Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HDS06-P01 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

2014 年 11 月 22 日に発生した長野県神城断層地震による斜面崩壊―初報
Landslides induced by the Nov. 22, 2014 Nagano Prefecture Kamishiro Fault Earthquake, Japan - a primary report

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To outline the characteristics of landslides induced by the strong earthquake (M6.7) occurred in northern Nagano Prefecture on Nov. 22, 2014 (Hereafter Nagano Prefecture Kamishiro fault earthquake), we interpreted landslide using aerial photos that taken just after the earthquake and partly conducted field survey. The earthquake was considered to be occurred on the Kamishiro fault, that dipping to east and is the northern part of the Itoigawa-Shizuoka tectonic line (The headquarters for Earthquake Research Promotion, 2014). The vertical and oblique photos taken by Asia Air Survey Co., Ltd on Nov. 24, 2014 were used for interpretation.

In the study area, about 58km2, a total of 104 landslides have been detected. Most of the landslides could be classified to shallow landslides. The most of the landslides occurred on terrace scarps, or around knick line of slopes. Meanwhile, many landslides occurred on slopes where previously occupied by old landslides.

In the study area, most of the landslides occurred within the distance of several km from the Kamishiro fault, in and around the Hakuba village and Otari village. However, landslides also have been confirmed in Nagano city where about 27 km distance from the source fault. In the study area, more than 70% of the landslides were located on the hanging wall of the source fault. This characteristic is coinciding with the features of landslides induced by reverse-fault earthquakes occurred in eastern Japan (e.g. Has et al., 2011). However, compare to the similar magnitude earthquakes, such as the Chuetsu earthquake in 2004 (Has et al., 2011) and Northern Nagano earthquake in 2011 (Has et al., 2012) occurred nearby the focal area of the Kamishiro fault earthquake, the number of landslides are much fewer and their dimension is much smaller. Future works are necessary for clarify these features how to related to the characteristics of strong motion, antecedent rainfall, topographical and geological conditions.

In this study, the interpretation of landslides was conducted in a very limited area, and also the field surveys were insufficient due to snow covering several days after the earthquake. For grapes the overall features of the landslides induced by the earthquake, detailed survey will be needed after snow melting.

キーワード: 地震, 斜面崩壊, 活断層, 長野県
Keywords: Earthquake, Landslide, Active fault, Nagano Prefecture

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HDS06-P02 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

A Study on the characteristics of the seismic signals produced by the man-made rockfall and debris flow

A Study on the characteristics of the seismic signals produced by the man-made rockfall and debris flow

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In this study we performed a set of field tests on a 5-meter model slope to investigate the characteristics of seismic signals induced by signal rockfall (single rock rolling) and man-made dry 'debris flow' down a slope. We used a backhaul to release the 3 single rocks in 3 different sizes, and measure/compare the seismic signals they generated during rolling. Furthermore, we used a truck to dump a load of about 3 metric tons of coarse debris with the 3 rocks that used for signal rock rolling test and measure/compare the seismic signals generated by the dry 'debris flow'. The Hilbert-Huang Transform (HHT) was adopted to perform the mode decomposition and to analyze the time-frequency spectra for the seismic signals that we obtained in time domain. We expect that the seismic signals generated by the 3 large rocks in the 3 different sizes will produce distinguishable time-frequency characteristics in the seismic signals; that is, we can recognize that what frequency contents in the time-frequency spectra were produced by which size of the 3 test rocks. The results of this study may help us on interpretation of the seismic signals that we collect from seismic stations and broadband station for landslides.

キーワード: landslide, rockfall, debris flow, seismic signal, time-frequency analysis, HHT
Keywords: landslide, rockfall, debris flow, seismic signal, time-frequency analysis, HHT

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HDS06-P03 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

付加体中の低角スラスト沿いに発生した豪雨による深層崩壊について
Rain-induced rock avalanches with sliding surfaces along low-angle-thrusts in accretionary prisms

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近年、世界各地で地球温暖化に関係すると考えられる異常気象が発生している。台風の巨大化により、これまでの観測記録を塗り替える豪雨が多発するようになった。それとともに、2006 年にフィリピンレイテ島で発生した山体崩壊、台湾では 2009 年に台風モラコットの豪雨による小林村の斜面災害など、豪雨に伴う大規模な深層崩壊が多発している。しかしながら、それらの発生場所予測手法は未だに確立されておらず、また、その地質構造的原因も必ずしも明らかになっていない。

