Embankment failures related with bedrock slide in the Shimanto Belt, south Kyushu, Japan

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Landslides Vol.39 No.4 Separately Printed.

Technical report

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Key words : bedrock slide, Shimanto belt, subduction, accretionary complex, turbidite, olithstoliths

1. Introduction

Erosion of mountainous landscapes occurs by valley incision and hill slope mass wasting (Burbank et al., 1996), usually. A common first-order control on rates and patterns of mass wasting is the heavy rains and earthquakes can preferentially affect different parts of a mountainous landscape (Iverson and Reid, 1992; Bouchon and Baker, 1996). Bedrock slides are volumetrically important and difficult to extrapolate historical studies over time scales relevant to landscape evolution in the mountainous region. Because of their heterogeneity and complex nature, subduction complex rocks are difficult geotechnical materials with which to deal in analyzing slope stability (Lee, et al., 1996).

Most of the rock falls and landslides found in the subduction complexes of the Shimanto terrains are related with the geological structure and distribution of fractured slump blocks. This interpretation is based on the field observation to distinguish between the deformation of bedrocks and structural attitude of the underlying rock bodies. Bedrock slides are interpreted as retrogressive failures from the toe of hill slope, overlying on the clay layers of shear zones, and trigger act primarily on the saturated hill slope related with the significant changes of underground seepage force in the underlying fractured sedimentary sequences. This paper describes the distinctive nature of bedrock and spring seepage condition in saturated hill slopes cause significant failures on the slope of mountainous areas and, then extend possible approach to landscapes in which the dominant triggering mechanism is unknown.

2. Regional Geology

The mountainous region in southwest Kyushu is made up mainly of the Mesozoic and Cenozoic rocks of the Shimanto Belt and shows a parallel distribution of fault-bounded accretionary complexes with a general trend of ENE-WSW direction.

The Shimanto Belt of Kyushu can be divided geotectonically into the Northern and Southern Belts by the Nobeoka Thrust, which is dipping gently towards the north. In South Kyushu, the Morotsuka Group (Cretaceous) thrust on the Hyuga Group(Eocene to Early Oligocene) bounded by the Nobeoka thrust, but its distri-

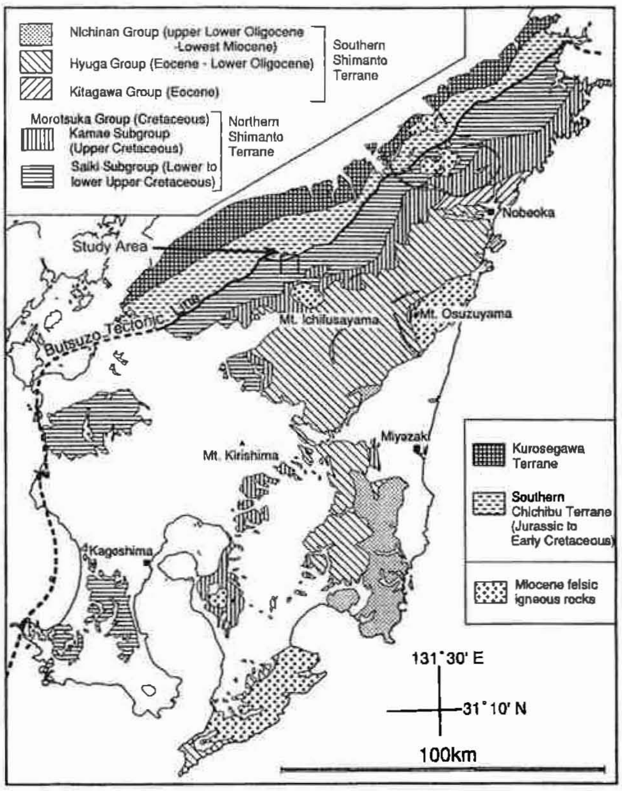

Fig. 1 Tectonic divisions of the Southern Kyushu (after Makoto Saito et al., 1995)

bution is restricted to a few areas such as northern part of the Kyushu (Fig.1).

