landslide distribution maps.

Keywords: constant vertical exaggeration stereoscopic map, topographical interpretation, Ebiradake landslide

Late Pleistocene paleolakes formed by landslide activities on the eastern foot of Mt. Kushigata, the Koma Mountains, central Japan

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Landslide activities are important agent on shaping slopes and creating landscapes in mountain areas. For example, geomorphic changes by landslide often provide natural environments rich in diversity.

Slope development of Mount Kushigata seems to have been affected by landslides activities and deep-seated gravitational slope deformation on both its eastern and western sides under earthquake-prone humid environments during the late Quaternary. In particular, on the eastern piedmont areas facing to the subsiding Kofu Basin and the active Kushigatayama fault, many large landslide bodies with secondary landslide activities are commonly identified on the basis of our geomorphic classification.

In this area, thick lacustrine sediments and debris flow deposits bearing the Ontake Pm-1 tephra layer (95 ka) are seen at several locations with different altitudes. Basically, those lacustrine sediments blanket large landslide bodies. Thus paleolakes would have been developed on closed depressions and gentle slopes formed on such landslide masses around 95 ka.

The timing of emergence and extinction of paleolakes are not clear due to the paucity of chronological information of the lacustrine sediments yet. However, those paleolakes were probably destructed and filled by valley head incision, secondary landsliding, and influx of debris from nearby slopes. Lacustrine sediments on the eastern face of Mount Kushigata demonstrate a portion of changing natural environments by landslide processes during the late Pleistocene.

Keywords: Tephrochronology, On-Pm1 tephra, lacustrine sediments, deep-seated gravitational slope deformation

Analysis of distribution of linear depressions based on decision-tree model in Kiso Mountain Range, central Japan

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Few studies have focused on mountain gravitational deformation in the sight of landform evolution. In this presentation, we discuss the relationship between linear depressions and (1) geomorphological processes and (2) geomorphological condition. We select the area of granodiorite (Geological Survey of Japan, AIST, 2015) in the northern part of Kiso Mountain Range.

Linear depressions, cirques and periglacial smooth slopes were classified based on Geospatial Authority Information of Japan (GSI) color aerial photographs. Cirques and periglacial smooth slopes were referred to Aoki (2000) and to Yanagimachi and Koizumi (1988) respectively. Landslides were based on landslide mass of landslide distribution map published by National Research Institute for Earth Science and Disaster Prevention. Drainage network and topographic data were obtained based on Fundamental Geospatial Data (10m mesh elevation) by GSI using ArcGIS10.2.2. We did decision-tree analysis using WEKA 3.6.13 (Hall et al., 2009) for investigating distribution of linear depressions. Explanatory variables are as follows: number of stream, average stream length, average stream gradient, average stream relative height, drainage density, stream bifurcation ratio, stream slope ratio, stream length ratio and drainage density ratio of each stream order, and maximum altitude, minimum altitude, relative height, stream length, stream gradient, drainage density, area, slope direction (East or West), slope direction (North or South), existence of glacier in Last Glacial Maximum, that of glacier in Younger Dryas, that of landslide mass and that of periglacial smooth slope in each unit drainage basin. Explained variables are two groups of unit drainage basins divided by density of linear depressions. Its value is 0.5 [km/km^2].

It is suggested that the characteristics of unit drainage basins with high density of linear depressions are as follows: (1) existence of landslide mass and (2) third-order stream with gradient greater than about 30 degree.

Keywords: Decision-tree, Linear depressions, Kiso Mountain Range, Mountain gravitational deformation, Geomorphological analysis

Frequency distribution of the deep-seated rapid landslide area in different events in the same region

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Deep seated rapid (catastrophic) landslide (hereafter DCL) often trigger debris flow and sometimes generate a landslide dam, and have sometimes had serious impacts on humans. Therefore, it is important to predict the scale of DCL to prevent and mitigate disasters due to DCL.
The scale of DCL should be strongly controlled by geological and geomorphological settings. Thus, in this study, it can be propose a hypothesis that the scale of DCL should be comparable to the past DCL in the same region. We tested this hypothesis using DCL inventories in Fuji river basin in Yamanashi and Totsu river basin in Nara, Japan. We prepared a map of ancient DCL scars through the interpretation of stereoscopic aerial photographs and evaluated the timing of each DCL occurrence by using multi-temporal DCL inventory map and various sets of aerial photographs. Then, we compiled 3 events and clarified the relationship between landslide area and frequency of DCL. Also, we identified shape of rock creep using high resolution slope map made by LiDAR data and clarified the relationship of area and frequency of rock creeps.
As a result, we found the similar scale characteristic in DCL of Fuji river basin for all events, although the landslides occurred in 1982 were slightly smaller compared to the rest of the event. In Totsu river basin, the scale characteristic of DCL occurred in 1911 and 2011 had almost similar trend. These results supported our hypothesis that there is the site-specific relationship between landslide area and frequency of DCL. Moreover, the scale of rock creep and DCL were almost similar, except DCL of 1982 in Fuji river basin. Long-lasting, small-scale mass movements called gravitational mass rock creeps sometimes lead to deep catastrophic sliding. So, it can be thought that the scale of DCL might be determined at the stage of long-lasting, small-scale mass movements before landslide occurrence, supporting the hypothesis that the scale of DCL should be controlled by geological and geomorphological settings.
These suggest that the scale of the future DCL will be equivalent to the scale which have occurred in the past in the same basin and it have might be related to the scale of rock creep.