日本の西南日本外帯には、広く白亜紀から新第三紀の付加体堆積物が分布している。これらの地域では、豪雨に伴う深層崩壊が多発している。紀伊半島では、2011 年に台風 12 号の豪雨により 50 箇所以上の深層崩壊が発生した。そこで、著者らは、$2 \times 10^6 m^3$ と $8 \times 10^6 m^3$ の崩壊が発生した紀伊半島中央部の赤谷地域を中心として地質調査を行い、深層崩壊と地質特性との関係を調査してきた。

その結果、二つの崩壊は、大規模な低角断層沿いに発生したものであることがわかった。この低角断層は、北西から北北西の 29°～40°傾斜をなし、水平方向に少なくとも 5km 以上にわたり連続している。この断層を川原樋衝上断層と名付けることにする。この断層の最大幅は 1.5m で、粘土質断層角礫中にガウジが主剪断面沿いに数条含まれている。この低角衝上断層は、厚い粘土質の破砕帯を伴い、その傾斜角が 30°～40°であることから、付加体中の連続性のよい弱面を容易に構成しやすい。さらに、水理地質学的に不透水層として機能し、豪雨時に地下水流を遮水し、高間隙水圧を発生させる原因になっている可能性も高い。この低角断層は長期間の河川侵食作用により河岸に露出したもので、スラストの上盤をなす流れ盤斜面が不安定化して重力変形を起こし、豪雨を誘引として最終的な深層崩壊に至ったことが示唆される。また、低角衝上断層に加えて、赤谷の崩壊では、崩壊部の両サイドが高角断層により切断されていたことを発見した。このような高角断層は、赤谷東の崩壊でも存在している可能性がある。

深層崩壊の発生しやすい場所を抽出し、そのランク付けを行うことは、災害を軽減する上で非常に重要である。重力変形斜面を抽出することに加え、大規模な低角断層とそれを切断する高角断層を調査することにより、より精度の高い発生場所の予測が可能となると期待される。上記の知見は、紀伊山地のみならず、西南日本外帯の付加体に共通する可能性が高い。

キーワード: 深層崩壊, 付加体, スラスト
Keywords: rock avalanche, accretionary prism, thrust

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HDS06-P04 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

Fluvial incision history that controlled the distribution of landslides in the Central Range of Taiwan

Fluvial incision history that controlled the distribution of landslides in the Central Range of Taiwan

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Hillslope processes, which are affected by long-term river incision, give rise to the risk of landsliding in active orogens. We studied the river incision history and the subsequent response of rock slopes in the upstream Dahan River catchment, north Taiwan, by analyzing river long profiles, hillslopes, and landslide scars. The results were combined with chronological data from several landform surfaces to reconstruct the history of landscape evolution. At the study area, the landscape comprises three levels of knickpoints and corresponding slope breaks. These knickpoints propagated upstream along trunk and tributary rivers, undercutting and destabilizing nearby slopes, of which the oldest is a paleosurface dated to ca. 150 kyr by cosmogenic nuclide dating. Consequently, three levels of V-shaped inner gorges (up to 600 m deep) are incised into the paleosurface. The inner slopes of the three levels of gorges have mean inclinations of 35.6 degrees , 37.7 degrees, and 39.8 degrees, and steepen from the higher to the lower inner gorges. These three series of knickpoints and corresponding slope breaks suggest the occurrence of three phases of river incision. Based on analyses of the steepness indices of the river long profiles, cosmogenic nuclide dating, and the regional tectonic and climatic history, the two earlier phases of incision are inferred to have been caused by prevailing tectonic uplifts during the middle to late Pleistocene, and the most recent phase by climate change in addition to uplift. The long-term history of river incision has controlled the distribution of deep-seated gravitational slope deformation and landslides. Many areas of deep-seated gravitational slope deformation and deep-seated rockslide-avalanches are aligned along the higher and middle slope breaks, and debris slide avalanches are concentrated along the middle and lower slope breaks.

Reference:

Tsou, C.-Y., Chigira, M., Matsushi, Y., Chen, S.-C., 2014. Fluvial incision history that controlled the distribution of landslides in the Central Range of Taiwan. Geomorphology 226, 175?192.

