On the fluidized landsliding phenomena on gentle slopes triggered by the 2016 Kumamoto Earthquake

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During the 2016 Kumamoto earthquake, numerous landslides had been triggered in Minamiaso Village. Most of the landslides originated on steep slopes, whereas some of them occurring on gentle slopes were fluidized and the displaced debris travelled long travel distance, resulting in causalities and severe damage to many houses on the downslope. In this study, we examined the geological features of these fluidized landslides occurring on gentle slopes, and performed both in-situ direct shear tests and dynamic ring shear tests on the soils taken from the sliding surface. During the tests, the samples were prepared at different initial water contents, and dynamic tests were performed by applying cyclic loadings with regular frequency and amplitude of shear stress, and also by coseismic loading referred from seismic motion recorded in a seismic station nearby. Based on these results, we finally analyzed the possible initiation and movement mechanisms of these fluidized landslides.

Keywords: fluidized landslide, earthquake, tephra

LANDSLIDES CAUSED BY THE 14 NOVEMBER 2016 KAIKOURA EARTHQUAKE, SOUTH ISLAND, NEW ZEALAND.

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At 12.03 am local time on 14th November 2016 (UTC: 11.03 am 13th November 2016) a shallow magnitude 7.8 earthquake, with an epicentre located near Waiau in North Canterbury, struck the North Canterbury and Marlborough regions of NZ. The strong ground shaking caused widespread damage to buildings and infrastructure across the sparsely populated areas of the northeast of the South Island. The most visible consequence of the strong ground shaking was widespread landslides. Given the sparsely populated area affected by landslides, only a few homes were impacted and there were no recorded deaths due to landslides.

Tens of thousands of landslides were generated over 10,000 km^2 of North Canterbury and Marlborough, with the most intense landslide damage concentrated in 3500 km^2 around the areas of fault rupture. Landslides caused major disruption with all road and rail links with Kaikoura being severed. The landslides affecting State Highway 1 (the main road link in the South Island of New Zealand) and the South Island main trunk railway extended from Ward in Marlborough all the way to the south of Oaro in North Canterbury.

A feature of this earthquake is the large number (more than 200) of valley blocking landslides it generated. This was partly due to the steep and confined slopes in the area and the widely distributed strong ground shaking. The largest landslide dam has an approximate volume of 12(±2) M m^3 and the debris from this travelled about 2.7 km down slope where it formed a dam blocking the Hapuku River. The long-term stability of cracked slopes and landslide dams from future strong earthquakes and large rainstorms are an ongoing concern to central and local government agencies responsible for rebuilding homes and infrastructure. A particular concern is the potential for debris floods to affect downstream assets and infrastructure should some of the landslide dams breach catastrophically.

The majority of landslides occurred in two geological and geotechnically distinct materials: Neogene sedimentary rocks (sandstones, limestones and siltstones) where first-time and reactivated rock-slides were the dominant landslide type, and; Torlesse “basement” rocks (greywacke sandstones and argillite) where first-time rock and debris avalanches dominated.

At least thirteen faults ruptured to the ground surface or sea floor, with these surface ruptures extending the Emu Plain in North Canterbury to offshore of Cape Campbell in Marlborough. The mapped landslide distribution reflects the complexity of the earthquake ruptures. The landslides are distributed across an elongated area consistent with the elongated area affected by fault ruptures and intense ground shaking. The landslides are not clustered around the earthquake epicentre. Initial results from our landslide investigations suggest: predictive models relying only on ground-shaking estimates may underestimate the number and size of the larger landslides that occurred. The largest landslides triggered by the earthquake are located either on or adjacent to faults that ruptured to the ground surface. Surface faults

may provide a plane of weakness or hydrological discontinuity and adversely oriented surface faults may be indicative of the location of future large landslides.

Keywords: Kaikoura, earthquake, landslides, dams, New Zealand, faults

Finite element simulation for seismic ground response in mountainous areas at the time of 2015 Nepal Gorkha Earthquake

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In this study, the 3D dynamic elasto-plastic finite element method is used to simulate the overall distributions of earthquake-induced slope failures in the targeted area in intermountain regions in Nepal, which can be regarded as a pilot case survey for future detailed investigations. The analytical method adopted in here is almost the same as the previous relevant studies by the authors (e.g., Wakai et al. (2015)). The area is located near the Dhunche Town along the Trishuli River, in the transition zones between the higher and lesser Himalayas.
In the analysis, nonlinear material properties of the ground as well as 3D topography, geological conditions and input motion are taken into account appropriately. Those factors strongly influences the dynamic amplification effects relevant to slope failures. The numerical results obtained from this analysis include the distributions of the maximum horizontal acceleration response and residual displacement at the ground surface, and the maximum shear stress mobilized in the surficial layers. After the comparisons of the results between the calculated one and observed facts in local areas, it can be concluded that the proposed numerical method has a sufficient ability to predict the phenomena and can be possibly utilized for predicting overall dis-tribution of earthquake-induced landslide which would be helpful for developing landslide susceptibility maps in mountainous areas in Nepal.

