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

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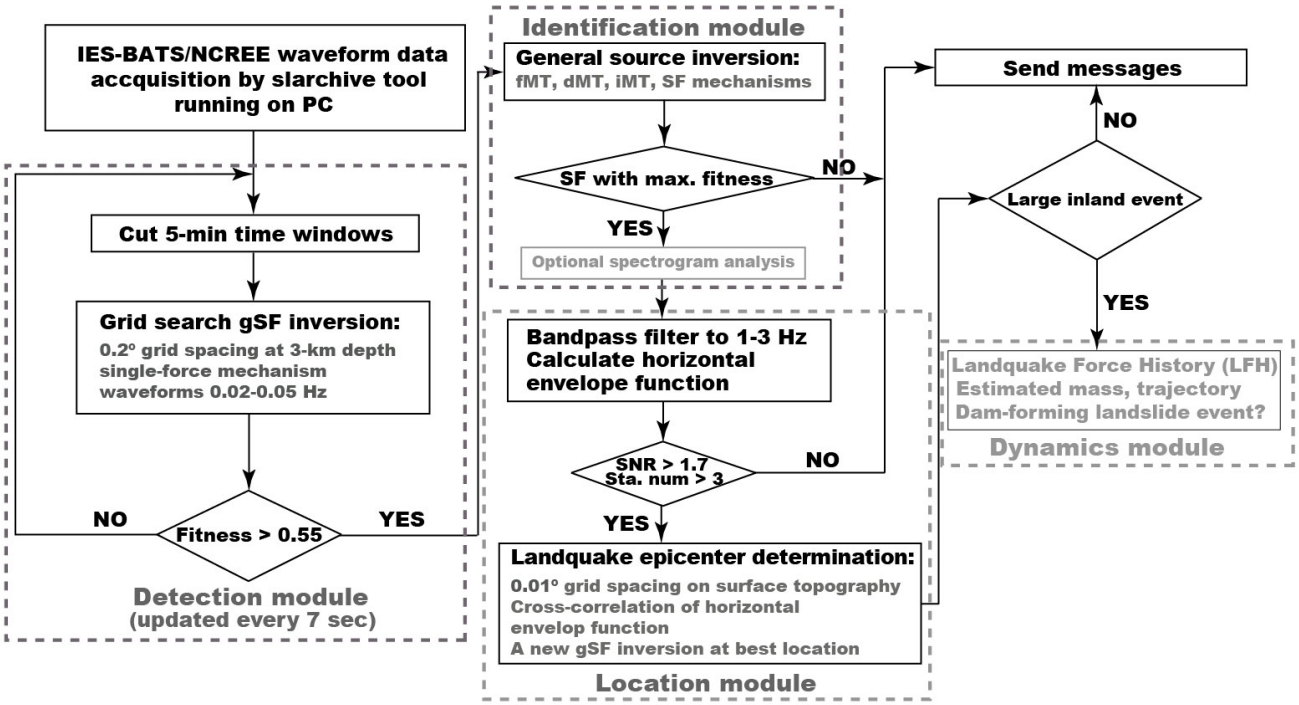
Landquakes such as rockfalls, landslides and rock avalanches are one of the most deadly kinds of natural disasters. In active mountain belts, such gravity-driven events dominate erosion dynamics that strongly depend on the occurrence of extreme rainfall or high seismicity. Recent studies have demonstrated 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)



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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

