THE MICRO-TOPOGRAPHY OF MOUNTAINOUS WATERSHED USING AIRBORNE LASER ALTIMETRY AND BASE-ROCK SLAKING TENDENCY

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ABSTRACT

This paper describes topological and landslides characteristics in the tributary of the Saru river watershed, Hokkaido, Japan. In 2003.8, thousands of shallow landslides are induced in the Saru river watersheds by Typhoon ETAU. Through the field survey, landslides are classified into two types, such as rotational landslide and surface failure. The Saru river watersheds located west side of the Hidaka collision zone. The bedrock geology of the study area is characterised by Permian to Jurassic accretionary complex and cretaceous sedimentary rocks. Detailed field survey, air borne laser scanning and slaking tendency tests are conducted to clarify sediment production processes. The study results are as followings. 1) Surface failure occurred mostly in the bedrock of accretionary complex and most landslides exposed bare rock. 2) Rotational landslide occurred mostly in the Cretaceous sedimentary rocks and most slide blocks are still remains and strong slaking tendency is shown on surface. 3) Slaking test resulted hat the Cretaceous sedimentary rocks behave rapid slaking tendency in a few days.

Key Words: Airborne laser altimetry, Shallow landslides, Sediment yield.

INTRODUCTION

Frequent shallow landslide disaster caused by large storm lead to the large sediment accumulation in the mountainous stream channels (Murakami *et al* 2004). The storm induced sediment motion must be clarified to manage river bed aggradations, reservoir sedimentations and coast line conservations. A comprehensive sediment management is promoted by the Japanese government from 1998. Sediment transport process monitoring has been started in targeted rivers in Japan. However, slope process has not been well investigated for estimating sediment contribution to stream channel. This study focus on the slope processes in a small tributary of the Nukabira river which characterised different geology, such as sedimentary rocks and accretionary complex. Over 4,000 shallow landslides are occurred in the Nukabira river watershed, biggest tributary of the Saru river (fig.1), as a result of record storm in August 2003 (JSCE 2004).

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As shown in , the Saru river basin has a relatively complicated geology, such as of metamorphic rock, accretionary complex, plutonic rock and sedimentary rocks. With the conventional sketching method had taken in the study streams in 2004, it showed that there is common landslide tendency along the streams by the basement rock geology. At that time, we could not define those features are common in the same geology area. Fortunately, ministry of land, Infrastructure, transport and tourism implemented high resolution laser altimetry scanning over major rivers watershed in Hokkaido in 2006. A detailed topography relief map is produced and it confirmed that specific landslide type is commonly appeared not only along the stream but also in the same geology area. This case study try to describe sediment production tendency is diversified in complex geological condition.

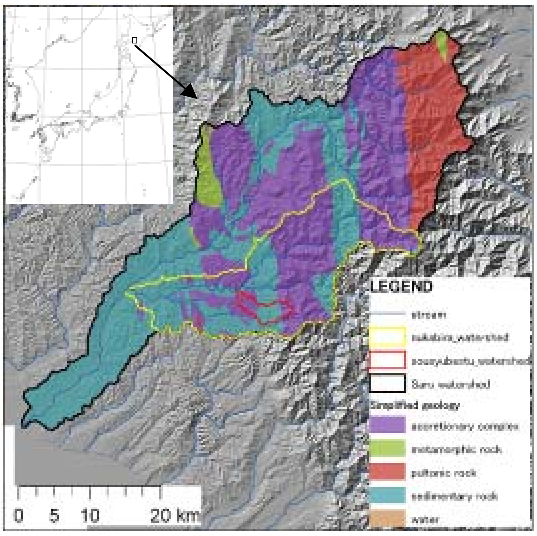

Fig. 1 Simplified geology map of the Saru river watershed. (geology data:Geological Survey of Japan, AIST (ed.). 2007)