Keywords: deep seated rapid landslide, landslide area, rock creep, LiDAR data, aerial photograph

Experiment for effects of preferential flow and entrapped air on slope failure

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Although many previous studies examined the mechanism that slope failure s concentrated around the rainfall peak, and the process that collapsed soil quickly tuned into debris flow, to date there is no widely used theory for describing these phenomena. Recent studies proposed possible explanation about the process of slope failure induced debris flow. Several processes explain drastic decline of safety factor with the increase of rainfall intensity have been proposed. According to filed observation for the landslide scars, a number of studies suggested that the preferential flow through soil pipe might effect on drastic decline of safety factor with the increase of rainfall intensity. Several studies confirmed that the preferential flow through soil pipe gave an impact on the redistribution of pore water pressure in soil layer. Also, other studies suggested that the drastic decline of safety factor can be influenced by the extra pore water pressure due to entrapped air in the soil layer.
Therefore, we conducted the artificial hillslope experiment to test the influence of the preferential flow thorough soil pipe and entrapped air on slope failure . Figure shows our experimental model. We set manometers in each 20 cm along the soil layer to monitor positive soil pore water pressure distribution at the bottom of soil layer. To examine the effect of entrapped air on slope failure occurrence, we used two ways, rainfall simulator and upper water tank, to supply water to the soil layer. Steel wire netting and cloth was attached between the soil layer and upper water tank to support the sand. For several cases, we didn’t use rainfall simulator, since we assumed that the if water was supplied only at the upper end of the hillslope, the pore air in soil layer easily went out. While, once the surface layer of hillslope was saturated, pore air might be entrapped in the soil layer. To enhance the saturation of surface layer, in several cases, we put shallow fine sand layer at the surface of hillslope.
To simulate soil pipes, we set the artificial soil pipe made by polyvinyl chloride tube, which was made holes (φ4 mm) in each 2 cm. To test the effect of water pressure in soil pipe, the upper end of the artificial soil pipe was connected to another water tank to control the water pressure in the upper end of the artificial soil pipe. Further, we attached gate valve at the intermediate of soil pipe to disturb water flow in soil pipe. So, we changed water levels in both upper water tank and water tank connected with soil pipe and monitor pore water pressure and displacement of hillslope. We found that slope failure occurred just after the increase of water pressure in soil pipe, indicating that water pressure in soil pipe strongly controlled slope failure occurrence and movement. Moreover, the effect of entrapped air was not obvious.

