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Fractured Zone Type Landslide and Electrical Resistivity Survey — 2 —

(Information obtained from electrical resistivity survey)

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Abstract

The usefulness of the electrical resistivity survey in Fractured zone type landslide areas was examined at the Chōja and Wada landslide areas in Kōchi Prefecture having many similar landslide characteristics. From the results it was clarified that the electrical resistivity survey could be applied to Fractured zone type landslide areas as well as to the Tertiary type, and that much informations on the investigated landslide areas could be obtained by the electrical resistivity survey.

The author conducted electrical resistivity surveys at many other Fractured zone type landslide areas in Kōchi Prefecture in order to thoroughly test and to examine Fractured zone type landslide areas from information obtained by the electrical resistivity survey.

From the results of this investigation and study the following information was obtained.

1. From the assumed diagram of the underground structure.
   a. Outline of the underground structure of the investigated landslide area.
   b. Approximate information on the form and existing depth of the bedrock surface and slide surface.
   c. The landslide area can be divided into blocks on account of the landslide area's topographical map which plotted the discontinuity belts of the resitivity values from the assumed diagrams of the underground profile.
   d. Even if the bedrock exists so deeply that the existing depth of bedrock can not be estimated by the electrical resistivity survey, the shallow slide layer which caused damaged to fields and houses may be sufficiently detected.
2. From the analyzed results of the horizontal electic profiling.
   a. It is assumed that the distributed areas of the low apparent resistivity values belong to one of following areas; an area of existing abundant underground water, an activity area of present landslide movement, a weathering promoting area of landslide soil mass or an existing area with possibility of producing landslide in the future.
   b. Containing the distributed area of low apparent resistivity values and discontinuity belts of the resistivity values which are obtained from the assumed underground structure, the landslide area can be divided into blocks, these blocks having importance in the case of landslide movement.

1. Introduction

The usefulness of the electrical resistivity survey at the Fractured zone type landslide was examined taking the Chōja and the Wada landslide areas in Kōchi prefecture, these having many similar landslide areas as examples.[1] From the results applicable it was made clear that the electrical resistivity survey was at both the

Fractured zone type landslide area and at the Tertiary type much useful information was obtained concerning these areas. The author therefore carried out the electrical resistivity survey at other Fractured zone type landslide areas in Kōchi Prefecture, thouroughly investigating this method and examining the information.

2. On the landslide areas in Kōchi Prefecture

Landslide areas which were designated as landslide preventive areas existed at 65 areas in Kōchi Prefecture (1965). The greater part of these aresa were investigated by Dr. Tochigi who was a professor of Kōchi University.[2] From the results, the greater part of the landslide areas in Kōchi Prefecture were shown to exist in the Fractured zone of the Paleozoic, and distributed from the ENE to the WSW direction of the north part of the prefecture. Divided geologically, those divided into landslide areas belonging to the Sambagawa crystalline schist zone, areas belonging to the Mikabu green rocks zone and areas belonging to the Chichibu terrain. Examining these in detail, the Sambagawa crystalline schist zone was divided into the Sambagawa proper of the north part, the Kiyomizu tectonic zone of the central part and the Sambagawa south shore zone which was strongly metamophied, of the south part. Generally, the landslide area in the Sambagawa crystalline schist zone distributed mainly in the black schist zone and did not distribute very much in the green schist zone. Comparing between the characteristics of landslide areas distributing in the three divided zones, the Kiyomizu tectonic zone and the Sambagawa south shore zone have a higher distrbuting density of landslide areas than the Sambagawa proper, and have a larger scale than the Sambagawa proper. The landslide areas which distribute in the Kiyomizu tectonic zone and the Sambagawa south shore zone are malignant landslides giving rise to more damage than the landslide areas which distributed in the Sambagawa proper. In the landslide areas which distribute in the Sambagawa crystalline schist zone, the boundary between the landslide area and nonlandslide area is not as clear as the landslide areas which distribute in the Mikabu green rocks zone.