Keywords: earthquake, Nepal, finite element method

Silent Landslide -Waveform Records from a Seismometer Settled on a Moving Landslide Block-

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We recorded seismic waveforms during landslides using a seismometer settled on a moving landslide block with the thickness about 5 m. The landslide started to move at eleven O’ clock on Jun. 17, 2016, continuing to move for next 20 hours, together with the seismometer. We examined the seismograms and running spectrums, and resultantly, only ten events with short durations were found during sliding. We also calculted the background amplitude levels in the several frequency bands. They marked higher values, compared with those in sunny days. However, such high amplitudes were experienced several times in the cases of past heavy rains and storms. Therefore, these high background amplitude levels derived from ambient noises due to rain, winds, and oceanic waves. We could conclude that the landslide generated very small seismic energies, at least below the ambient noise level.

Application of the high-resolution APHRODITE precipitation product to rainfall-triggered fatal landslide occurrence in Nepal

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Rainfall triggers landslides worldwide, and understanding the relationship between local precipitation and slope failure is important in mitigating against disaster. The southern slopes of the Himalayas experience tremendous numbers of fatal landslides due to steep mountain slopes and heavy precipitation in summer monsoon season.
This study uses the fatal landslides database over Nepal assembled using systematic metadata online search tools identifying the location of a landslide between 2004 and 2015. A daily rain-gauge based grid precipitation (APHRODITE, 0.05 degree) data is used for the same period. We concentrate on the summer monsoon season (June-September), and rainfall-driven landslides with fatalities. Two clear west-east oriented rain-bands are observed from the west to the east of Nepal. These heavy precipitation zones correspond to the mountain slopes of Great Himalaya (north band) and Mahabharat (south band). Many fatal landslides occur along the north band, but that is few along the south band. The most number of fatal slides occurred in July, but the largest number of fatalities occurred in August. As a result, in some areas the probability of landslide occurrence increased as the amount of daily precipitation increased.
We classified pentad precipitation pattern over Nepal and found a linkage between weak monsoon indices and heavy precipitation in the central and the western part of Nepal. Especially, in July, when global monsoon signal is strong, moisture converges in India and Nepal has less precipitation. On the contrary, when the monsoon trough is weak, moisture tends to converge in Nepal. Namely, the Indian-monsoon break phase causes heavy precipitation in either western and the central Nepal. The areas 1) Farwest Hill, 2) Mid-west Hill, 3) West Hill and 4) Central Hill have strong negative correlation between monsoon index and local precipitation, where percentage of fatal landslide occurrence is very high. Landslide risks exceeds 50% if they have more than 100 mm rainfall in two days in those areas.

Keywords: Himalayas, precipitation, APHRODITE

A flume test for seepage and overtopping failures of model landslide dams

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A flume test was performed for seepage and overtopping failures of model landslide dams. We used non-polarized electrodes and accelerometers to monitor the self-potential variation and seismic signals during the failure processes. For the seepage failure tests, we found that self-potential variation corresponds well during the head ward progressive erosion failure of the model dam. In addition, repeating sliding of the model dam was observed and can be proved by the recurrent seismic signals. For the overtopping failure tests, the self-potential dropped sharply when the electrodes were exposed outside a model dam, which can be applied to indicating the eroded positions of a model dam.

Keywords: landslide dam, seepage, overtopping, dam breach, flume test

Morphological changes of a gully complex forming on landslide deposits and implications for erosion variability

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Gully complexes are landforms which are initiated by incision of water erosion (gully erosion) and further enlarge by mass movements due to oversteeping gully walls. These rapidly erosion landforms can reach the ridge top and comprise their entire catchment. Gully complexes cause on-site damage such as loss of fertile land and destruction of infrastructure. Off-site damage includes river aggradation and negative effects on aquatic habitats, as large quantities of sediment are supplied from slopes to rivers.
The transition from gullies to gully complexes has been described in many publications. Here the focus is on the erosion variability of a large gully complex eroding into landslide deposits. Morphological changes are assessed on decadal scale during the past 60 years to understand erosion varability in a gully complex.
The gully complex is 1.6km long and has a catchment area of 1.2km^2. The complex is located in the Waipau catchment on the North Island, New Zealand. The study area consists of variably indurated, sheared and crushed mudstone and thin sandstone of Late Cretaceous age. Most of the study area is used for pastoral farming.
Aerial photography taken in 04.1957, 09.1971, 06.1988, 05.2005, and 01.2012 was interpreted to map active and inactive landslides, gullies, and the gully complex itself. Differential digital elevation models were calculated using ERDAS IMAGINE Photogrammetry to estimate topographic changes.
Mapping results for the earlier decades indicate that inactive deep seated landslides cover the western section of the catchment right up to the gully channel. On the steeper eastern slopes small-scale gully erosion and falls occured. Next to an increase of the gully complex over all time slices, a prominent 210m long and 355m wide active slump was evident on the 1988 imagery, which buried the channel of the gully complex by 3-8m. The new gully channel developed 31-45m east of the original channel by undercutting the gully flank. This indicates that the development of gully complexes on unstable slopes are not uni-directional, as landslides deposits are reworked by slumping followed by excavation by water incision. Incision into highly erosion-susceptible materials such as deposits of inactive landslides might be continued until sediment storage is depleted.
These finding might help to develop approaches on gully complex development on erodable landslide deposits, which include the spatial and temporal variability of incision and infill as well as high sediment export rates to appropriately and effectively manage such erosion prone environments.