Morotsuka Group is an accretionary complex of early Late Cretaceous (Sakai and Okada, 1997), and occurs in the study area near Mizukami village, SE Kumamoto Prefecture. Morotsuka Group consists mainly of massive to thick-bedded sandstone with interbedded sandstone and siltstone, and is accompanied by slaty shale sequences along with disrupted sandstone blocks in the lower part.

3. Landslide occurred in the Northern part of Shimanto Belt

3.1 Locality and Geology

The study area is located at the Umenoki-Tsuru forest road, northern part of Mizukami Village, Kuma region, SE Kumamoto Prefecture, and situated at the down slope side of roadway embankment (Fig. 2 and Photo 1). The slopes are generally high and steep (950-1000m), and the rocks of the region are highly fractured. Massive to bedded sandstone bodies are exposed on the middle part of slide area (Block-B), and underlying slaty shale units are occurred at the toe of

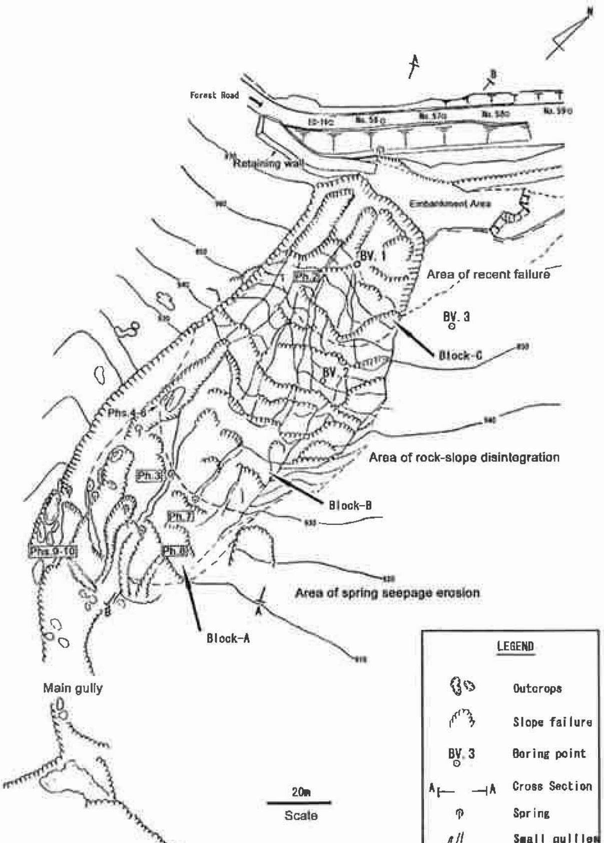

Fig. 2 Map showing failure blocks and stability conditions of Umenoki-Tsuru Forest Road landslide

Photo 1 Side view of landslide area. Looking to NE direction
Width of Landslide Zone = 70m, Length of Landslide Zone = 150m
Middle part of hill slope indicating delineation of gullies by debris flows.

landslide(Block-A) zone (Figs. 3－5). General trend of the bedding strike and dip are around N30° E/40° NW to S25° E/50° SW. The avalanched embankment was situated on the Quaternary clayey soil units and groundwater springs flowing from the head of scarp were also occurred at the slip surface (Block-C).

3.2 Evidences

At the head of the landslide zone (Block-C), slip surface developed on the clayey soil layers and the thick embankment fill was collapsed to down-slope of the hillside (Photo 2). The main scarp, about 5m-10m high, was clearly formed at the top of the slope and many seepage zones are occurred on the slip surface. This slip surface is thought to be the boundary of collapsing embankment fills and underlying clayey soil materials. Shear cracks are also found on the slip surface and western part of slide-wall (Photo 2).