The Mikabu green rocks zone is on the south of the Sambagawa south shore zone. This zone has many landslide areas. Especially, the distributed areas of agglomerate-green rock, phyllite-green rock and tufficious-green rock. Comparing between the landslide areas which distribute in the Mikabu green rocks zone and the landslide areas which distribute in the Sambagawa crystalline schist zone, the former have a larger scale than the latter, on the movement form, the latter move intermittently, the former move slowly, mainly in and out of season. For this reason, in the landslide areas which distribute in the Mikabu green rocks, the boundary between the landslide area and non-landslide area is very distinct. On the face of land utilization, the land has many inclinated fields at landslide areas which distributed in the Sambagawa crystalline schist zone, on the other hand, in the landslide areas which distribute in the Mikabu green rocks, the land has many rice fields to a high elevation due to the following; abundant underground water exists to a very high altitude and the green rocks are very easily weathered by underground water. This is a specific characteristic of landslide areas which distributed in the Mikabu green rocks zone.

The Chichibu terrain is to the south of the Mikabu green rocks zone. This terrain has a strong relation to the Fractured zone type landslide but the distributed condition of landslide areas can be recognized as having a great difference at each zone in the terrain. The Chichibu terrain is divided into three zones by two large fault lines which run in the east-west direction. The landslide areas distribute mainly in the Kurosegawa tectonic zone which divides the north zone and the central zone and in the north zone on this tectonic zone. On the character of rocks, many landslide areas are in the distributed area of ultrabasic rocks (serpentine rock) inserted in clay slate or along the east-west fault line. (Fig. 1)

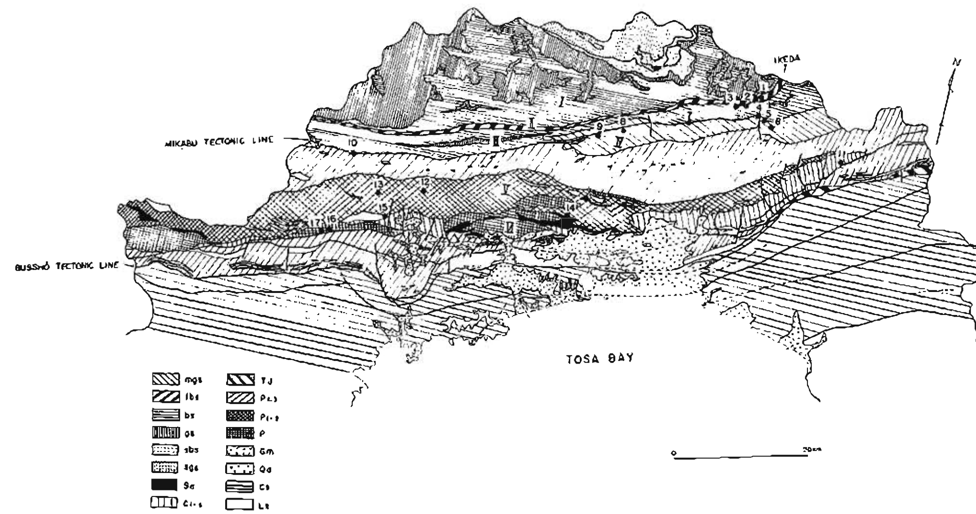

Fig. 1 Location of the investigated landslide areas.

I... Main zone of the Sambagawa crystalline schist zone
II... Sambagawa crystalline schist zone Kiyomizu tectonic zone
III... Sambagawa crystalline schist zone south shore zone
IV... Mikabu green rocks zone
V... Chichibu terrain north zene
VI... Cbichibu terrain Kurosegawa tectonic zone

