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Significance of Dissected Deep-Seated Landside Topography and Hydrothermal Alteration in Active Mountain Belts

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Abstract: Overlooked geological risks in active mountain belts of non-volcanic regions like the Himalayas include large-scale dissented landslide topography and hydrothermal alteration from past igneous activity. The keynote lecture will present case studies from the Shikoku Mountains in Southwest Japan and their application to the Nepal Himalayas.

Keywords: ***Dissected landside topography, Hydrothermal alteration, Active mountain belts.***

Introduction

Geological risks that are overlooked in non-volcanic mountainous regions such as the Himalayas are hydrothermal alteration caused by past volcanic activity. Another geological risks are large-scale landslides that have no remaining landslide topography. In the keynote speech, I will present case studies from the Shikoku Mountains in Southwest Japan and their application to the Nepal Himalayas.

Geological setting

The Himalayas have been formed by the collision of India and Eurasia plates. Southwest Japan is located where Philippine Sea plate subducts under the Eurasian plate. Although the Himalayas and the fore-arc side of Southwest Japan are in non-volcanic belts, the Miocene granitic rocks have played important role in upheaval of mountain ranges and hydrothermal alterations to surrounding bedrocks. The leucogranites distributed along in the Higher Himalayan Zone are closely related to the highest peaks such as Mt. Everest (Sagarmatha), Mt. Manaslu etc. The radiometric age of the leucogranite is 9 to 24 Ma. The occurrence of many hot water springs along the vicinity of the Main Central Thrust (MCT) indicates the hydrothermal solution along the MCT. The remaining heat of the Miocene leucogranite could be a thermal source of such hot springs (Hasegawa and Dahal, 2017).

The middle Miocene granitic rocks are sporadically distributed in the Shikoku Mountains, Kii Mountains Peninsula. The highest peaks, such as Mt. Ishizuchi (1982 m) in Shikoku Mountains and Mt. Hakkyogatake (1915 m) in Kii Mountains are closely related to the Miocene granitic rocks (Hasegawa, 2009). The radiometric age of the granitic rocks is around 14 Ma. The water temperature is 90℃ at Yunomine hot spring in Kii Mountains where the Middle Miocene granitic rocks are distributed in the direction of north to south. Although no Quaternary volcano is distributed in the Higher Himalaya and Shikoku and Kii Mountains, present hydrothermal activities are recognized in both areas. The thermal source of hydrothermal activities of both areas must be closely related to the hidden Miocene batholith.

Case studies in shikoku mountains

Recognition of hydrothermal alteration is very important because it had spread along major faults and has prepared clayey sliding surfaces of deep-seated landslides. Engineering geological investigations on large-scale landslides along the major faults named Median Tectonic Line (MTL) in Shikoku have revealed that smectite-bearing clay-rich zones are the origin of sliding surfaces (Hasegawa et al., 2021). The smectite is inferred to be formed by hydrothermal alteration which is originated from Middle Miocene volcanism. Detection of low resistivity zones by airborne electromagnetic surveys and analysis of their causes by drilling surveys are effective means of assessing the impact of hydrothermal alteration in mountainous areas. Large-scale dissected landslide masses which had formed in early Pleistocene are distributed along the MTL in Southwest Japan (Figure 1; Hasegawa, 1991). Recently, Kanbara et al. (2021) proposed three criteria for recognition dissected landslide topography: 1) ridge discontinuity, 2) the landslide head being lower in elevation than the original slope, 3) spreading of the landslide body to form a gentle slope. H/V spectra obtained by microtremor surveys are an effective means of distinguishing a landslide body from a stable, sound rock-mass in the field.

The rock-mass types of tunnels along the MTL are divided into four types from geological history of landslide and hydrothermal alteration (Figure 2; Hasegawa et al., 2006). The large convergence tends to appear in H-type and HS-type tunnel ground which have affected hydrothermal alteration (Figure 3). X-ray diffraction analysis suggests that smectite-bearing clay veins originated from hydrothermal alteration and have caused large convergence during tunnelling. Therefore, it is very important to confirm the presence of the swelling clay mineral (smectite etc.) before and during tunnel construction.

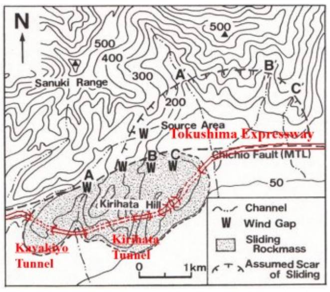

Figure 1, Kirihata hill is dissected landslide hill which had slid from Sanuki Mountain Range about 1 Ma and it have been dislocated 2 or 3 km right-laterally by the Chichio fault, an active fault of the Median Tectonic Line (Hasegawa, 1991).

Landslide \ Hydrothermal alteration	×	O
×	N-type Sound	H-type Expansive
O	S-type Cracky & loosened	Cracky loosened HS-type & Expansive

O: affected, ×: unaffected

Figure 2, Characterization of tunnel ground from geological history of landslide and hydrothermal alteration (Hasegawa et al., 2006).

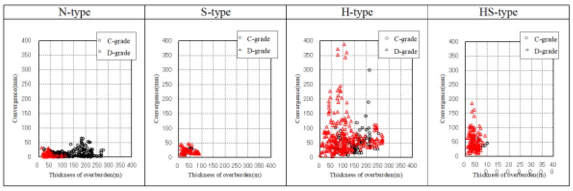

Figure 3, Convergences of four types of tunnel ground to thickness of overburden (Hasegawa et al., 2006).

Application to Nepal Himalayas

Hasegawa et al. (2009) have revealed by X-ray diffraction analysis that large-scale landslides along the highways in central Nepal have significant clay mineralization in sliding zones. The substantial hydrothermal alteration in the Lesser Himalaya during and after the advancement of the MCT and thereby clay mineralization in sliding zones of large-scale landslides are the main causes of large-scale landslides.

Unexpected troubles in large-scale construction projects are related to hydrothermal alterations and dissected large-scale landslides. Most of fragile rock-masses in Himalayas are caused by landslide deformation which is often misunderstood as tectonic origin. This indicates that large-scale landslides in the Himalaya might be triggered by strong earthquake caused by not only mega-thrust along the plate boundary but also hidden active faults beneath landslide masses and sediments. Kathmandu Valley, extraordinarily wide and high in elevation, is surrounded by hills that were formed by large-scale dissected landslide hills. The Nagdhunga Tunnel was the first road tunnel in Nepal which has been constructed in a hill west of Kathmandu. This hill was a huge slid mass that slid from the Shivapuri Mountains more than 1 Ma. The tunnel bedrock is composed of sandstone and slate with irregular cracks that can be easily broken down with a hammer.

Conclusion

In conclusion, recognition of hydrothermal alteration caused by past volcanic activity and large-scale dissected landslides topography are essential in engineering geology in active mountain belts.

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