GELOLOGY OF THE STUDY AREA

The Nukabira river catchment area is approximately 384 km^2 located to the west of the Hidaka mountain range in southern Hokkaido. The geological conditions of this river basin can be roughly divided into 1) sedimentary rocks (Jurassic and Neocene), 2) accretionary complex (chert, basalt rock and pillow lava), 3) plutonic rock, 4) metamorphic rocks (the Hidaka metamorphic rocks), (see fig.2). An accretionary complex is formed from sediments that are accreted by tectonic movement at a plate boundary. For example, in the Permian and Jurassic accretionary complex zone of the Nukabira river basin, pillow lava, basalt rock and chert are commonly distributed. Stream network is formed by relatively steep valley walls

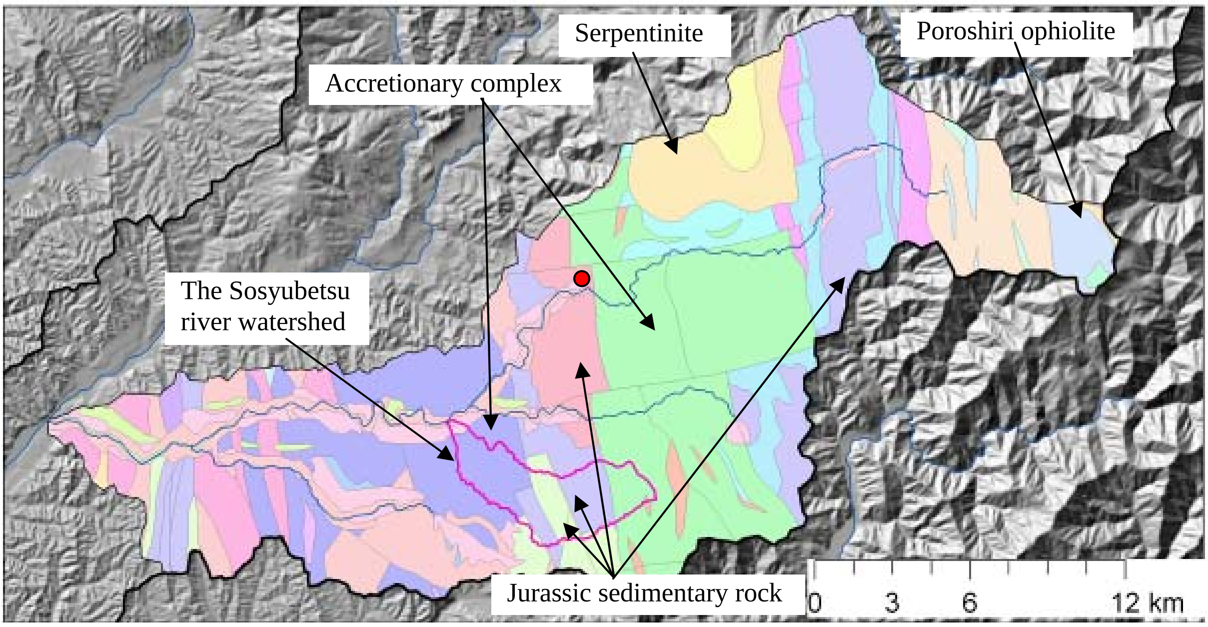

Fig.2 A detailed geology map of the Nukabira river watershed. The study catchments, the Sosyubetsu , is illustrated as red line.