キーワード: landscape evolution, landslide, river incision, knickpoint, convex slope break, cosmogenic nuclides
Keywords: landscape evolution, landslide, river incision, knickpoint, convex slope break, cosmogenic nuclides

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HDS06-P05 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

鉛直振動下における斜面崩壊の小型実験
Small-scale laboratory experiments of slope collapse under vertical shaking

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土砂から成る斜面は地震によって土砂崩れが誘発される。地震動の代表的なパラメータとして加速度、周波数、継続時間があり、これらのパラメータに崩壊現象が依存するはずである。振動による斜面崩壊の実験は土木工学の分野で多く行われてきた。近年では粉粒体物理学の観点からも、振動実験が行われている (Rubin et al. 2006, Katz and Aharonov, 2006)。しかしパラメータを数桁変えて、それらに対する依存性を詳しく調べたモデル実験は少ない。本研究では粒子斜面のモデルを用いて加速度と周波数をそれぞれ 2、3 桁変えた振動実験を行い、崩壊の臨界加速度、崩壊の速度、崩壊様式のパラメータ依存性を調べ、粉粒体物理学の観点から斜面崩壊現象を理解することを目的とする。

実験はホッパーを取り付けたアクリル容器に、ガラスビーズを封入した実験セルと、振動台を用いて行う。ホッパー内部に溜められたビーズは隙間から勢い付かずに流れ落ち、再現性の良い斜面を容器内壁に形成することができる。加速度センサーをアンプを介してオシロスコープにつなぐ。振動調節機の周波数、加速度を設定して 60 秒間の鉛直振動を加える。実験パラメータとして、周波数は 10Hz、100Hz、1000Hz、5000Hz の 4 通り、また振動加速度の重力加速度に対する比である無次元数Γ=a／ g(a:振動加速度 (m／ s^2)、g=9.8(m／ s^2)) を 0.08～5 の範囲で変えて行う。崩壊の様子はカメラによって動画を撮影し、画像解析を行う。

斜面の初期形成角度はθ=23.4°± 0.5° (平均値±標準偏差) であった。ガラスビーズの安息角が約 24°であるため、およそ安息角に近い値である。実験を行ったところ、加速度依存性と周波数依存性の両方を認めることができた。加速度を変えることによる斜面の振る舞いは周波数によって異なり、「静止」、「崩壊」、「対流」、「跳躍」の 4 つのレジームに分けることが出来る。100Hz では崩壊が急激で短時間で停止する。一方、1000Hz では崩壊が少しずつ進行し、長時間持続する。観察される崩壊様式と 0~5(sec) における傾斜変化 ((d θ／ dt)) の値を用いてレジームダイアグラムを作成した。ここで振動開始から 60 秒後における傾斜変化が 0.02°以上の場合を「崩壊」と定義した。(d θ／ dt) は 0~5(sec) の間は臨界加速度が約 100Hz で極小値となるが、時間の経過に伴い、極小となる周波数が約 1000Hz へシフトする。レジームダイアグラムにおける臨界加速度の極小値を説明するために、振動 1 周期あたりのエネルギーである Shaking Strength(S) と、振動が粒子に与える力の変化である Jerk(J) という 2 つの無次元数を導入する (Yasuda & Sumita, 2014)。S=(A^2 (2 π f)^2)／ gd 、J=(A(2 π f)^3)／ (g／ (2d／ g)^(1／ 2)) であり、ここで A は最大振幅 (m)、f は周波数 (Hz)、d は粒径 (m) である。崩壊開始の臨界加速度Γが~100Hz で極小となることは、顕著な崩壊が起きるためにはΓ>0.3、S>3.0 × 10^(-5) と J>0.3 の 3 つの条件が必要であると考えると説明ができる。次に「跳躍」レジームを考える。粒子が振動台から上方向に跳躍した時の振動台に対する最大変位 z’を計算すると高Γ、低 f で大きくなることが分かる。「跳躍」レジームは z’>10d によって説明できる。