1. Nagabuchi, 2. Kawai, 3. Nakauchi, 4. Wada, 5. Nishikawa, 6. Gotokukani, 7. Sugishimo, 8. Matsukino, 9. Tatewari, 10. Souzu, 11. Gooudo, 12. Taninouchi, 13. Tokoroyama, 14. Engyoji, 15. Kusugami, 16. Taketani, 17. Chōja. *mgs*... Mikabu green rocks, *fbs*... highly fissile black shcist (Kiyomizu tectonic zone), *bs*... formation mainly composed non-spotted black schist, *gs*... formation mainly composed of non-spotted green schist, *sbs*... formation mainly composed of spotted black schist, *sgs*... formation mainly composed of spotted green schist, *se*... serpentinete, C_{1-5}... Cretaceous, *T-J*... Otochi group, $P_{2,3}$, and P_{1-2}... Permian, *P*... Permian?, *Gm*... Mitaki igneous rocks, *Qa*... quatermary, *Cs*... Cretaceous (Shimantogawa group), *Ls*... limestone.

In landslides known as the Fractured zone type landslide area, from the difference of the geology there are many landslide areas which have a different movement, landslide scale, existent condition of underground water and utilization of land etc.. Therefore, in order to examine these differences, the difference in geology and rock types and the existing condition of underground water, are shown to exist from the results of the electrical resistivity survey. The electrical resistivity survey was carried out at as many landslide areas as possible.

The electrical resistivity survey was carried out at the following landslide areas.

Sambagawa crystalline schist zone Kiyomizu tectonic zone.....Nagabuchi

Sambagawa crystalline schist zone south shore zone.....Nakauchi, Kawai

Mikabu green rocks zone.....Tatewari, Nishikawa, Souzu, Gotokudanigawa, Wada, Sugishimo

Chichibu terrain north zone.....Tokoroyama, Taninouchi, Gooudou

Chichibu terrain Kurosegawa tectonic zone.....Chōja, Taketani, Kusugami, Engyouji

3. From the assumed underground structure shown by the electrical resistivity survey

In order to assume the underground structure of each landslide area, data obtained by the electrical resistivity survey which gave the ρa-a curves using standard curves and on the basis of the results the underground structure of each investigated landslide areas was assumed.

Fig. 2 compares the investigated results of boring which were carried out on the basis of the results from the electrical resistivity survey with the assumed underground structure by the above mentioned method. In this figure the wave formed lines show the location of the slide surface obtained from the results of the internal strain meters.

Utilizing this figure various aspects were examined comparing the underground structure assumed from the electrical resistivity survey with the assumed underground structure by the boring investigation.

In the former, it was made clear from observation of the internal strain meters that many slide surfaces were included in the slide layer assumed by the electrical resistivity survey. From this fact it was thought that the notion of slide layer adapted to the Tertiary type landslide areas was adapted to the Fractured zone type landslide area too.

In the latter, comparing the assumed bedrock depth by electrical resistivity survey with the confirmed bedrock depth by boring, the following facts were clarified: In cases were a deposit of mud flow was producing active landslide movement, as at present in the Gotokudanigawa landslide area, the assumed bedrock depth from the electrical resistivity survey was in accordance with the confirmed bedrock depth by the boring investigation. The assumed slide layer or slide surface depth were in accordance with the obtained slide layer or slide surface depth show by the internal strain meters. (Fig. 3) In cases were boundary and neighborhood between a clay layer with gravel or deposit of landslips and bedrock at a comparatively shallow depth was shown to be producing landslide movement as at the Kawai, Nakauchi, Tatewari, Wada, Chōja and Kusugami landslide areas. The assumed results by the electrical resistivity survey was in accordance with the confirmed results by the boring investigation and the observation of the internal strain meters in every landslide area. (Fig. 4) In cases were the bedrock was at a greater depth however (70–100 meters), and the deposit layer and weathered bedrock layer were very thick, it was difficult to estimate the depth of the bedrock by the electrical resistivity survey. (Fig. 5) But from the results of the internal strain meters in such landslide areas, and from the damage