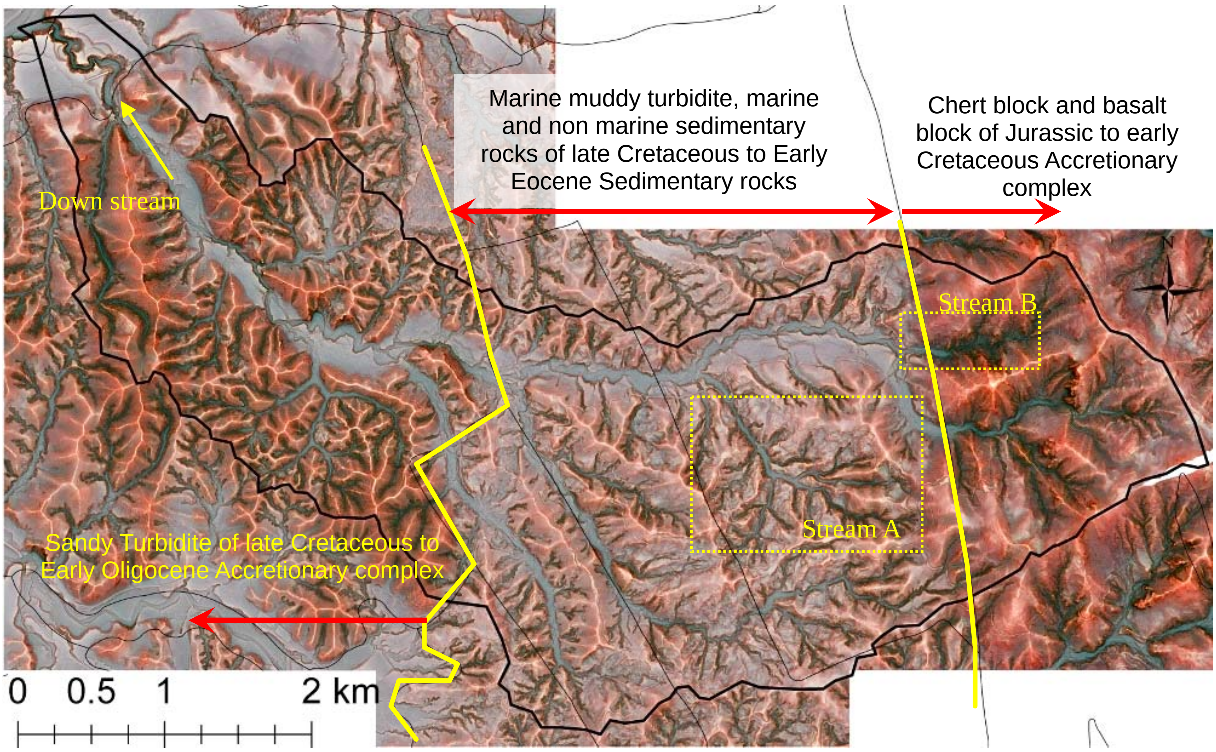

Fig.3. Red relief image map of the Sosyubestu river watershed. High resolution DEM is obtained by airborne laser altimetry in 2006

in this geology. In the Jurassic sedimentary rock zone, mud stone and sand stone are commonly found and most of the bare rock surfaces have a slaking tendency. Topography of this geology tends relatively gentle from contour map.

COMPARISON OF FIELD SURVEY AND AIRBORNE LASER SCANNING RESULT

Field investigation is conducted to observe the relationship between geology and sediment yield characteristics on the study streams in 2004. This investigation including shallow landslide mapping, transactional survey and slaking tendency test. Airborne laser altimetry survey was conducted in 2006 over the Saru river watershed. 1.5m resolution RRIM(Red Relief Image Map, Chiba *et al*, 2007) is shown as Fig.3. This map illustrated the Sosyubetsu river watershed topography, ridges are expressed bright and steep slopes expressed dark colour. Yellow lines are plotted as geological boundary of the accretionary complex and sedimentary rock. The commonality of topographic feature in the geology area is recognized from browse through impression. Right side of the Fig.3 indicated that streams are composed steep valley slopes. And middle of the fig.5 also indicated that relatively gentle slopes are appeared. Fig.4 shows sketch map and RRIM image of stream A witch belongs to Cretaceous