Keywords: gully complex, landslide deposit, New Zealand

Dating rock failure by speleothem and cave use of Japanese monkeys: a case study of Saru-ana Cave in the karst region along Kurobe Gorge in eastern Toyama Prefecture of central Japan

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Saru-ana Cave, a main cave system in the karst region, approximately 120 m and 40 m in plan length and relative height respectively, consists of combined galleries of horizontal passages and vertical shaft. It opens onto the south-facing steep cliff, which has probably originated as rupture surface of an ancient rock failure. In this study, we have investigated the cave and its surrounding landform comprehensively, and conclude that ancient rock failures occurred at least twice during the last 14,500 years, and opened the entrance of the cave intermittently.

The karst region for research is heavily snowy area where snowfall cover ranges in depth from 2 to 3 meters in winter. The Japanese monkeys (*Macaca fuscata*) of this area use Saru-ana Cave for protecting themselves against severe winter coldness during the mid-snow season. Five ^{14}C ages measured from skeletal remains of Japanese monkeys recovered from the cave inside are 500-2,740 cal BP, suggesting that the cave entrance has been opened to the cliff surface since 2,800 cal BP.

Speleothems, which are secondary deposits in caves, form generally under the cave environment: completely dark space with nearly 100 % moisture. Around the entrance of Saru-ana Cave, there are abundant speleothems, which cover the ceiling and walls, and they had already been dried to stop growing due to aridification, sunlight from the entrance and active air circulation between inside and outside of the cave. The existences of speleothems around the entrance suggest that the area around the present cave entrance was primarily enclosed by the limestone mass, hence speleothems could grow under the cave environment.

A specimen of a stalactite collected around the entrance consists of the two layers: the inner typical stalactite has concentric, transparent layers, and the outer tufa-like layer is similar in porous and white-colored to tufa deposits, which usually precipitates outside the cave. 14,400 BP of ^{230}Th age were measured from outermost surfaces of the stalactite layer and 9,500 BP from outermost surfaces of the tufa-like layer, respectively. In general the growth cessation of speleothems is caused by decreasing or suspension of supersaturated H_2O-CO_2-$CaCO_3$ solutions supply through the fissures of the limestone bedrock or aridification within the cave due to active air circulation. The presence of tufa-like layer suggests that the environment around the present entrance during the 14,400-9,500 BP period was not suitable for speleothems to glow. The ancient rock failure about 14,400 years ago removed the surficial rock masses of steep slope to let the enclosed cave passage to be opened physically to the outside. ^{230}Th age for the outermost tufa-like layer indicates that more ancient rock failure probably occurred after about 9,500 years ago and activated the air circulation between the inside and outside of the cave.

Here we formulate the rock failure-induced cave-opening hypothesis based on ^{230}Th ages for a stalactite, ^{14}C ages of the skeletal remains of Japanese monkeys and behavior as cave use by Japanese monkeys, to be more precise, at least two ancient rock failures occurred about 14,400 years ago and during 9,500-2800 years ago. For dating the slope movements within the karst region, various pieces of information obtained from caves; e.g. speleothems, behavior as cave use by some kinds of mammals, and others, may be useful tools.

Keywords: rock failure, stalactite, cave, cave use, Japanese monkey, speleothem

Rock avalanches controlled by a thrust fault and river incision in an accretionary complex of the Shimanto Belt

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The purpose of this study was to clarify the geological and geomorphological background of rain-induced rock avalanche occurred in the Shimanto accretionary complex. We performed the detailed geological survey for the area of 5.4 km^2 in the middle of the Kii Mountains in Japan. In this area, the two large rock avalanches (Akatani and Akatani-east, both have the volume over 10^6 m^3) induced by the heavy rain of Typhoon Talas in 2011. Using the 1 m DEMs made before and after the landslides, we performed the detailed geological survey and geomorphological analysis of deep-seated gravitational slope deformation. We investigated the distribution of the thrust faults with the incohesive brittle facture zone in the mountain slopes and the inner structures of these thrusts. And, we performed the mineralogical analysis, permeability test and direct shear test to know the material features of the gouge. Around the Akatani landslide we investigated the faults distribution in the slope by boring data.
As a result, we found out that the two large rock avalanches have the main sliding surfaces corresponding to the same thrust (we named the Kawarabi thrust) with the clayey brittle fracture zone with the maximum width of 6 m. Two landslides slid under the condition of wedge failure consisting of the Kawarabi thrust and some high-angle faults. It is estimated that the gravitational deformations started at the timing when the depth of the Kawarabi thrust under the slope toe reached the threshold value. The Kawarabi thrust has the clayey crushed materials to the surrounding rock mass, and form the discontinuity of ground water, and prevent the ground water flows, and builds up the pore water pressure in the heavy rain.