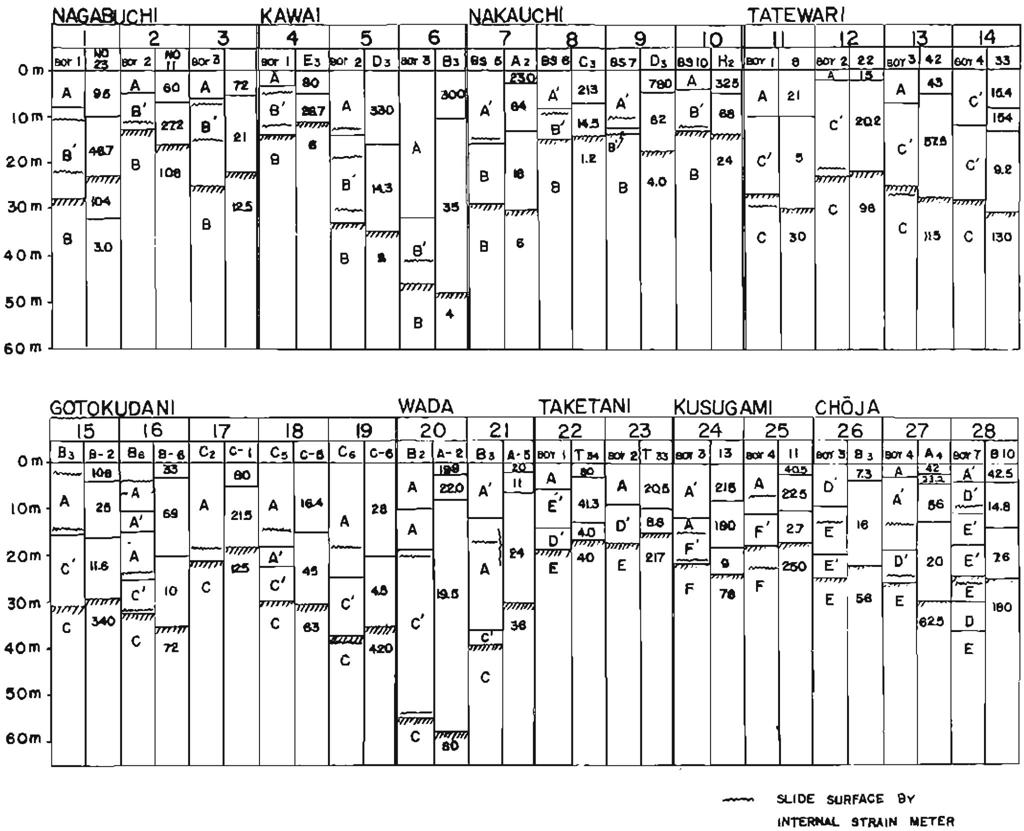

Fig. 2 Comparison of boring profile with the assumed underground structure from the electrical resistivity survey. (units of numbers = kΩ-cm)
A... clay with gravel or gravel with clay, A'... debris, B... non-weathering rock of crystalline schist rocks, B'... weathered material of crystalline schist rocks, C... non-weathering rock of green rocks, C'... weathered material of green rocks, D... non-weathering rock of serpentine, D'... weathered material of sperpentine, E...non-weathering rock of clay slate, E'... weathered material of clay slite, F... non-weathering rock of schalstein. F'... weathered material of schalstein,

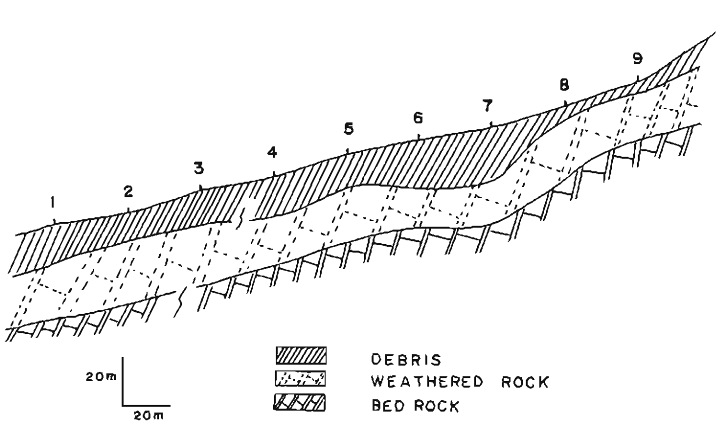

Fig. 3 Assumed underground structure of the Gotokukanigawa landslide area.

