Crushed Rock Mass in Landslide Body of the Cretaceous Sedimentary Rocks

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Abstract

We have got an opportunity to observe the cutting slope of a massive landslide body of the Cretaceous sedimentary rocks. Various rock masses, which have been deformed, crushed or rotated by the past landslide movement, appear inside of the landslide body. As a result of the observations, distribution and characteristics of crushed rocks possibly results from the geologic structures such as bedding or joint planes and the extent or progress of landslide movement. Therefore, it is effective to investigate how the geologic structures have remained, continued or changed in order to analyze landslide mechanisms. It is important to survey and examine carefully about distribution and characteristics of crushed rocks along bedding planes especially if stratified rocks had been continuously distributed like in this area.

Keywords: landslide body, observation at slope, characteristics of crushed rocks

1. Introduction

It has been reported that landslide bodies consist of not only randomly crushed rocks but also fault rocks in some case (Wakizaka et al.,2012). When to discriminate between landslide bodies and basement rocks geologically, it is important to examine carefully about quality and continuity of geological fracture based on rock types and geological structure of it.

We have got an opportunity to observe the cutting slope of a massive landslide. Various rock masses deformed, crushed and rotated by the past landslide movement were found inside of the landslide body. Then we report the correspondence of the crushed rock mass with geological structure and notes of observation at outcrops and borehole core.

2. General information of the landslide

The landslide of this report is facing southwest along the Koutou River in Kagawa prefecture, Japan. Basement rocks of the landslide consist of mainly sandstone and shale in the Cretaceous Izumi Group. Layers are tilting towards slightly upstream side to the bedding plane dipping 30 ～ 40° at south or southeast. The size of the landslide is geographically estimated about 300m long and 200m wide (Fig. 1). About twenty cores were drilled into the landslide body (Seven of them were high-quality cores). Rocks inside the landslide body tend to be broken into some blocks caused by many cracks along bedding and joint planes. And some shale layers along bedding planes are accompanied by several centimeters thick clay.

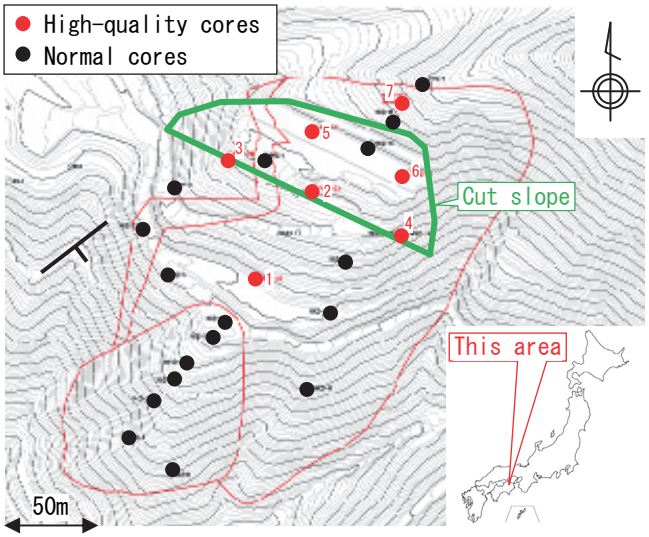

Fig. 1 Location map of the slope and borings

3. Observation at the cut slope

At the slope cutting through the landslide body about 100m long and 50m high, we observed geology and geological structure and to classify grade of crushing (Fig. 2, Photo 1～4, Table. 1).

Shale, sandstone, tuffaceous shale and tuff are mainly distributed on the slope. There are some slip surfaces ① ～ ③ which are formed along bedding planes inside the landslide body. Rock masses between each slip surfaces appear different grade of crushing, which tend to more crushed