Keywords: slope failure, soil pipe, pore water pressure

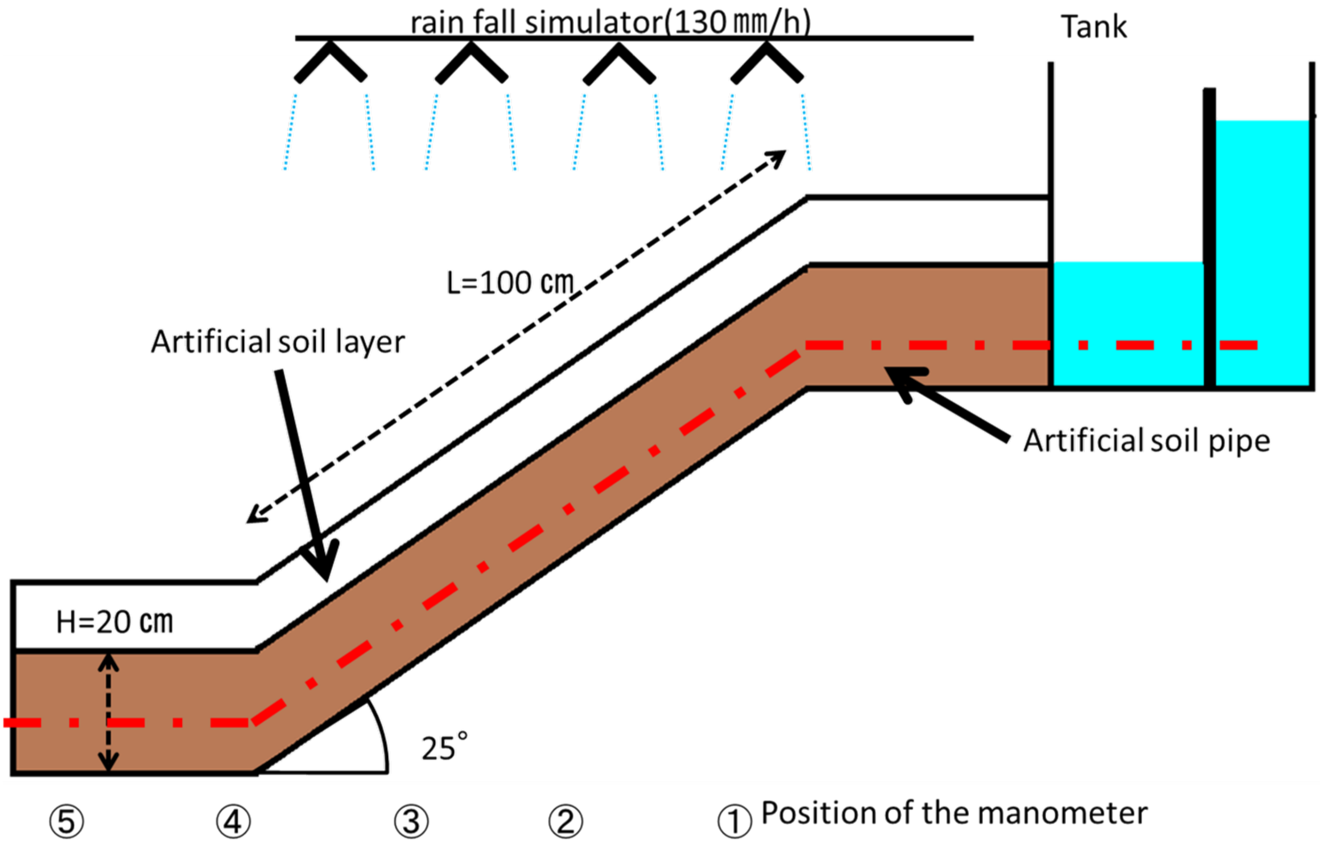

Figure experimental equipment

Study on the peak ground acceleration effect on the seismic landslide

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After the South Hyogo earthquake in 1995, a method assessing the risk of a slope failure caused by the earthquake has been examined, using slope gradient, curvature, and peak ground acceleration as evaluation factors.
Consequently in the South Hyogo earthquake case study and with identical topographic condition, we confirmed the rate of landslide linearly increased with the increase of the peak ground acceleration. On the basis of this tendency, a susceptibility assessment method was proposed and has been inflected.
On the other hand, strong ground acceleration was observed during recent earthquakes, such as 2004 Niigata Chuetsu earthquake and 2008 Iwate, Miyagi inland earthquake, large-scale landslide occurred frequently.
In areas where the peak ground acceleration has been very strong, it may be different from the relationship of the peak ground acceleration and landslide rate, which was confirmed by South Hyogo earthquake.
In this study, we examined the relationship of peak ground acceleration on landslide rate and landslide scale, including strong seismic motion areas. The area analyzed in this study is 700 km^2 which is the focal region of the 2004 Niigata Chuetsu earthquake. As preparations for analysis, we extracted the position of the landslide using GIS data produced through aerial photo interpretation. In addition, we calculated topographic features such as slope gradients using DEM data (10m mesh). This DEM data was made from the contour line before the earthquake. We calculated the area rate of the landslide every 100 gal of peak ground acceleration, and every 5 degrees of slope gradient.
As a result, the relationship between slope gradient (*Slope*) and the rate of landslide area (*P*) can be explained with equation 1, in any range of peak ground acceleration. During the peak ground acceleration division the degree of leaning was almost maintained the same (around 0.1).
The intercept of the equation increased so that the peak ground acceleration of the earthquake became strong.
$\ln(P) = a \times Slope + b$ eq. 1
In this case the intercept b can become the function of the peak ground acceleration of the earthquake.
Subsequently, landslides were divided into two groups in terms of landslide area. We investigated relations such as the peak ground acceleration, slope gradient, slope curvature and landslide scale.
The result shows that, on the same slope gradient, the lower threshold of the maximum acceleration for the large-scale landslide (area> 1 ha) occurrence is 100 ~ 250 gal larger than that of small-scale landslide. Moreover, the threshold acceleration for large-scale landslide on convex slope was smaller 20 ~ 60 gal smaller than that of the concave slope.

Keywords: Landslide, Peak ground Acceleration, Slope gradient, Earthquake