There are many localities of groundwater seepage along the boundary between slide masses (sandstone bodies ; width : 1.0m to2.5m, and length : 2m to 5m) and minor failures at the boundary of sandstone blocks and underlying slaty shale beds (Photo 3). Clay layers with high water content are investigated under the slump sandstone blocks and ground water lubrication for the slides was occurred along the boundary between impermeable slaty shale and permeable sandstone (Photos 4－6). Concentrations of large sandstone gravels, and driftwood with tilted pine trees were found in the central part of downstream area suggest the high mobility of the landslide mass. Degradations of the vertical head scarp with groundwater springs leading to

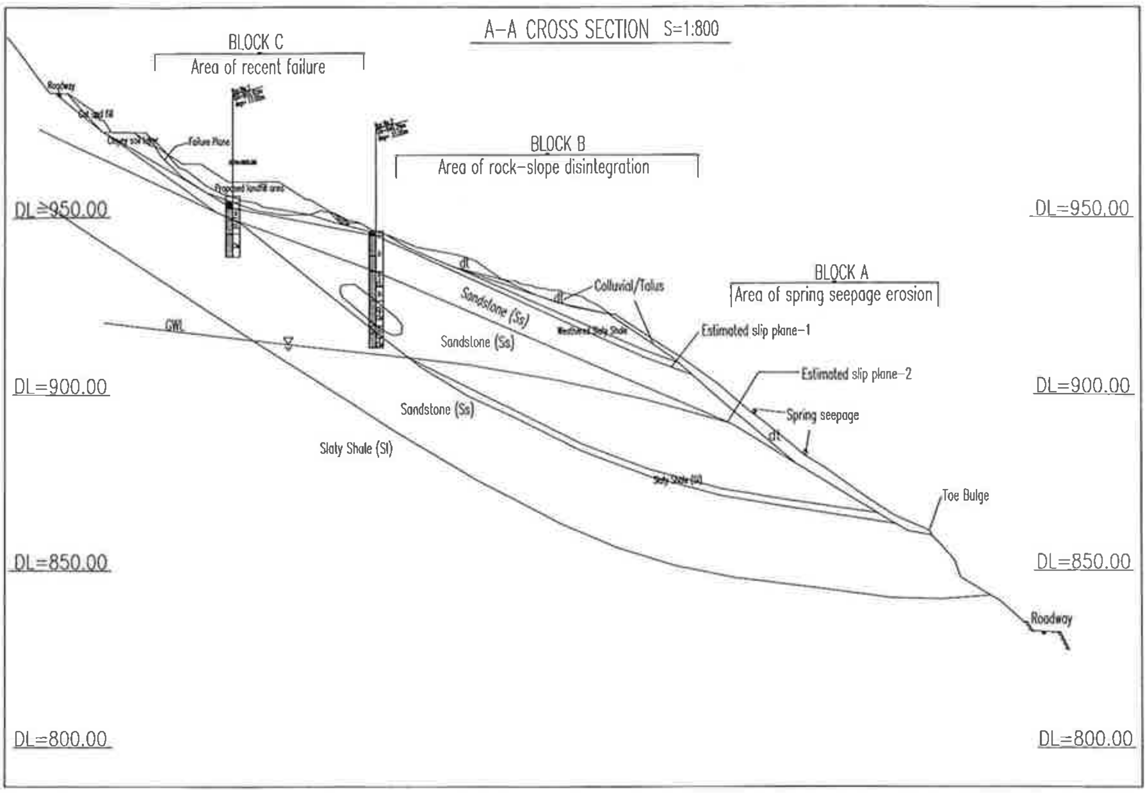

Fig. 3 Geological cross section along A-A

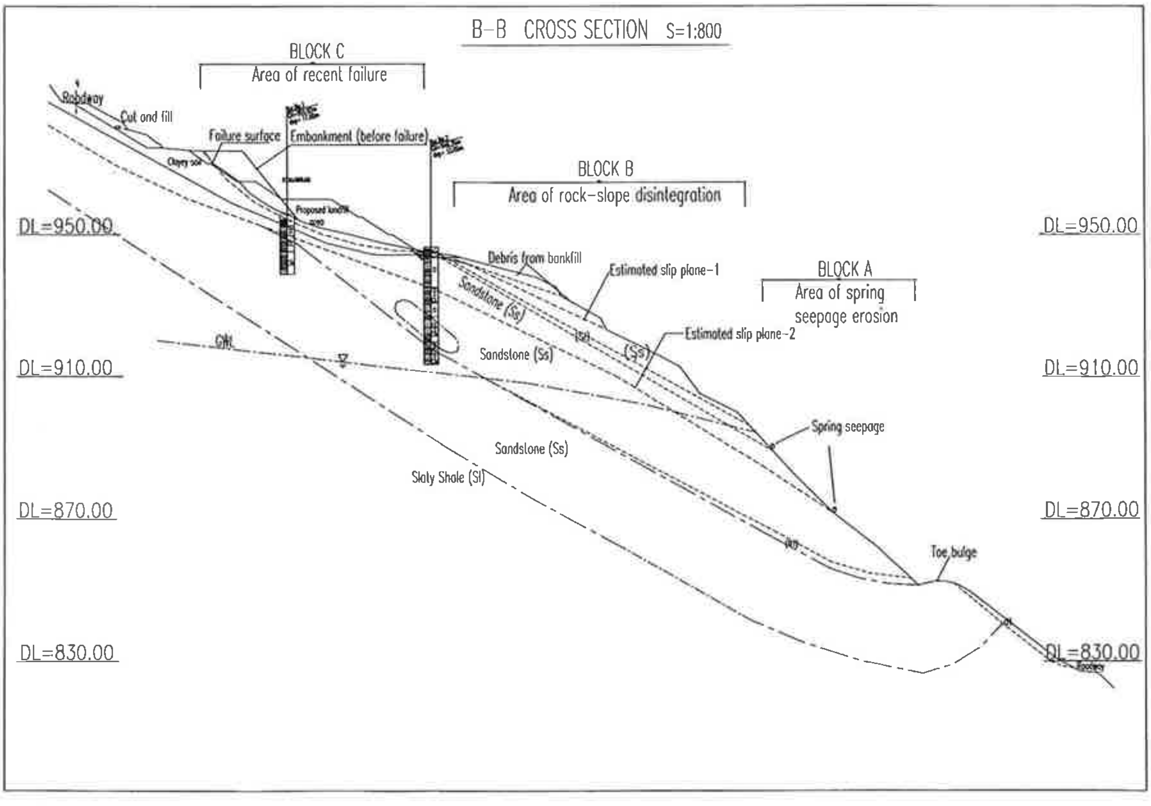

Fig. 4 Geological cross section along B-B

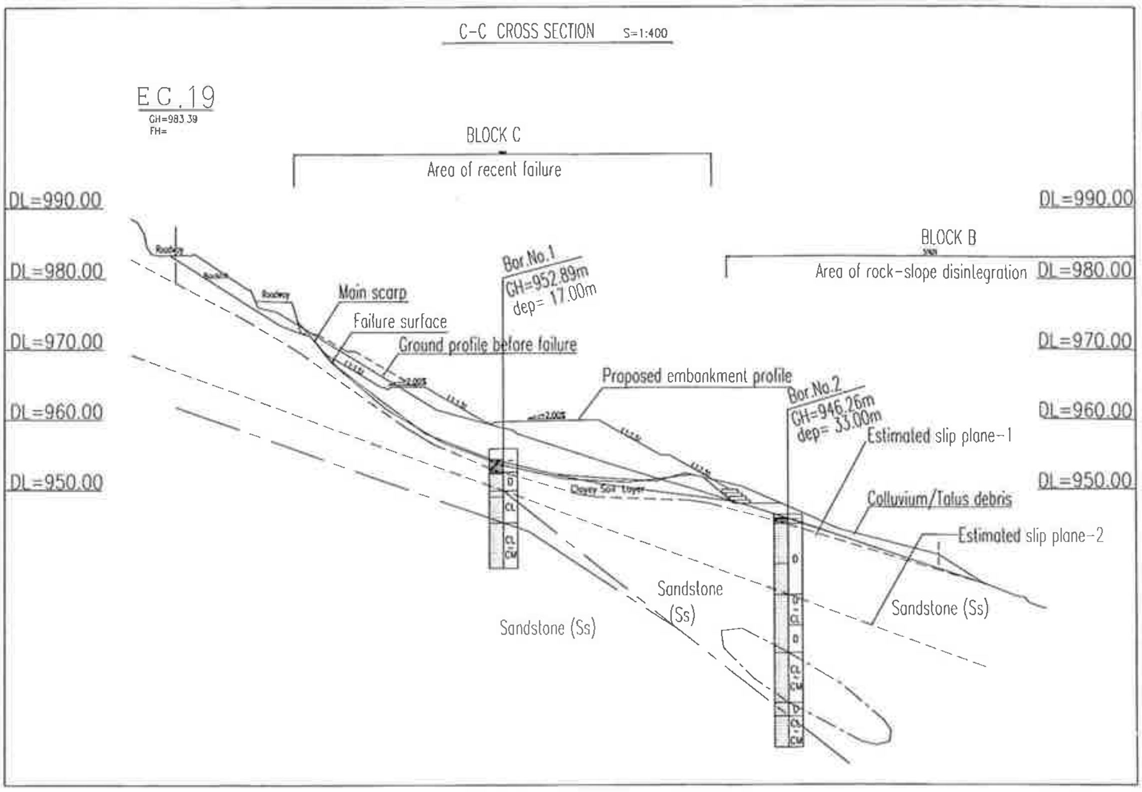

Fig. 5 Longitudinal cross section through station No. EC. 19

Photo 2 Head scarp exposing black and reddish brown clayey soil layers showing failure plane with striations. Note, debris from the embankment slides consisted of fragmented sandstone and clayey soil. The soil cover was less than1m thick and the sliding exposed the underlying bedrock

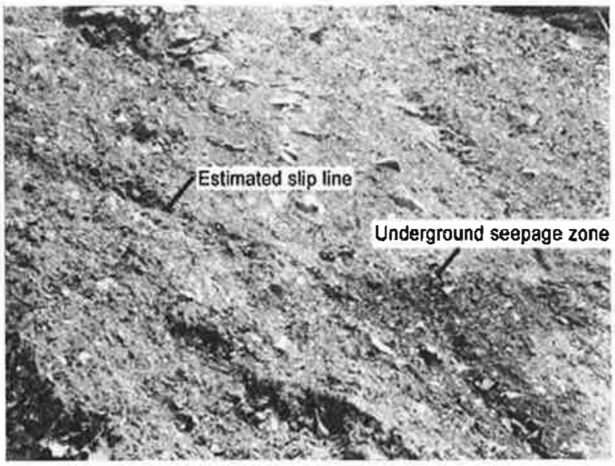

Photo 3 Small gully and groundwater seepage (dark area) on the cobble-size gravelly hill slope (Block-B)

quick condition were found in the area of the slip surface between the Block-B and Block-A (Photos 7 and 8).

4. Discussion and Conclusion

There are many localities of underground seepage along the boundary between slide masses (sandstone bodies; width: 1m to 2.5m, and length: 2m to 5m) and slaty shale layers (Photo 8). There are two pinkish to reddish brown color clay layers are directly recognized on the hill slope surface. Upper one is directly overlain by the sandstone slide masses. And another one is occurred along the major stratigraphic boundary between thick-massive sandstone unit and slaty shale unit (Figs. 3−5).

