

## The Assessment of Landslide Displacements Using Digital Photogrammetry and Numerical Analysis

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Instead of comparing remote sensing images between before and after a landslide event, this study compares aerial photographs over the years with the velocities of surface movements of landslide to evaluate the feasibility of aerial photographs as a monitoring tool. Before the total collapse of the slope of Freeway No.3, there were signs showing sliding of the slope, but no equipment was set up for monitoring. We use GIS to discriminate aerial photographs of different years to evaluate the displacements of specific objects or marks. From 2002 to 2004, the average displacement was 49.5cm, and the average displacement rate was 23.7cm/yr; from 2004 to 2007, the average displacement was 22.5cm, and the average displacement rate was 7.3cm/yr.

According to time-dependent creep behavior, the primary creep might have occurred from the beginning of the excavation in 1998 to 2004. And the secondary creep was from 2004 to 2007, so the velocity was comparatively lower than the previous stage. As for the tertiary creep, the displacement rate might rise since 2007 till the total collapse in 2010. The software Plaxis 2D based on the finite element method will be used to analyze the displacement process of the slope. The numerical model is set up according to the digital terrain model (DTM) of the slope. The numerical results will be calibrated with the results of the digital photogrammetry. We expect to obtain the creep behavior of the slope such as the slope strength reduction with time and the changes of surface displacement rate with time.

キーワード: digital photogrammetry, Freeway No.3 landslide, displacement rate, creep  
Keywords: digital photogrammetry, Freeway No.3 landslide, displacement rate, creep

## Lidar データによる鮮新世～更新世堆積岩類山地の変形解析 (予報) Deformation Analysis of the Pliocene-Pleistocene Sedimentary Rocks Mountain using Lidar Data

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### 1. はじめに

紀伊半島や大井川流域での四万十層群の変形が話題となることが多い中、これよりも地質年代が若く強度も小さい鮮新世～更新世の堆積岩類の変形がどのように進行しているかについて Lidar データの解析結果をもとに報告する。対象とする地域は、新潟県と長野県との県境付近に位置する新潟県津南町周辺の山地斜面である。津南町～小千谷市付近には信濃川に沿って広大な河岸段丘が発達することでもよく知られているが、津南町は松山ドームの南側に位置し、鮮新世～更新世の魚沼層が広く分布している。

### 2. 津南町周辺の地形地質と山体変形

津南町の北西部は標高 200～1100 m の急峻な山地で、魚沼層の砂層、シルト・砂互層、塊状シルト層、火山岩類などが分布している。地質構造上信濃川に面しては南東傾斜の単斜構造となっており、魚沼層の傾斜角度は概ね 15～40 度で全体に単調な広がりを示す。本地域では多くの地すべりが発生しているが、長野県北部地震 (2011 年 3 月 12 日、M6.7、震源; 長野県栄村) の際に、これが原因と思われる大規模な層面すべりが発生した。また、当地域の西側に隣接する関田山地には柄山崩壊堆積物をはじめ中期～後期更新世と考えられる多くの大規模崩壊が推定されている。

### 3. Lidar 計測とデータ解析

#### 1) Lidar 計測

山地地形解析のために津南町北西部で Lidar 計測が 2013 年 5 月 14 日に実施された。計測は ALS60 システムにより実施され、計測された面積は約 30km<sup>2</sup> である。計測データからグリッドセルサイズ 1 m のラスターデータを作成した。

#### 2) 解析手順

山体変形の特徴を把握するため以下の手順で山地斜面の地形解析を行った。特に、地質構造上層面すべりが発生しやすい条件下にあるため、この候補斜面に注目した。また、一部斜面については現地調査を開始した。

#### 解析 1

- グリッドセルサイズ 1 m データの作成
- 斜面勾配分類 (グリッドセルサイズ 5 m)
- 斜面勾配 15～40 度のセルの抽出
- 面構造の把握
- “層理面 (すべり面状)” 斜面の抽出

#### 解析 2

- グリッドセルサイズ 1 m データの作成
- 画像処理
- 線状構造・エッジなどの線変状地形の抽出
- 陥没帯などの面変状地形の抽出
- 解析 1 と 2 との総合解析

#### 4. 解析結果と議論

Lidar データの画像処理と GIS 処理によって多くの特徴的な線構造・面構造等が明らかとなった。Lidar データの処理によって得られたセルデータを整理することによって層理面と考えられる斜面が山地に非常に広く認められることが判明した。更に、その地形的特徴から、この層理面をすべり面とした痕跡のある斜面を 2 か所抽出した。これらの斜面はいずれも変則的な線状凹地と地形面を伴う層面すべり地形を示す特徴的な斜面を形成している。もっとも規模の大きな線状凹地は山腹斜面を斜めに走り、その延長は 550～600 m に達し、線状凹地のなす変形した地形ブロックの厚さは最大約 6～10 m である。これらの地形的特徴は層理面が大規模な山体の変形と崩壊に大きな役割を果たしたことを示唆している。以上は四万十層群の変形などには見られない特徴的な地形であり、層面すべりによる山体変形を抽出する際のキーポイントとなり得る。

#### 5. まとめと課題

Lidar データの解析により、当該地域では大規模な山体変形が過去に発生したことをうかがわせる特徴的な斜面の分布を確認した。今後は現地での調査を進め山体変形の解明を進めたい。

HDS05-P02

会場:3 階ポスター会場

時間:4 月 29 日 18:15-19:30

参考文献 竹内圭史、ほか (2000) 松之山温泉地域の地質. 地域地質研究報告 (5 万分の 1 地質図幅), 地質調査所, 76p.  
柳沢幸雄、ほか (2001) 飯山地域の地質. 地域地質研究報告 (5 万分の 1 地質図幅), 地質調査所, 144p.