Keywords: rock avalanche, thrust, river incision, accretionary complex, gravitational slope deformation, rain

A flexural toppling failure in the northern Central Range, Taiwan

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On December 19, 2016, a rockfall occurred on the right bank of the Baishi Valley at the downslope of the Taigang village, in Taiwan. The rockfall continued lasting more than two weeks, opened a number of new tension cracks in the head area and the rock masses did not travel far, but formed a steep cone at the foot of the slope. However, no trigger for the collapse is evident. Geologic and geomorphic investigations indicate the rockfall occurred in a old landslide scar within a gravitational deformed slope at its lower part. The strata is mostly composed of argillite and alternating beds of sandstone and mudstone at the foot of the slope. The argillite strata has well developed slaty cleavage, which strikes NE–SW and generally dips at 80˚ along the riverbed to the north of this slope, but was observed to have flexurally toppled downslope in the landslide scar and in the deformed slope. In addition, the alternating beds are also bent downslope. Toppled beds had open fractures, which had been created during toppling deformation, and had also resulted in small scarplets of about 1 m high beyond the landslide crown. Moreover, morphological phenomena on the upper slope such as a ridge-top depression and a juxtaposing convex slope indicate that the slope deformation have already taken place long before and this deformation provides a basic cause for the occurrence of rockfall event.

Keywords: flexural toppling, rockfall, gravitational slope deformation, Taiwan

A near real-time landquake monitoring system (NRLMS) using the broadband seismic network

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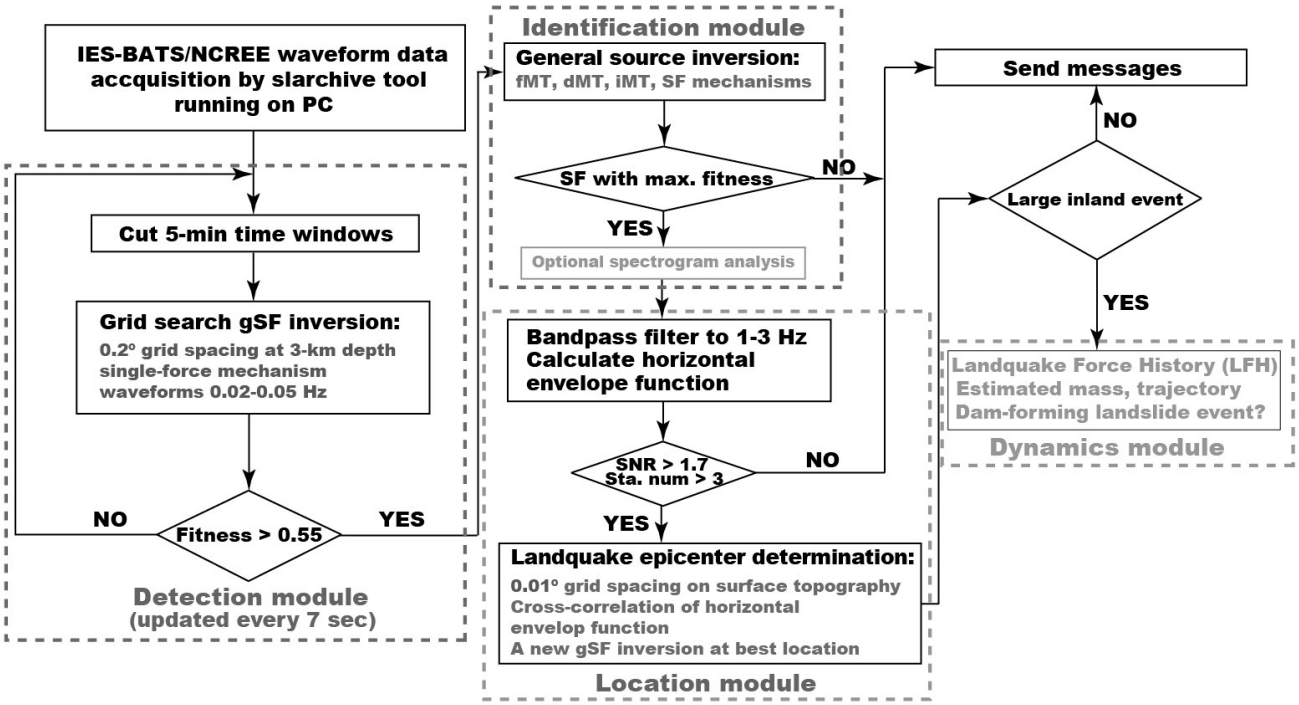
Landquakes such as rockfalls, landslides and rock avalanches are one of the most deadly kinds of natural disasters. In active mountain belts, such gravity-driven events dominate erosion dynamics that strongly depend on the occurrence of extreme rainfall or high seismicity. Recent studies have demonstrated that seismological monitoring is also an effective technique to detect landquake events. Based on the real-time broadband data in Taiwan, we have developed a near real-time landquake monitoring system (NRLMS), which is a fully automatic process based on waveform inversion that yields source information (e.g., location and force mechanism) and identifies the landquake source by examining waveform fitness for different types of source mechanisms. Starting in 2015 and supported by the Ministry of Science and Technology (MOST) of Taiwan, the NRLMS has been continuously monitoring landquake activity in Taiwan, which provides a complete landquake catalog for the comprehensive landtoring (landquake monitoring) laboratory (CoLLab, http://140.112.57.117/main.html). In practice, certain levels of station coverage (station gap < 180˚), signal-to-noise ratio (SNR 5.0), and a threshold of event size (volume > ~10^6 m^3 and area > ~0.20 km^2) are required to ensure good performance (fitness > 0.6 for successful source identification) of the system. The NRLMS can be readily implemented in other places in the world with real-time seismic networks and high landquake activities.