The bedrock slides occur in the subduction complex sequences of Shimanto Belt, include mainly slump masses and slope components. They contain massive

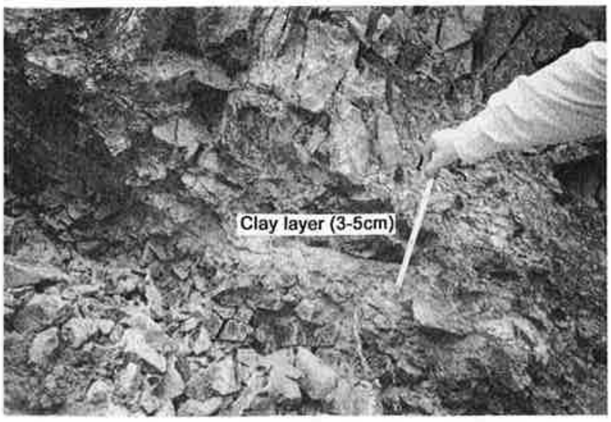

Photo 4 Close-up view of clay layer (sliding surface) interlayered between the highly jointed sandstone block (upper) and fragmented sheared zone (lower)

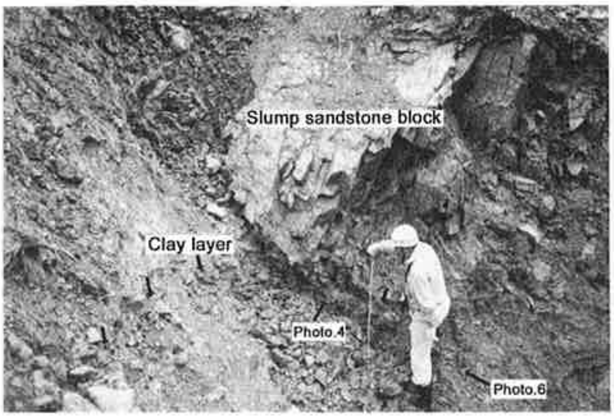

Photo 5 Overview of slumped massive sandstone body exposed due to the gully erosion in the upper part of hill slope surface (Block-B)

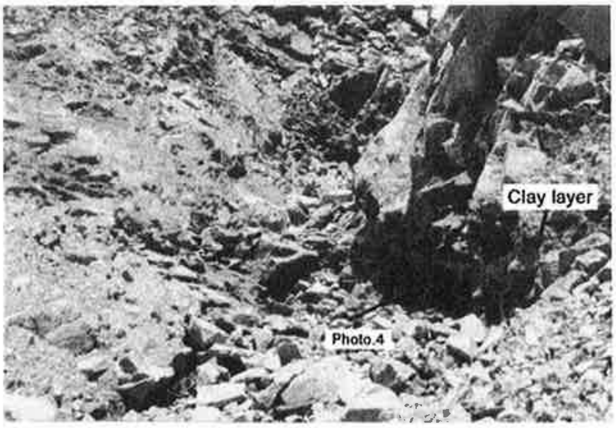

Photo 6 Close-up view of highly jointed slump sandstone body overlying on the highly fractured zone composed with sandstone clasts and silty clay layer

Photo 7 Gully erosion starting from the boundary between Sandstone unit (upper) and slaty shale unit (lower). Underground springs and slope failures occurred at the lower part of Landslide area (Block-A)

Photo 8 Underground spring zone at the lower part of gully. Note slaty shale bed exposing on the lower part of landslide area

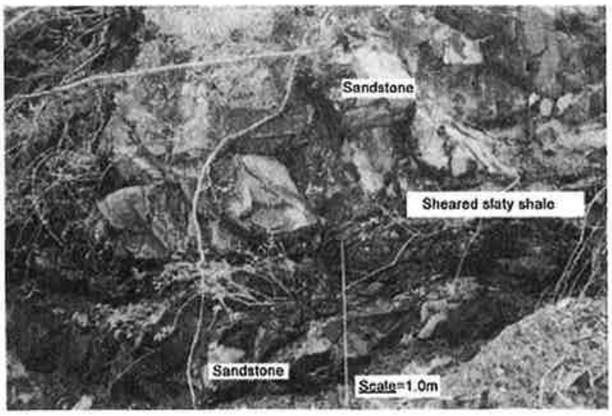

Photo 9 Close-up view of thick-bedded sandstone block overlying on the sheared slaty shale layer (Yellow pole=1.0m)