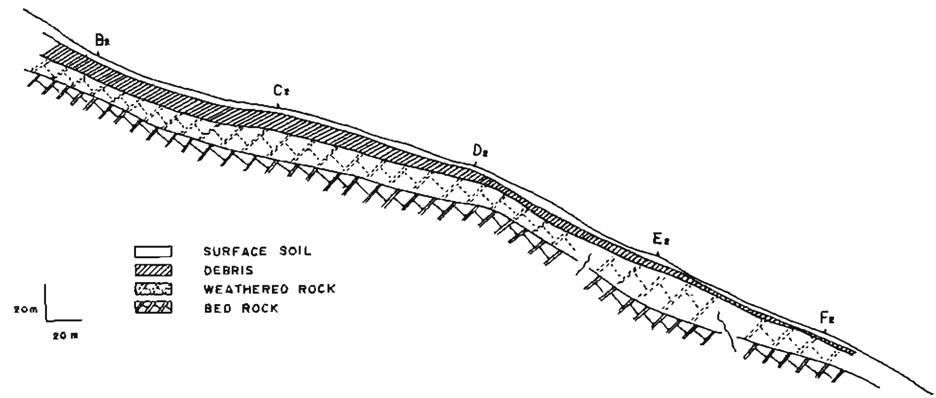

Fig. 4 Assumed underground structure of the Kawai landide area.

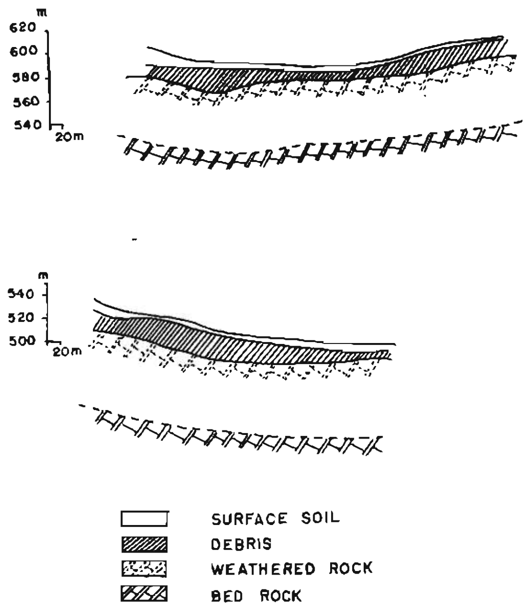

Fig. 5 Assumed underground structlure of the Nishikawa landslide area.

rate to farms and houses, it was considered that the shallow slide surface (boundary deposit layer and weathered bedröck layer) had a greater effect than the deep slide surface (boundary bedrock and weathered bedrock layer). It was indicated that the investigated results should be examined attaching importance to the shallow slide surface. Eventually the slide surface or slide layer giving rise to great damage to farms and houses, in practice existed in the deposit layer or in the weathered bedrock layer and even if the landslide area is seen on a large landslide topography, the landslide area actually consists of small scale landslide blocks and these small scale landslide blocks are producing landslide movement having a shallow slide layer or slide surface. The deep slide layer or slide surface, if it existed, did not moved rarely. Accordingly, it was shown that in such a landslide area the electrical resistivity survey can be used satisfactory if the focus shows the detection of a shallow slide layer or slide surface.