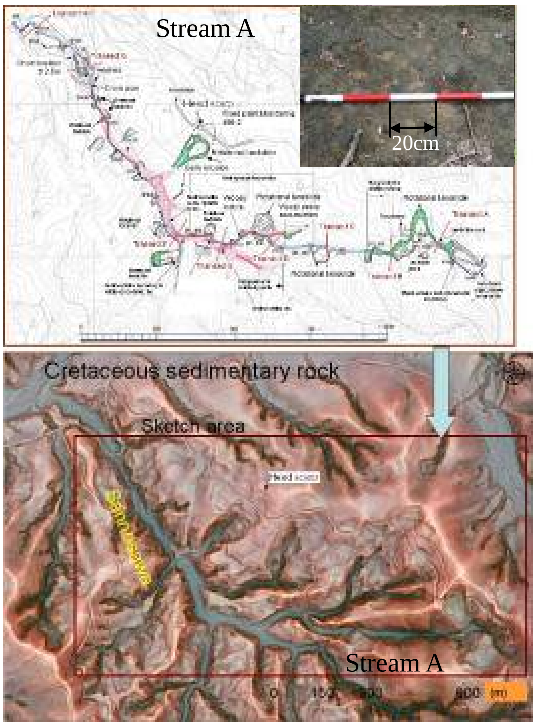

Fig.4 Sketch image (upper) and Red Relief Image Map(lower) of stream A.

sedimentary rock. Most of the landslide type along the stream A is rotational one. RRIM image reconfirmed that rotational landslide patterns are scattered in this geology area. The river bed materials of this stream have high slaking tendency. Major part of river bed grain size is pebble (around few mm).

A sketch image of Fig.5 shows surface failure distribution and bare rock expose site in stream B, this area belongs to accretionary complex. Through the field observation, most of the shallow landslides traces are bare rock exposure and leave a few surface sediment and woody debris. Green colour area in sketch image of Fig.5 indicated that bare rock surface at newly occurred failure trace. Red relief image map also indicated that surface failure occurred mostly in this geology area. The slaking tendency is not found in this area. River bed materials are mostly basalt rock, chert and other hard materials. The river bed materials of stream B categorise with boulder. Stream A is close to stream B, but, landslide type and river bed materials are completely different. Careful consideration should be given to analysis of sediment yield characteristics.

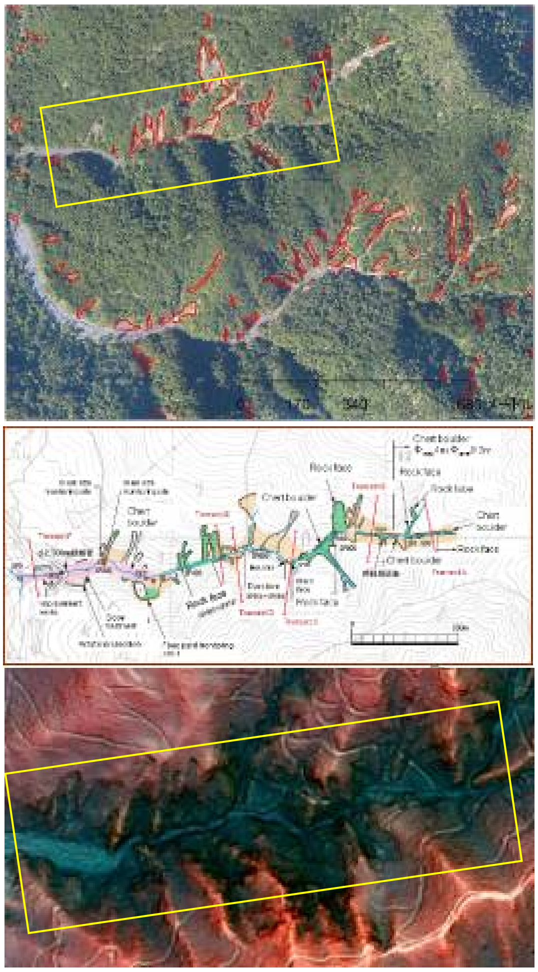

Fig.5 Aero image (upper,2006), Sketch image (middle,2004) and RRIM(lower,2006) of stream B

SLAKING TENDENCY TEST

Through the field survey, natural slaking tendency is found quite common around the Saru river channel. For example, 2 month after the 2003.8 storm event. Boulder size mud stones are scattered around the shalow landslide site (upper image of Fig.6). 7 month later, most of the boulders are slaked like lower image of Fig.6. The slaking tendency affect a broad sediment transport. Traditionaly, name of the Saru river originated from native Ainu language “Shishirimuka“ means frequent river mouth closure by transported sediment by river flow. Slaking tendency is one of the reason of rich sediment production environment is existing in the Saru river watershed. The slaking characteristics of the bedrock were therefore examined. Field observation indicated that exposure of rock due to slaking was observed mainly in the Cretacuous and Neocene sedimentary rock zone. In this study, focus was placed on geological conditions typical