Keywords: landquake, broadband data, near real-time landquake monitoring system (NRLMS), comprehensive landtoring laboratory (CoLLab)



Insights on the co-seismic responses of a deep-seated landslide by monitoring

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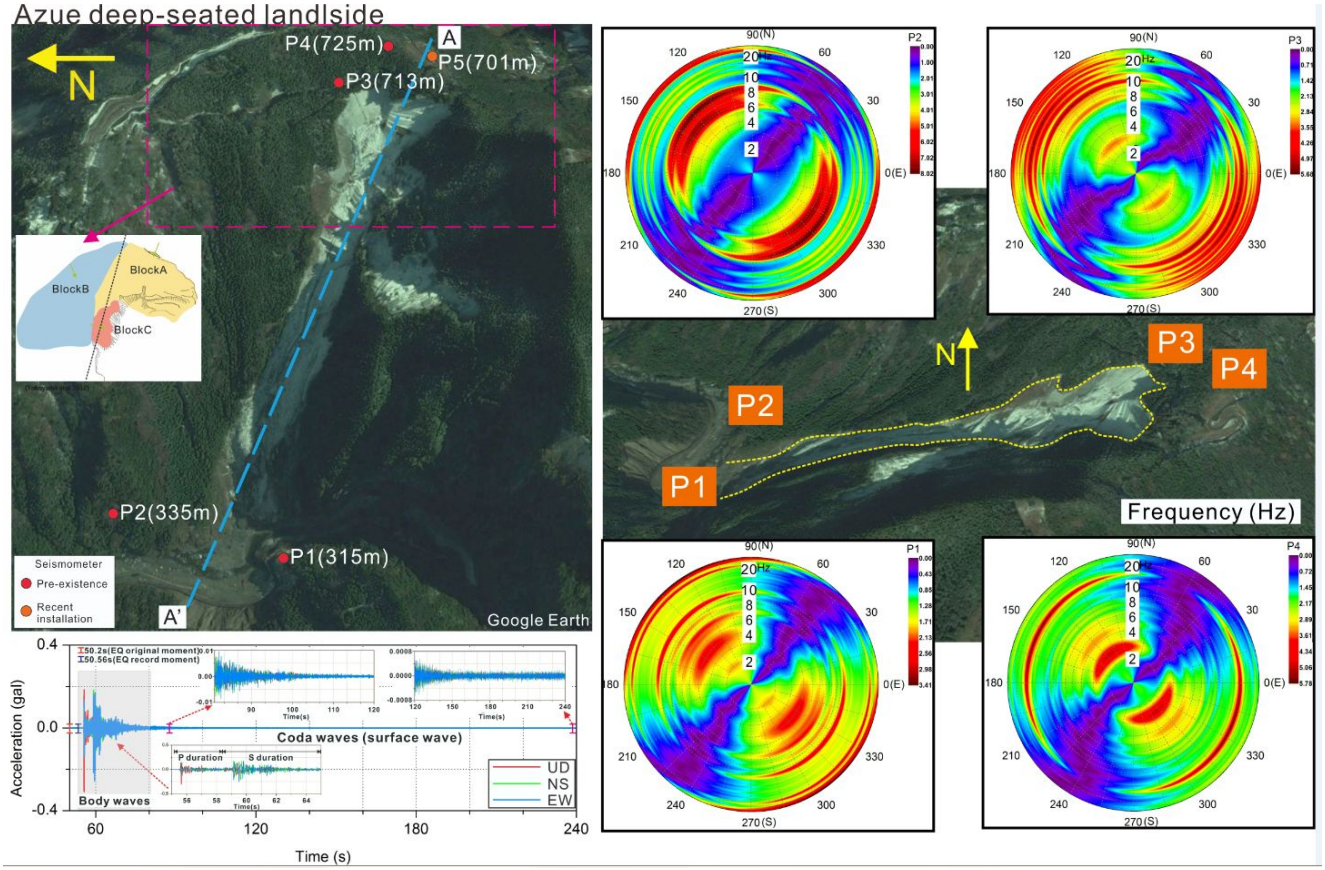
In recent years, earthquakes have triggered numerous landslides.To prevent or at least to mitigate this kind of geohazards, great efforts had been paid to the study on understanding the properties of co-seismic landslides. By now, the co-seismic site responses on landslides had been analyzed by means of various methods and evidences showed that the seismic responses of landslide can be affected by various factors especially in those deep-seated landslides, where the geological and slope structural conditions can be more complicated. However our understanding on the co-seismic response of deep-seated landslides is still very poor. Thus to better understand the this issue, we then performed long-term seismic monitoring with five high-sensitivity seismometers on different locations of an old deep-seated landslide on Azue area, Tokushima prefecture, which were reactivated by heavily rainfall. By using these records, we analyzed the site responses, especially the amplification effects. The amplifications on the location of talus area present peak values in high frequency toward to azimuth obviously; however multiple amplified peaks of these with wide azimuth bands emerge on block B of the landslide. Differing from former results, one evident peak appears in low frequency on block A of the landslide. In addition, the amplifications on bedrock outside of the landslide area show relatively small values in frequency bands and distribute in wide azimuth bands. Meanwhile, The predominant peak values maintain stably in a narrow frequency band on talus area in different periods in approximated one year but they scatter in different frequency bands on blocks of landslide around the same periods.
Above all, due to the contamination from complex geological settings and/or ground water level, or other reasons probably, the seismic energy redistributes in landslide mass, which incorporates more complicated amplification effects rather than deposit areas or bedrock. Finally, multidisciplinary approaches will be adopted for analyzing the co-seismic responses on this landslide in the future.