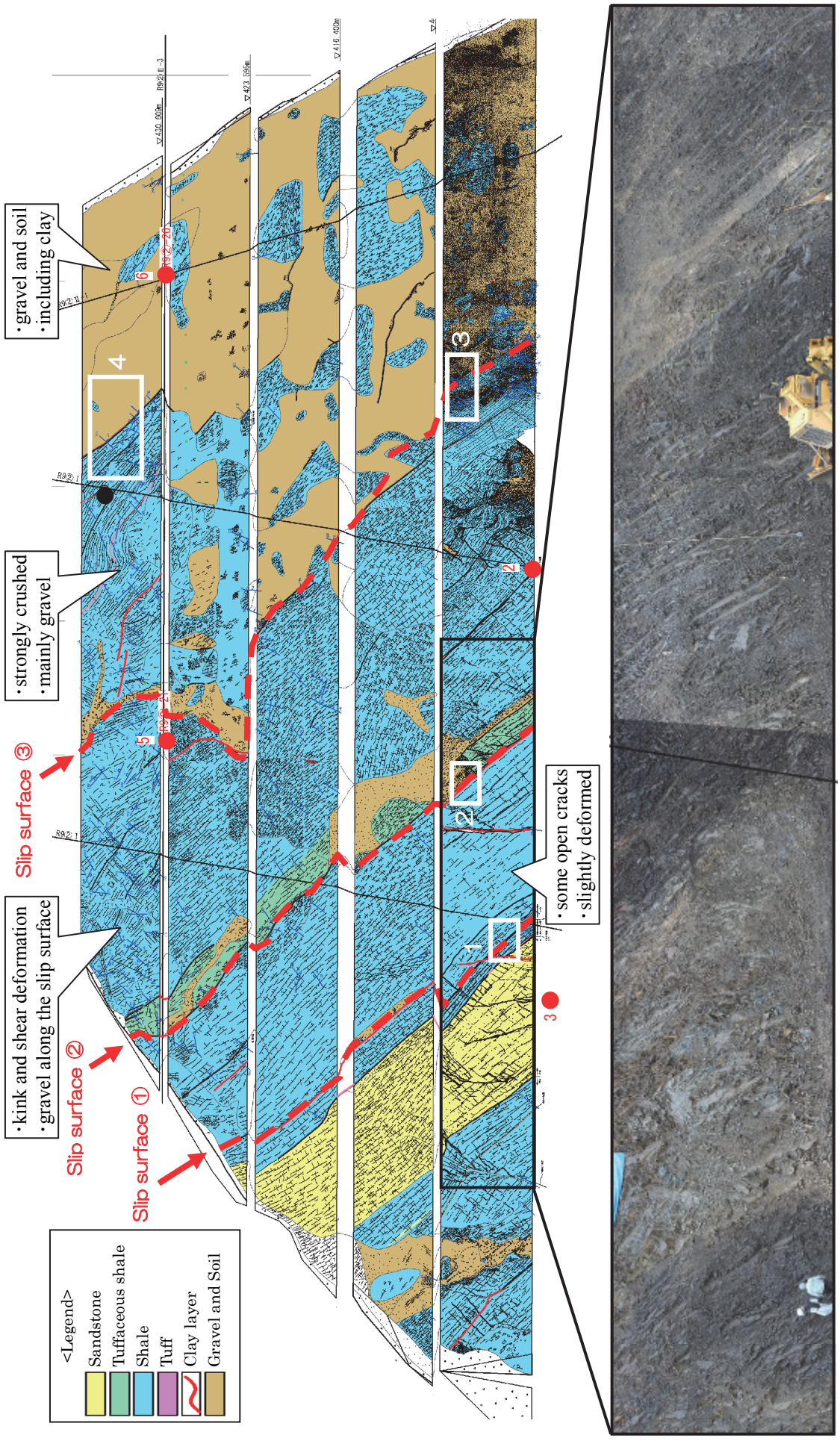

Fig. 2 Outcrop of the slope (showing the landslide bodies)