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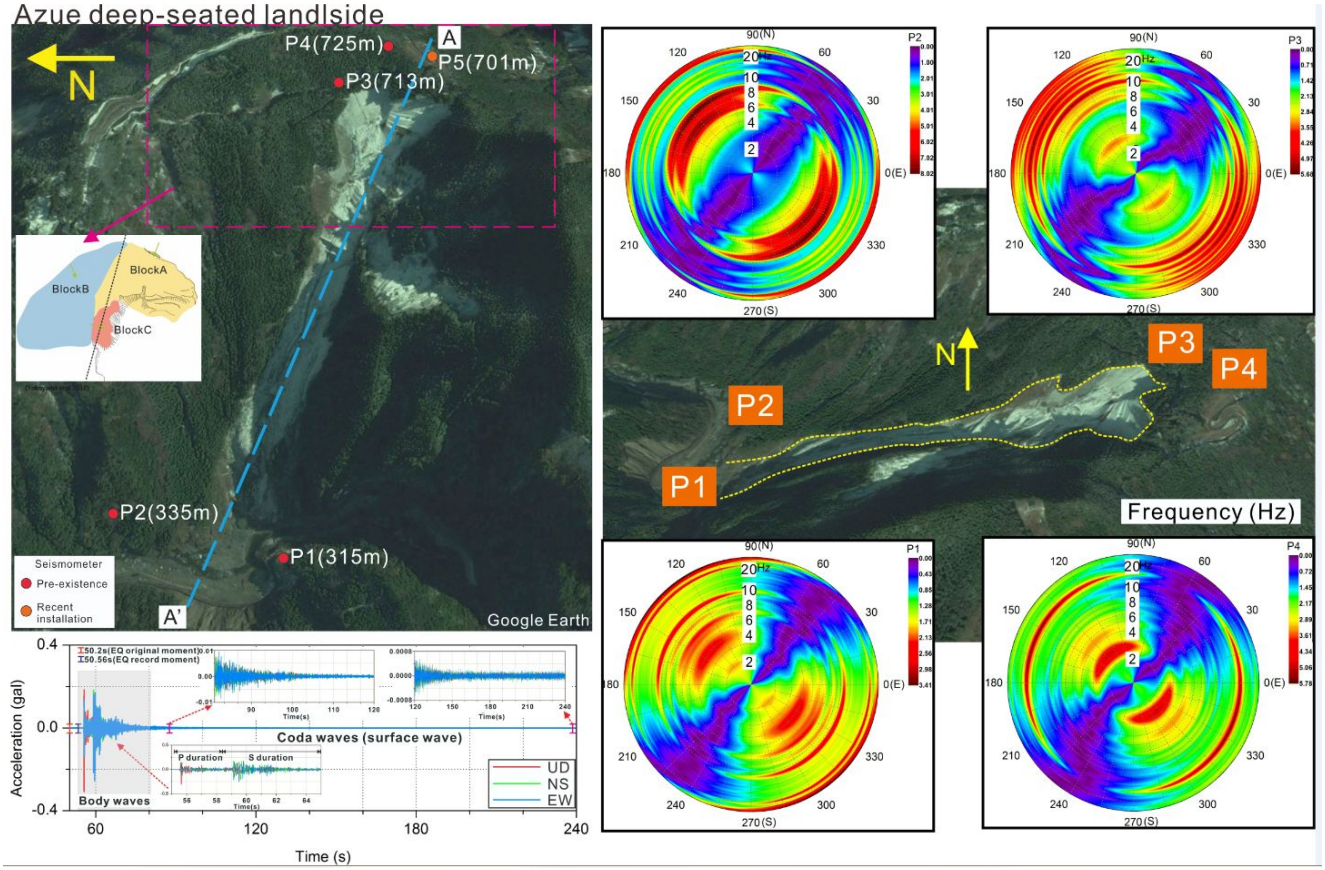

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Measuring the ground surface movements by applying the object based approach

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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

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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

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

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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

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Granular flow in a varying width rotating drum

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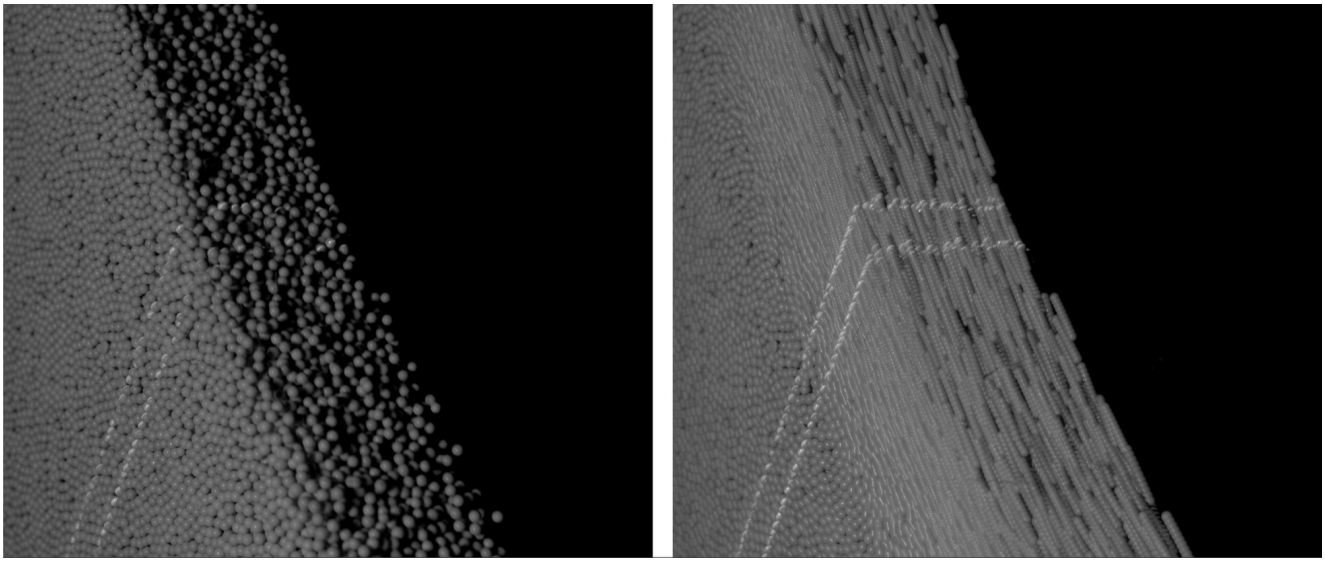
A landslide is a form of mass move abruptly, and that is prone to be triggered by an earthquake or high intense rainfall. Rapid flows of granular materials on inclined surfaces are often encountered in engineering applications, and also found in geophysical situations.
In this study, we focused on the 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



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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

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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

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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

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