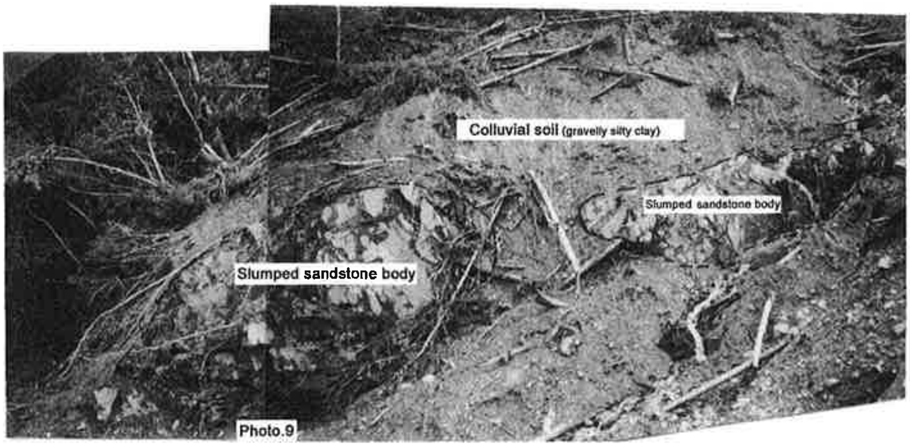

Photo 10 Large sandstone bodies with underlying slaty shale layers drifting along the erosional gully at the western side of landslide area

to thick-bedded sandstone units, sandstone and shale alternative unit and shale and slaty shale unit. The massive to thick-bedded sandstone blocks are highly jointed and fractured showing intense deformation (Photos. 4 – 6). Most of these sandstone blocks are lenticular in shape and sometime showing folded-nature (Photos. 9 and 10). These channel-shaped sandstone bodies are encased within the thin-to medium-bedded sandstone and shale units. In some places, these interbedded units are also folded and fractured due to the propagation of faults and slumping. In the channel-shaped sandstone bodies, upper and lower parts are more fractured than the inner part of the body. Sandstone units are more porous and permeable than shale and slaty shale units.

In this case, seepage forces in well-saturated hill slopes cause significant changes in effective stresses during and after heavy rain. Spatial gradients in seepage force increase the body forces on hill slope materials (e.g. olithstoliths, slump blocks etc.), and so drive failure. Failure potential is considerably higher at the toe of a saturated hill slope than upper part and continues upward increasing the failure because of localized upward-and outward-directed components of the seepage force. Hill slope saturation due to heavy rain and storm cause landslides that cluster near hill slope toes, although heavy rain and storm triggered, middle and upper slope failures involving both bedrock and colluviums even embankment fills.

The correspondence between the incompetent bedrocks and landslides triggering by heavy rain leads increased seepage and forming in response to base-level fall if the incision rate at the toe of the hill slope exceeded the erosion rate at the top including the presence of incompetent bedrock, continued base-level fall, and predominance of debris slides forming slope-clearing landslides. These landslides can be interpreted as the primary landslides and continue to the disintegration of slope by weathering and erosion of underground seepage. There is a need for further research including the determination of mechanical properties of clay between the slide mass (sand bodies) and underlying sequences, in future.

Acknowledgment

First author would like to thank Miyazaki Masaharu and Fujii Satomi of the Geological Investigation Section, for their field assistance and preparation of the manuscript, and the authors wish to acknowledge Akihiko WAKAI, Department of Civil Engineering, Faculty of Engineering, Gunma University for review of the manuscript.

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(Received April 11, 2002, Accepted September 27, 2002)