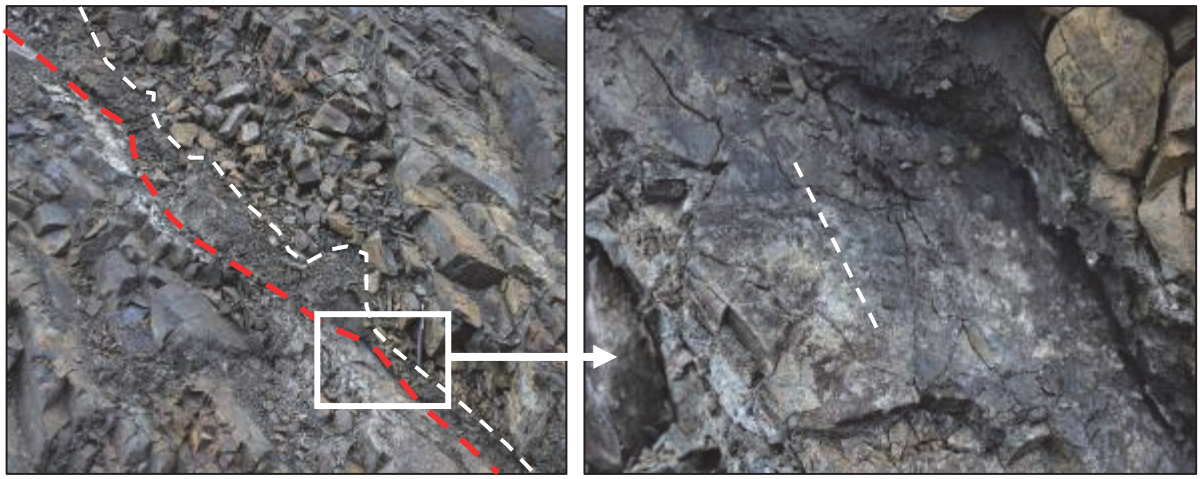

Photo. 1 Slip surface ①

Almost 15 centimeters thick clay layer is distributed. There are some linear marks caused through shearing processes, called slickenside.
Bedding: N55°E42°S, Linear marks: S11°W32°

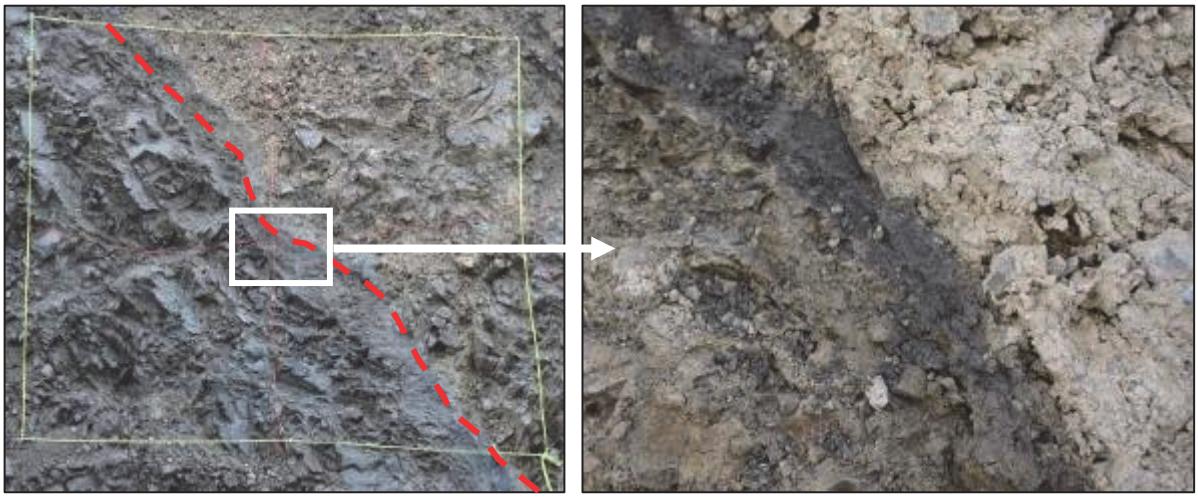

Photo. 2 Slip surface ②

Almost 5 centimeters thick black clay is underlain by crushed rock (Cr3 grade). The slip surface is harmonic with bedding planes. Tuffaceous shale rocks have been crushed into block and gravel.
Bedding: N57°E34°S, Linear marks: S47°W7°