キーワード: L i d a r, 表層地形, 層面すべり, 線状凹地, 山体変形

Keywords: Lidar, surface morphology, bedding plane slip, line trough, edifice deformation

## 大規模崩壊地における土石流の流下と河床条件の相互作用 Interaction between river bed condition and debris flow in Ichino-sawa subwatershed of Ohya-kuzure landslide, Japan

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In recent years, there has been significant concern about large-scale sediment movements, such as deep-seated landslides, that are expected to occur more intensively due to changes in rainfall patterns. These landslides not only induce immediate sediment disasters downstream but also produce a large amount of unstable sediment that is transported gradually following the landslide. Most of the unstable sediment residing in a deep-seated landslide area is first discharged as debris-flow forms. Thus, after the occurrence of landslides, debris flows have a long-term affect on the watershed regime through their impact power, riverbed aggradation, and the production of turbid water, among other effects.

To facilitate better prediction of debris flows from landslide areas, this study investigated the interactions among topographic conditions, bed-material conditions, and debris flow events in a headwater catchment where a deep-seated landslide had occurred.

The study site was the Ichino-sawa subwatershed in the Ohya-kuzure basin, Shizuoka Prefecture, Japan. The basin experienced a deep-seated landslide about 300 years ago and is currently actively yielding sediment with a clear annual cycle. During the winter season, sediment moves from the hillslope to the channel bed because of freeze-thaw activity and weathering. In the summer season, the deposited sediment is discharged incrementally by debris flows related to storm events.

Topographical surveying and grain-size analysis were carried out several times between November 2011 and November 2013. Point cloud data were acquired during the topographical surveying, using a ground-based laser scanner, and used to create a high-resolution digital elevation model. Grain-size analysis was conducted in the upper, middle, and lower parts of the study site. A line-grid method was employed for the in situ analysis, and the fine particle fraction was determined by sieving the sampled materials. Debris flow occurrences were also being monitored in the same period by a sensor-triggered video camera. Rainfall was observed during the summer season for comparison with debris flow occurrence and magnitude.

Several debris flows with different magnitudes were observed during the study period. Although rainfall events in the early spring season altered bed inclination, the thickness of deposited sediment, and the grain-size distribution of the bed material, more significant changes were detected after the debris flows. While the initial grain-size distribution in early spring was roughly identical over the study site, the subsequent grain-size distribution changed differently, according to location. The source, transport, and deposition areas of the debris flows were different among different rainfall events, resulting in different transitions in geomorphic conditions at different locations. The lower part of the study site changed from a source area to a deposition area through the summer season.

A comparison of the topographic conditions, bed-material conditions, and debris flow events indicated that, in addition to the conditions of the triggering rainfall, topographic and bed-material conditions affected debris flow occurrence and magnitude. These interactions could be observed in the deep-seated landslide area, where a substantial and continuous supply of sediment prevents stabilization of the channel bed through exposure of bedrock or by armoring of bed materials.

Thus, to predict the long-term impact of large landslides, it is necessary to assess the subsequent debris-flow discharge considering the sediment dynamics and changes in topographic and bed-material conditions in the landslide area.

キーワード: 土石流, 深層崩壊, 地形条件, 粒度分布

Keywords: debris flow, deep-seated landslide, topographic condition, grain size distribution

**Deep seated landslides along the geological structure in Chishan River Watershed, southern Taiwan**  
**Deep seated landslides along the geological structure in Chishan River Watershed, southern Taiwan**

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Landslide is the common nature hazard in Taiwan. The Typhoon Morakot in 2009 brought huge precipitation and induced severe hazards in south-central and eastern Taiwan. Except the landslides, debris flow and flooding hazards induced by Typhoon Morakot, the large scaled deep seated landslides deserve more attention because they may cause the destructive disaster.

The Chishan River watershed which covered 750 km<sup>2</sup> is selected as study area. The study area is mainly composed of metamorphic and sedimentary rocks. Within the study area, 313 sites greater than 10 ha with sliding topographic features of deep seated landslide such as crown main escarpment, down slope scarp, and lateral cracks are recognized from LiDAR derived 1 m resolution DEM, and we noticed the distribution of these sites is close to the structure in our study area. In order to know the influence of structure in the development of deep seated landslides, landslide density are calculated. The landslide density decreases with increasing distance and there are 79% of deep seated landslides developed along the structure with a 1km buffer zone. The Result indicates that deformation zone associated structure is crucial in the development of deep seated landslides in the study area.

キーワード: Chishan River watershed, deep seated landslides, geological structure  
Keywords: Chishan River watershed, deep seated landslides, geological structure