Keywords: deep-seated landslide, co-seismic site response, monitoring



Measuring the ground surface movements by applying the object based approach

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The landslide is a kind of natural disasters and usually causes the damages for the people living near the landslide regions. Detecting ground surface movements may be an important clue to locate the landslide regions. Particle image velocimetry (PIV), an approach to measure the temporal displacements of a patch by comparing the similarities of the same patch shown in temporal orthophotos, has been widely applied to identify the landslide regions. Sometimes, the ground movement information can provide the warning signal to those people living in the areas such that the damages caused by land sliding can be reduced. However, for those areas suffering from natural disasters (like earthquakes, typhoons), the topographical surfaces in those areas have massive changes such that the texture information collected by the different sensor is partly different. The ground movements measured by PIV are not reliable if those areas of topographical changes are included. The paper proposes to classify the topographical conditions into two classes: one class contains large topographical changes, and another one does have few topographic changes. The object-based approach is proposed to segment the whole image into several sub-regions, and for those segmented regions with similar properties, those segmented regions can be further merged. In doing so, different objects can be formed in temporal orthophotos. Those areas with large topographical changes can be identified by comparing the objects shown in temporal orthophotos. PIV is used to those regions with few topographical changes to accurately measure the ground movements. The villages located in the mountain regions are also monitored and extracted such the whole villages can be treated as objects. Those village objects are employed as templates, and with comparing the changes of the templates from temporal orthophotos, the translations, rotations and scales of the templates showing in orthophotos can be determined by employing the correlations among the templates by measuring the similarities. In doing so, the distorted information among temporal orthophotos can be identified, and with continuously comparing the differences of the distorted information, the warning of the landslide can be issued if the differences are larger over the pre-defined threshold to keep the safeties of the monitored villages. In Taiwan, Li-Shing estate road is a mountain road which is famous for its geological complexity, and instruments used to monitor the displacements are installed along the road. This paper used the temporal orthophotos covering the villages located along the road as an example to demonstrate the feasibility of the proposed approach. From the processed results, the proposed approach offers an economical way the monitor the ground movements of the mountain villages and those areas without people living.

Keywords: PIV, Land Slide, Object-Based

Geomorphological and Geological Characteristics of Large Catastrophic Ancient Landslides along Minjiang River in Diexi, Western Sichuan, China

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In the upstream of Minjiang River, Sichuan, China, there are many large landslides aligned along a 15-km section of the trunk river of Minjiang. The largest one is Diexi landslide. “Diexi landslide” induced by the 1933 earthquake was partial failure of this larger and older Diexi landslide. This large landslide was inferred to block the river and form a suite of lacustrine sediments with the thickness of over 200 m in this area. The trunk river of Minjang has several knickpoints and the most outstanding one is located upstream of the Diexi and the nearby landslides. The long-river profile suggests that this knickpoint was formed not by landslides but by tectonic activity and that they propagated upstream. We made detailed geological field survey and topographic analysis to explore the history and mechanism of the ancient landslides including Diexi Landslide and its downstream Manaoding Landslide. Manaoding Landslide is of tightly folded alternating beds of sandstone and shale with fold axes plunging valleyward gently, which structure and joints with intersections nearly parallel to the fold axes were the basic structural cause of this landslide. Diexi Landslide is of mainly marble with two sets of joints; the joints and the bedding planes make intersections plunging gently valleyward, which destabilized the slopes in terms of wedge-failure. Long-term incision by the Minjang River undercut slopes with the above structural defects and finally caused large landslides. This geological history could be typical examples of landslides affected by river-incision along Minjiang River and could provide a conceptual model of geohazard prediction and mitigation in the Minjiang drainage basin.