<Legend>
Cr1a
Cr1b
Cr2
Cr3
Cr4
Cl

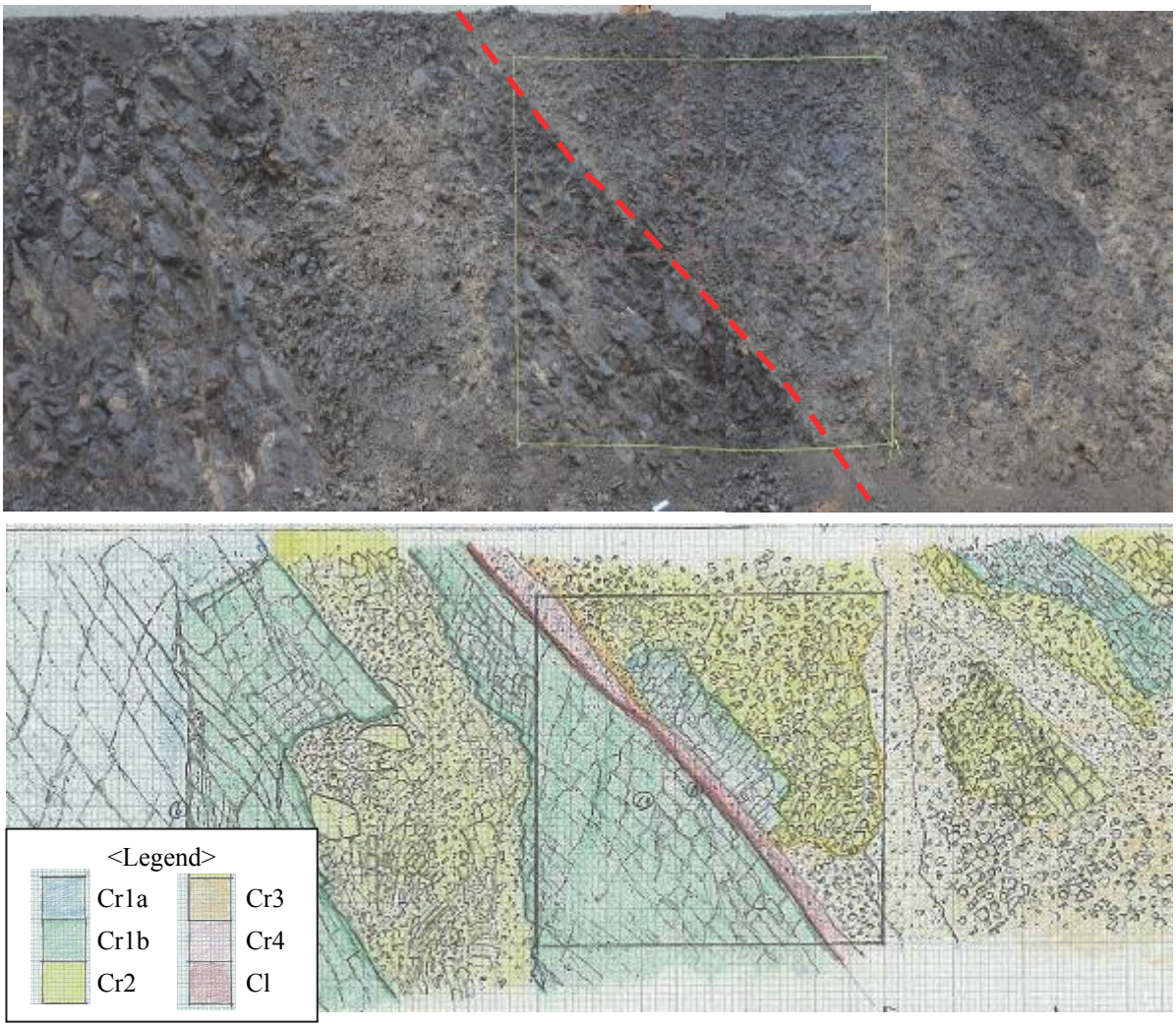

Photo. 3 Slip surface ③

Strongly crushed shale rocks are distributed at upstream area. The slip surface is partially harmonic with bedding planes.

Photo. 4 Boundary of the shale layer

Some clay layers are intermittently distributed along the layer.

toward upstream side corresponding to upper layer. Moreover, rotated rock lumps, kink and shear deformation by landslide moving along bedding plane have been found as grade of crushing increase.

Characteristics of slip surface ① ～ ③ are shown below (Table. 1).

Table. 1 Characteristics of slip sufaces

Slip surface	Characteristics (on outcrops of the slope)
①	・clay layer distributed within shale just upper layer of sandstone ・almost 15centimeters thick ・slightly deformed shale rocks ・harmonic with bedding planes
②	・clay layer distributed between shale and tuffaceous shale ・ including black clay, several centimeters thick ・crushed tuffaceous shale rocks into block and gravel ・harmonic with bedding planes
③	・gravel and soil layer within shale ・ strongly crushed shale rocks at upstream area ・ partially harmonic with bedding planes

4. Notes of observation at borehole core

We compared high-quality cores No.5 and 2 (Table. 2, Photo. 5～10) with outcrops of the slope. Then we considered about notes of observation at borehole cores.