以上の結果から、粉粒体斜面の崩壊様式と崩壊速度は加速度ばかりでなく、周波数・継続時間に強く依存することが分かった。地震の周波数は 0.1~10Hz 程度の幅を持つ。実験と同様に卓越周波数によって多様な崩壊が起き、また崩壊が起きるための臨界加速度が最小になる周波数帯が存在する可能性がある。多様性の一つとして見つかった「跳躍」レジームは地震動の非対称な上下動の原因として提案された「トランポリン効果」(Aoi et al. 2008) と対応している可能性がある。また本実験は周波数が異なれば、より低加速度であっても最終的な崩壊による傾斜変化が大きくなる可能性があることを示唆している。地震による斜面崩壊の危険性を評価する際には可能な地震の周波数範囲すべてを考慮することが大切である。

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キーワード: 斜面崩壊, 地震, 振動実験, 粉粒体, 加速度, 周波数
Keywords: slope collapse, earthquakes, shaking experiments, granular matter, acceleration, frequency

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HDS06-P06 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

XMP Radar application to optimize volcanic debris flow measurement in Merapi volcano

XMP Radar application to optimize volcanic debris flow measurement in Merapi volcano

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Merapi is one of the world's most active volcano that is well known for its disastrous volcanic debris flow (*lahars*). Previously it has been understood that lahars at Merapi were triggered by rainfall with minimum intensity about 40 mm in 2 hour. However after its 2010 centennial eruption that deposited 10 times volume of pyroclastic materials of 1994 and 2006 eruptions, lahars at Merapi experiences different behavior as it is easily triggered by lower rainfall intensity at 14 mm in 1 hour and were also reported occurred in some areas that had never experienced lahars flow within 40 years. Since it is triggered by lower rainfall intensity now, it has been observed that lahars in Merapi occurred not only during rainy season but also in dry season.

Rainfall intensity in Merapi volcano plays important role not only on triggering and migrating sediment but also determining the level of damages. When rainfall intensity exceeds its threshold, the onset of generated lahars would happen within few hours. For Merapi volcano, it was suggested that rainfall intensity should be monitored for at least every 30 minutes duration. Variation of Merapi topography should also be considered when observing rainfall characteristic, since rainfall is also influenced by this small scaled climate factor. Hence using single raingauge is not recommended due to difficulties of installation, distribution and maintenance. Using raingauge would give limited spatial and temporal resolution.

A Radar system offers a way of measuring areal precipitation with both high spatial and temporal resolution and therefore currently offer the best solution to measure rainfall spatial variability in catchment area. The spatial resolution offered by ground based radar systems can range from ten of meter up to a kilometer, whereas the temporal resolution can range from seconds to an hour. This is an important factors for lahars measurement because in Merapi lahars generated at higher elevations and become more hazardous at 450-600 m elevation in each of the 13 rivers which drain the volcano.

X band dual polarimetric (XMP) radar has been installed at 110.4 E; -7.6 S or 14.3 km from Merapi's summit, Yogyakarta Regency, Indonesia. It has 6 s temporal resolution whereas spatial resolution ranging at 50-250 m mesh. This XMP radar has 9 GHz frecuency and 3.33 cm wavelength which gives far greater resolution than what can be achieved by raingauge network or typical operational C Band radar. Two rivers, Kali Boyong and Kali Gendol that mainly experience lahars every year were chosen to be observed. Both are still in range of 30 km radius of radar detection and flow in dense populated area.

Research objective is to estimate lahars in Kali Gendol and Kali Boyong using improved hyperKANAKO model. HyperKANAKO model is graphical user interface system that is able to predict 2 dimensional debris flow with considering sabo dams planning to reduce loss due to lahars occurrence. This system requires upstream hydrograph, landform information and sabo dam conditions to simulate flow depth, river bed variation, flow discharge and sediment discharge.

Landform information would be gained using geographic information system whereas sabo dam information would be collected based on secondary data. There are 56 and 22 sabo dams respectively at kali Boyong and kali Gendol. Mathematical model between rainfall intensity from XMP radar and discharge data would be used to modify upstream hydrograph. Thus hyperKANAKO model in this research would directly use rainfall information derived from XMP-radar. Output of hyperKANAKO model is expected to not only give information about lahars deposits but also on better management of sabo dam construction

キーワード: Merapi, Lahars, Hyperkanako model, XMP radar
Keywords: Merapi, Lahars, Hyperkanako model, XMP radar

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HDS06-P07 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

能登半島における測地学的手法を用いた地すべり変動の検出
Detection of Landslide displacement by Geodetic techniques at the Noto Peninsula

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Natural disasters represented by earthquake, flood, and tsunami have occurred frequently in Japan. Landslides caused by earthquakes and/or heavy rains have caused great damages in many areas in Japan. Sliding of landslide moves slowly and continuously in general. Elucidation of the characteristic of spatio-temporal movement of landslide is important to understand the mechanism of landslide and to evaluate the assessment of its risk.