Keywords: Minjiang River, Landslide, Geologic structure, Geomorphology, River incision

Slope stability assessment by artificial neural network in EnShi region, China

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1. CUG

Landslide is one of the most common and damaging natural hazard type in mountainous areas. However, due to the uncertain failure time and complex mechanisms of a landslide, it determines that the research trend for landslide susceptibility would be the prediction of possibility for unstable slopes which are prone to landslides in specific region and under certain conditions, as well as the analysis of spatial distribution law for these unstable slopes. In order to effectively avoid the interference due to differences in failure mechanisms of different landslide types, unstable slopes only in Silurian stratum in EnShi region were chosen as the research object. Based on the field investigation and slope failure mechanism analysis, slope angle, slope structure, road influence, stream and gully influence were taken into account as the factor of evaluation index system. Then an intelligent unstable slope prediction model was developed by artificial neural network, which was well trained and tested by investigated landslide data, so as to get good prediction ability. Finally, the research obtained a spatial distribution of unstable slope zones which are prone to landslides in the study area. The prediction result also supported by remote sensing data and field investigation. The research not only proves the feasibility and reliability of the spatial unstable slope prediction method which based on computational intelligence theory and GIS technology, but also provides useful guidance for both independent landslide susceptibility assessment and land planning processes.

Keywords: silurian stratum, slope stability, spatial prediction, artificial neural network, geographic information system

Granular flow in a varying width rotating drum

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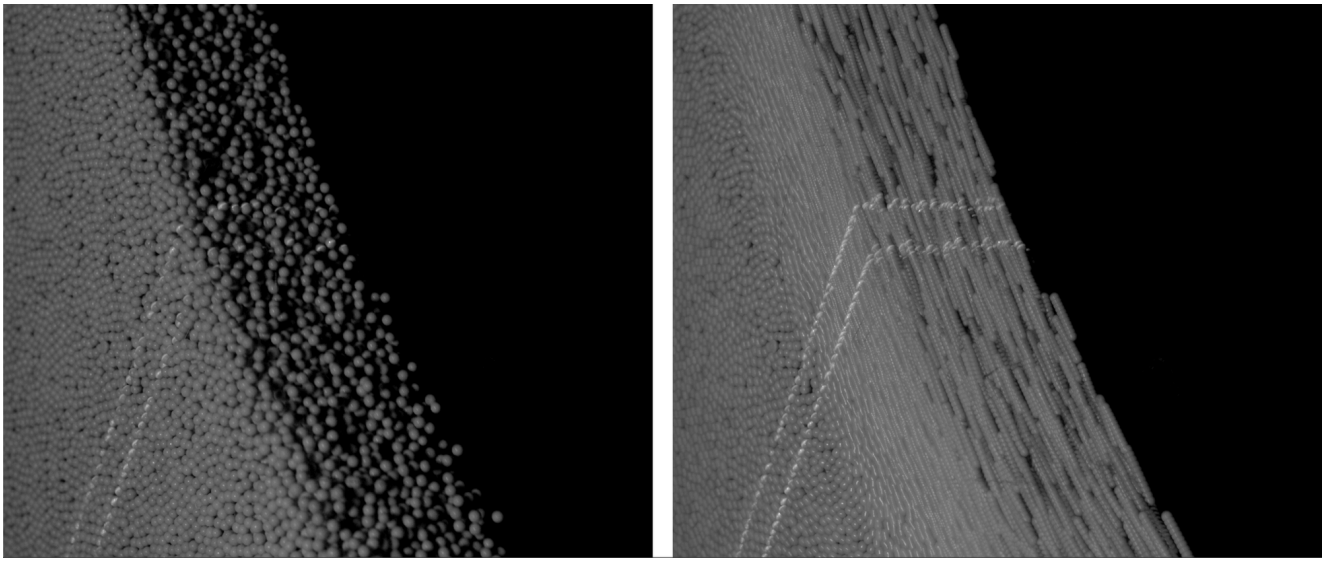
A landslide is a form of mass move abruptly, and that is prone to be triggered by an earthquake or high intense rainfall. Rapid flows of granular materials on inclined surfaces are often encountered in engineering applications, and also found in geophysical situations.
In this study, we focused on the variation of three-dimensional fluid velocity and the volumetric solid fraction in varying width channel. We have conducted experiments with a 40-cm-diameter grainflow-generating rotating drum designed to simulate simplified landslide. The rotating drum was half filled with 2 mm-diameter grains, which formed a thin grain-avalanching layer. The channel width was varied along the flow direction from 4 cm to 8 cm. The motion of moving particles was recorded by a high-speed camera with 1920x1080 resolution. A parallel laser system was used to reconstruct the position of particles, and particle tracking velocimetry (PTV) method was applied to construct three-dimensional velocity field. Also, by using the same laser system, the volumetric solid fraction was measured. (fig.1). In the end, we verified our results with granular flow theory prediction.

Keywords: granular flow, rotating drum, three dimensional velocity field, volumetric solid fraction



Assessment of the 2016 Minami-Aso Landslide in Kumamoto Prefecture using airborne LiDAR and LS-RAPID model

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A series of earthquakes hit Kumamoto Prefecture in Kyushu Island of Japan started from the foreshock with magnitude of 6.5 that occurred on 14 April 2016 with depth of 11 km. About 140 aftershocks were occurred within two days with the magnitude varied from 3 to 6.4. The main shock with magnitude of 7.3 was hit on 16 April 2016 as the result of strike-slip faulting at shallow depth of 12 km at 32.75 of north latitude and 130.76 of east longitude. According to the Ministry of Land, Infrastructure, Transport and Tourism of Japan, at least about 97 landslides were occurred, which mainly concentrated in the Aso caldera area, northeast from the epicenter of earthquakes. The most prominent landslide was occurred on the Japan National Road 325 in Minami-Aso that destroyed a 200 m Aso large bridge (Aso-Ohashi) into the Kurokawa River.