4.1 Characteristics of borehole cores

Shale, tuffaceous shale and sandstone are mainly distributed under boring No. 5. The tuffaceous shale ranges in depth from around 14 to 16 meters. And the range of sandstone extends from the depth around 28 to 37 meters. In terms of grade of crushed rocks, the upper layer of tuffaceous shale is slightly deformed to the grade of Cr1a or Cr1b with some open cracks, partially crushed to the grade of Cr2 as brecciated rock having the maximum particle diameter of around 20 millimeters. On the other hand, rocks in the lower layer of tuffaceous shale are rarely deformed and rotated with few oxidized cracks. Almost all the rocks of this layer remain the grade of Cr1a or never crushed, including several centimeters thick crushed zone with some planer structures.

As the same situation as No. 5, grade of crushed rocks of boring No. 2 seems to be changed at the border of tuffaceous shale that extends in the depth around 20 meters. Rocks in the lower layer of tuffaceous shale are rarely deformed and rotated, including thin crushed zone.

4.2 Common characters of slip surfaces

We considered about common features of lithofacies, grade of crushed rocks and slip surface of ① and ② existing in borehole cores, focussing on the depth of boring No. 5 and 2 by the strike and dip of bedding planes on the slope.

<Slip surface ①>

・Boring No.5 : the depth of around 25 meters
・Boring No.2 : the depth of around 33 meters
・The slip surface is distributed around the upper part of sandstone.
・It occurs as several centimeters thick crushed zone with some planer structures.
・Rocks of just upper and lower layer of the slip surface remain the grade of Cr1a or never crushed.

<Slip surface ②>

・Boring No.5 : the depth of around 15 meters
・Boring No.2 : the depth of around 20 meters
・The slip surface is distributed around the lower part of tuffaceous shale.
・Rocks around the slip surface are crushed to the grade of Cr2 or Cr3.
・The contrast between upper and lower side of grade of crushed rocks is viewed quite clearly.

Compared with the features of slip surfaces on outcrops of the slope, the features of slip surfaces in borehole cores seems to be less crushed in general.

4.3 Evaluation of the probability of slip surfaces

It has been quite difficult to discriminate landslide bodies especially like as slip surface ① from fault rocks only by the previous method of observation at borehole cores. Then it will be helpful to evaluate of the probability of slip surfaces by careful examination about quality and continuity of geological fracture.

(1) As geological features in this area, relatively continuous planes are distributed. And it is effective to examine about distribution of them. Layers of sandstone and tuffaceous shale are thought to be a factor of parting top and downstream side of the landslide. Because shale is softer than another rocks in this area, a crushed zone has been easily formed around boundaries between shale and another rocks. Surveys about factors of parting bottom and upstream side of the landslide are in progress.

(2) It is important to examine about quality and continuity of geological fracture especially along bedding planes. A slip surface is thought not to be wholly crushed in early stages that total displacement of the landslide has been very small. Slip surfaces in this case are easy to be evaluated fault rocks by mistake because there is some possibility that some planer structures are

Table. 2 Grade of crushed rocks of the outcrop of the slope and borehole cores

Grade	Characteristic	Outcrop of the slope	Borehole Cores
Cr1a	・some open cracks ・very little oxidized ・very small amount of sand and soil along cracks ・slightly deformed		 No.5 26.10-26.25m
Cr1b	・some open cracks ・slightly oxidized ・filled with sand and soil along cracks ・slightly deformed		 No.2 30.75-30.90m
Cr2	・mainly gravel ・5 ～ 30mm or larger in diameter ・clearly rotated and shear deformation		 No.2 20.70-20.85m
Cr3	・gravel and soil ・about 5 ～ 10mm in diameter ・strongly crushed ・wet and soft soil		 No.1 21.80-22.00m
Cr4	・mainly soil ・about 1 ～ 5mm in diameter ・strongly crushed ・wet and soft soil		 No.1 35.50m
Cl	・mainly clay ・including sand and silt ・spring water comes out sometimes in the rain		 No.2 5.40m

Photo. 5 Borehole core No. 5

・slightly deformed to the grade of Cr1a or Cr1b with some open cracks
・partially crushed to the grade of Cr2 as brecciated rock having the maximum particle diameter of around 20 millimeters

Photo. 6 Borehole core No.5 (GL-15m)

・the slip surface is distributed around the lower part of tuffaceous shale
・rocks around the slip surface are crushed to the grade of Cr2 or Cr3