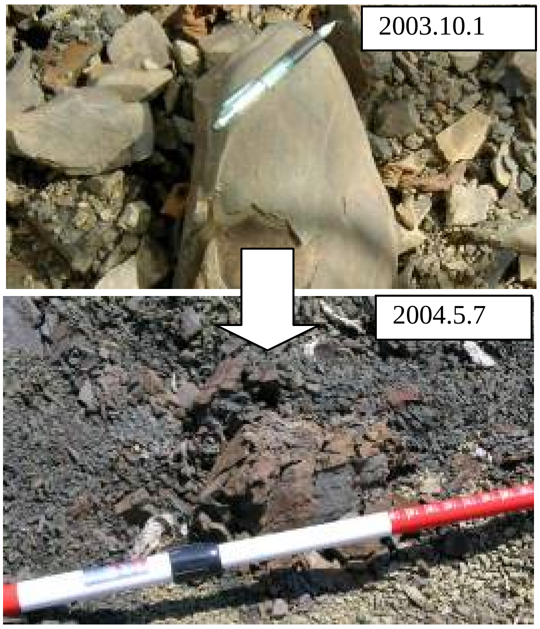

Fig.6 Natural slaking tendency at Toyonuka landslide site (indicated as red circle on Fig.3)

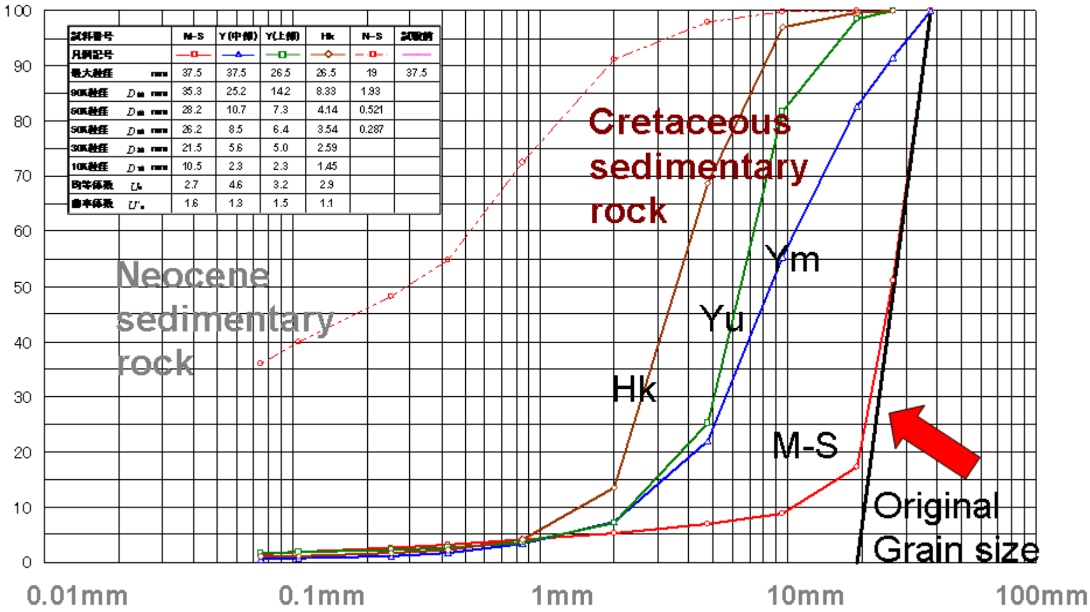

Fig.7 Grain size distribution change after the forced slaking test

Hakobuchi Group of Cretaceous sedimentary rock

Neocene sedimentary rock

Upper Yezo group of cretaceous sedimentary rock

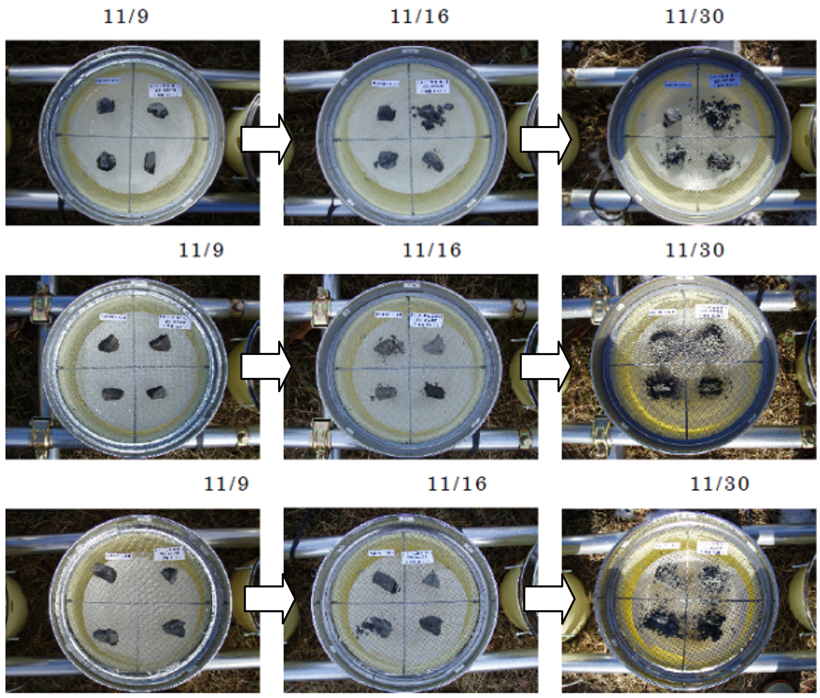

Fig.8 Open air slaking tendency test

of the Nukabira river basin, and a slaking ratio test is conducted after collecting unweathered bedrock. In this test, drying and wetting of bedrock was repeated 5 times by drying for 24 hours at 110°C, cooling to ambient temperature and immersing in room-temperature water for 24 hours. The test was conducted in accordance with the criteria of the previous Japan Highway Public Corporation (JHS110). After the slaking test, grain-size distribution is also examined. Samples are collected from unweathered mudstone-based bedrock of five geological conditions, Cretaceous sedimentary rock (Yezo Supergroup of upper and middle layer(Yu,Ym), Hakobuchi group(Hk)), Neocene sedimentary rock(N-S), and accretionary complex (Paleogene to Cretaceous periods (M-S)). Fig.7 shows the tendency of grain refinement from the original grain-size distribution. The results indicated that most strong grain refinement was shown as Neocene sedimentary rock, Cretaceous Hakobuchi Group and the Yezo group are followed this. The accretionary complex sample was the least susceptible to weathering. In other words, the slaking rate was higher in younger geological sections (in the order of N-S, Hk, Yu, Ym and M-S). The youngest geology of N-S (Neocene) had lost its original rock form almost completely.

An exposure slaking test was conducted in atmospheric conditions by preparing a simple test device to measure the time taken for the unslaked bedrock to progress under natural conditions. Although there was a possibility that the results were affected not only by drying and wetting but also by freezing, weathering began as early as the one-week point for samples of unweathered bedrock exposed to the atmosphere, and slaking to an extent of several millimeters or less was observed after just three weeks (Fig. 8). Although no slaking occurred in some types of bedrock during the test period of approximately one month, continuous observation is thought to be necessary.

CONCLUSIONS

From the results of field survey and interpretation of airborne laser altimetry based RRIM and bedrock slaking tests, the sediment yield characteristics of the study stream of the Saru river watershed can be summarized as follows;

(1) Cretaceous sedimentary rock zone is formed relatively gentle hills and with many rotational landslides. When the bedrock exposed to the atmosphere and affected by drying and wetting, materials are easily slaking in a week. That means sediments are continuously produced like pebbles without landslides.

(2) Accretionary complex zone is formed relatively steep slopes, and the bedrock is made from hard materials, including greenstone consisting largely of basalt lava, pillow lava and chert. Slaking tendency is very low.

(3) Airborne laser altimetry is effective tool for understanding the sediment yield characteristics in diverse geological conditions.

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