The objective of this study is to assess the characteristic of Minami-Aso landslide and try to simulate its mechanism and motion. The soil shear parameters necessary were obtained from laboratory experiment by means of undrained ring shear apparatus ICL-2 version. Seismic loading tests was carried out in the ring shear apparatus using the 2016 Kumamoto earthquake record, East-West component, from KMM005 observation station of K-Net (NIED, Japan). The results implied that the shear strength of Minami-Aso samples was reduced significantly during earthquake together with rapid rise of the excess pore water pressure, causing rapid motion of landslide with huge energy which destroyed the bridge. To obtain more detail and accurate topography profile to be used in the LS-RAPID model, we applied the airborne LiDAR data from Asia Air Survey Co. Ltd. to generate high resolution of digital elevation model. In result, the initiation mechanism and motion of Minami-Aso landslide was clearly described in the LS-RAPID model, started from the initiation process from seismic loading up to the moving process which involving the volume enlargement and traveling process of the landslide mass. However, factor of ground wetness in the vicinity area is need to be considered in further, since we found significant amount of rainfall took place in one week before the landslide event.

Keywords: Minami-Aso landslide, Airborne LiDAR, Kumamoto earthquake, Ring shear tests, LS-RAPID

Supplementary analysis of stability assessment of dip slopes using a fracture model

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Dip-slope landslides frequently cause large-scale hazards. The benchmark approach to stability assessment of dip slopes adopts a limit equilibrium method (LEM) that considers the slope mass as rigid. Therefore, failure anywhere on the potential plane would occur at one time, i.e., the stress conditions are identical throughout on the failure plane. However, a progressive movement of slope mass is evident, as indicated by the development of tension cracks near the slope crest. The slope stability prior to this type of global failure cannot be estimated by LEM. This study proposes a fracture model for supplementary analysis to evaluate the stability of dip slopes. The characteristics of a dip slope with jointed bedrock fracture parameters are considered, and the factor of safety is redefined using a fracture mechanics approach. Accordingly, the local failure in the rock slope is represented by the weakness of the bedding interface, which fulfills the progressive process of inherent fracturing before global slope failure.
In this study, the influences of geometry and material properties on the driving force of a dip-slope landslide were first discussed by a series of sensitivity analyses. The safety factors evaluated in this study were then compared with those obtained by LEM. Finally, the critical joint persistence was obtained using back analysis, indicating the threshold value of reduction of the rock-material property. The internal crack growth is sufficient for slope instability, so the slope mass detaches from the failure plane. These findings can complement conventional dip-slope stability analyses.

Keywords: slope stability, dip slope, fracture mechanics

Employing electron microscopy integrated with X-ray spectroscopy for Kuntawa Landslide assessment

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This work centres on Kuntawa landslide assessment owing to the enigmatic nature of a 2003 landslide which buried 4 people and a truck in Kuntawa village, of Nigeria.
A Phenom ProX Scanning Electron Microscope (SEM) integrated with Energy dispersive X-ray Spectroscopy (EDS) and Particlemetric software was employed to generate morphology, particle size data, elemental identification data and topography (at 3500x) of earth samples scooped from the landslide site. For a core sample 1 at depth, *d*=3.75m, average circle equivalent diameter, area and volume by area of 11.5 μm, 249 μm² and 3680 μm³ were generated respectively; at *d*=3.785m, , and of 6.19 μm, 30.1 μm² and 124 μm³ were generated respectively; at *d*=3.82m, , and of 11.5 μm, 130 μm² and 1380 μm³ were generated respectively. For a core sample 2, at *d*=3.75m, and of 5.54 μm, 26 μm² and 108 μm³ were generated respectively; at *d*=3.82m, , and of 19.4 μm, 338 μm² and 5240 μm³ were generated respectively; 243 particles were scanned.
One of the results from specific surface for samples 1 and 2, reveals that it would take twice and four times the amount of water needed to wet an entire surface both at *d*=3.82m than at *d*=3.785m and *d* =3.75m respectively.
Additional laboratory facilities reveal that soil water content, volumetric water content, porosity, soil water-filled pore space bulk density, decreased with increasing—this situation may have contributed to this earth surface event.
Elemental composition at the landslide site were generated from the EDS: oxygen (O), Silicon (Si), Bromine (Br), iron (Fe), Carbon (C) and Aluminium (Al). O and C had the highest and lowest concentration of elemental compositions of 68.5% at 3.75m depth and 1% at 3.82m depth for samples 1 and 2, respectively. The significant amount of oxygen unravelled from the result, is suggestive of algae presence at the landslide site—intense soil microbial activity may have contributed to landslide occurrence.
Micro-faults from granular topography and morphology are probably tips of bigger faults down below—inferring that past earth tremor events may have occurred leading to landslide.

Keywords: EDS, Particlemetric, SEM, Micro-fault, topography