・rarely deformed and rotated with few oxidized cracks
・almost all the rocks of this layer remain the grade of Cr1a or never crushed

Photo. 7 Borehole core No.5 (GL-25m)

・several centimeters thick crushed zone with some planer structures

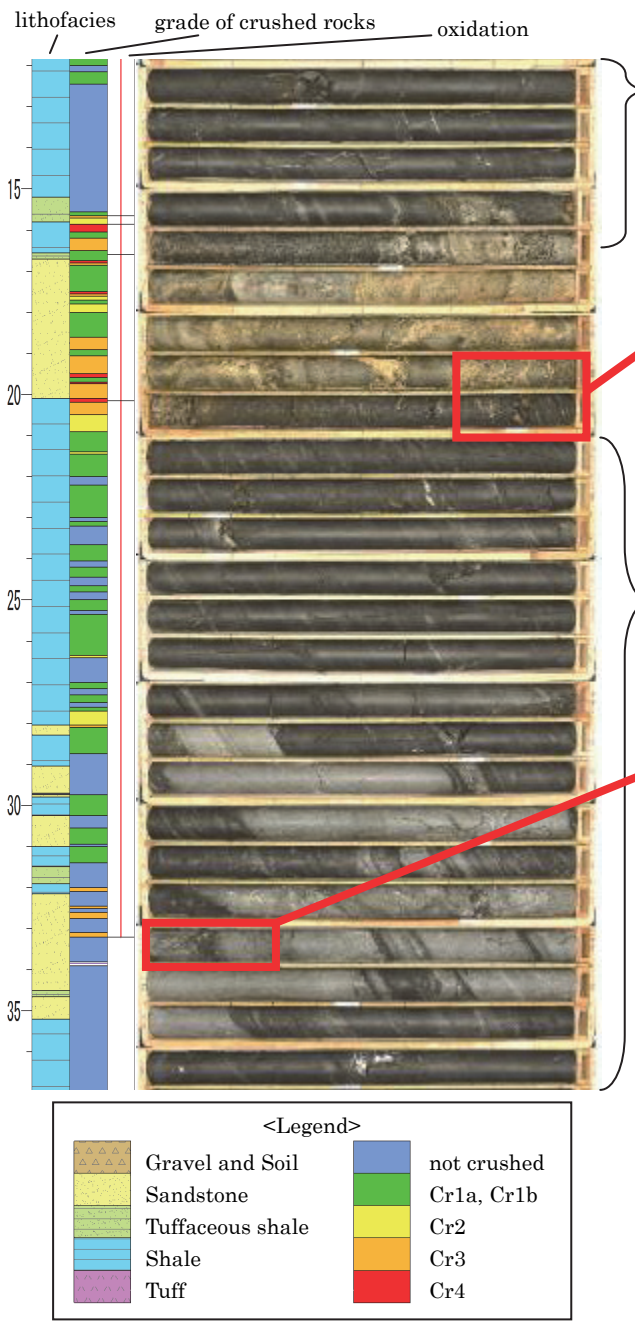

Photo. 8 Borehole core No. 2

included in slip surfaces and landslide bodies. Therefore it is necessary to examine about quality and continuity of geological fracture by observing more than one borehole core. In addition, it is quite important to analyze about consistency between topographic features and grade of crushed rocks, considering about generation and development of the landslides.

Some slight displacements have been recorded at the depth of slip surface ① or ②. Surveys about the mechanism of the landslides are in progress, keeping the previous mentioned notes in mind.

・the grade of Cr1b with some open cracks

Photo. 9 Borehole core No.2 (GL-21m)

・crushed to the grade of Cr2-3 as brecciated rock having the maximum particle diameter of around 10 millimeters

・almost all the rocks of this layer remain the grade of Cr1a or never crushed

Photo. 10 Borehole core No.2 (GL-33m)

・crushed zone with some planer structures

5. Conclusions

As a result of the observations, there is a possibility that influence of crushing such as bedding or joint planes and the progress and extent of landslide movement appears on distribution and characteristics of crushed rocks. Therefore, it is effective to considerate about continuity of the previously mentioned geological factor for analyzing mechanism of landslides. It is important to survey and examine carefully about distribution and characteristics of crushed rocks along bedding planes especially if relatively continuous planes had been distributed like in this area.

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References

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