In this study, we estimated landslide displacements by geodetic techniques and analyzed the characteristic of landslide movement with ground surface observations at Wajima City, Ishikawa Prefecture, in the Noto Peninsula. We conducted GPS observations of the landslide during July 2014 to March 2015, and detected ground surface displacements from a change in the positions of the GPS sites. We also conducted SAR (synthetic aperture radar) analyses of InSAR (SAR interferometory) and PS-InSAR (persistent scatterer SAR interferometry) using 10 ALOS/PALSAR images acquired from December 2006 to October 2010. Furthermore, we used the ground data observation records of the borehole extensometers obtained by the Ishikawa Prefecture from 2008 to the present. We examined a landslide history of the analyzed area by tracking a topographic map published in 1970 and 5 m DEM released by GSI (Geospatial Information Authority of Japan) recently.

The InSAR analysis reveals landslide displacements of several tens cm/year in the area of 500 m x 500 m and horizontal displacements of 0.6-1.0 cm/year are estimated from GPS. The magnitudes and directions of the landslide displacements are coincident with the monitoring result of the borehole measurements and previous researches. We estimate the average rate of the landslide displacements of 0.5-0.8 m/year from the tracking topographical characteristics using the topographic data. These observations confirm that the landslides in the analyzed area have been active in recent years and suggest that active landslides in the past forms distinct scarp terrains and causes the past disasters written in historical materials.

Acknowledgements: PALSAR 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, the University of Tokyo). The ownership of PALSAR data belongs to METI (Ministry of Economy, Trade and Industry) and JAXA. We would like to thank for the use SIGMA-SAR software for InSAR analysis [M.Shimada, 1999], StaMPS software for PS-InSAR analysis [Hooper et al., 2004, 2007], DEM (Digital Elevation Model) by GSI using SAR analysis, and GMT (Generic Mapping Tools) [Wessel,P. and W.H.F.Smith, 1998] and QGIS software to draw the result.

キーワード: 地すべり変動, 測地学的手法, GPS, InSAR, 能登半島
Keywords: Landslide displacement, geodetic techniques, GPS, InSAR, Noto Peninsula

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HDS06-P08 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

ALOS データから発見されたサイクロンアイラにより引き起こされたブータンの大規模地すべり
Observation of a gigantic Bhutan landslide caused by Cyclone Aila in 2009 using ALOS data

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The kingdom of Bhutan is located in the Himalayan Range in a mountainous area of weak geology. Landslide disasters occur every year, mainly induced by heavy rain. In 2009, the Mangde-chu River, one of the primary rivers in the country was blocked at 1,063 masl of its river bed by huge volumes of debris discharged from a tributary. Moreover, a National Highway connecting Bhutan with India was covered by the debris and closed to traffic. In spite of the significance of the event, no research was conducted on the debris transport process of the tributary.

Therefore, we conducted observations of the topographic condition of the tributary basin using satellite images produced by the Advanced Land Observing Satellite (ALOS, Daichi) of the Japan Aerospace Exploration Agency. Interpretation of the topography was done using a counter Digital Surface Model of ALOS PRISM data (5 m resolution). The ALOS data were observed just after Cyclone Aila. As a result, we detected the topography of a gigantic landslide with fresh scarps, at an upstream site of the tributary. The body of the landslide was 1.2 km wide and 1.1 km long; moreover, the landslide occurred in the vicinity of an older landslide.

We think that this landslide was induced by Cyclone Aila and became the source of the huge volume of debris that blocked the Mangde-chu River. The landslide is divided into blocks and is assumed to be unstable. It is important to conduct more detailed work and assessment in a timely manner because the government of Bhutan has constructed hydro-power facilities along the Mangde-chu River.

This work was supported by JICA/JST SATREPS ”Study on GLOFs (Glacial Lake Outburst Floods) in the Bhutan Himalayas”.

Keywords: landslide, ALOS World 3D, geomorphic analysis, Cyclone Aila, Bhutan