Making diagrams of the underground structure from the electrical resistivity survey in each landslide area, the discontinuity belts of the underground structure were shown to exist here and there in resistivity. (Fig. 6) The meaning of these dis-

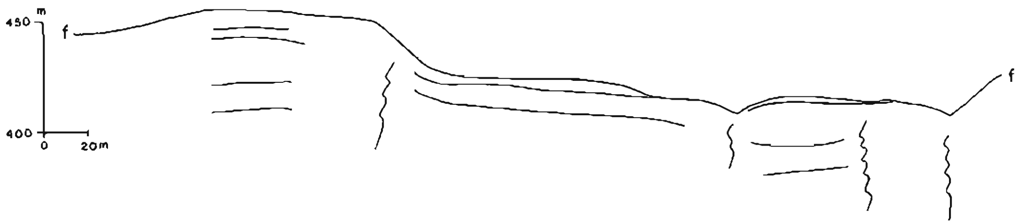

Fig. 6 Assumed underground structure of the Matsukino landslide area. (I)

continuity belts was not clear at each measuring line, but making an entry of the discontinuity belts which were obtained at each measuring line into the landslide topographical map and connecting the discontinuity belts, the landslide area was divided into blocks and each divided block had a specific meaning in the landslide area. The meaning was different at each landslide area and must be interpreted including the geological and topographical factors for each.

4. From the results of the horizontal electric profiling

There is a horizontal electric profiling as an expression of the results of the electrical resistivity survey. This is the method which examined the distributed condition of the apparent resistivity values for each depth.

Conducting this method at each landslide area and drawing the distributed diagram of the iso-apparent resistivity values at each electrode span, the distributed areas of the low and high apparent resistivity values were shown in one landslide area. It was confirmed in the Tertiary type landslide area that the distributed areas of low apparent resistivity values were the areas of abundant underground water, the more weathered area of landslide soil mass, or areas having the possibility of producing landslide movement in future.[3] Therefore on the assumption, that these facts can be adapted to the Fractured zone type landslide area, analysis by this method was conducted at each landslide area. From the results it was assumed that the distributed areas of low apparent resistivity values in the Tatewari, Wada and Chōja landslide areas, were areas of abundant underground water, and the matter was confirmed from the results of underground water collecting wells and drainage bore holes. It was assumed that the distributed areas of low apparent resistivity values in the Gotokudanigawa, Tokoroyama, Matsukino and Chōja landslide areas were active areas of landslide movement, and the matter was confirmed from the results of internal strain meters and ground surface movement. In other landslide areas it was assumed and confirmed that the distributed areas of low apparent resistivity values had the above-mentioned meaning.

From the results of horizontal electric profiling, some distributed areas of low apparent resistivity values were in one landslide area. Comparing these distributed areas therefore, with the discontinuity belts mentioned in section 3, a landslide area can be divided into several landslide blocks.

For example, at Matsukino landslide area belong to the Mikabu green rocks zone, the landslide soil mass consists mainly of a clay and gravel agglomerate-with phyllite-green rocks. Topographicaly, the landslide area is enclosed by mountains some 570 meters above sea level. The top edge of the landslide area is near the pass at 520 meters above sea level. On the other hand, the tip part of this landslide area is near to 310 meters above sea level, and the landslide soil mass exists in blocks between the top part and the tip. (Fig. 8) Both sides of this landslide area are distinguished by a steep slope and the landslide topography is very distinct. The whole area is utilized as rice fields.

Electrical resistivity survey was conducted in order to estimate the underground structure of this landslide area. From the results, shown in Fig. 7, there were some discontinuity belts at each cross section. Making the discontinuity belts into a landslide topographical map, the landslide area could be divided into three blocks A, B and C. (Fig. 8) In order to understand these blocks, the distributed diagrams of the iso-apparent resistivity values were drawn at each electrode span (a=2, 5, 10, 16, 20, 24, 30, 36, 42, and 50 meters). On the basis of these diagrams, the distributed diagram of low apparent resistivity values was given. (Fig. 9) From the results, there were five distributed areas of low apparent resistivity values in this landslide area of blocks 1, 2, 3, 4, and 5. Comparing Fig. 8 with Fig. 9, it was clear that each block was related to the next; Block A=Block 1, Block B=Block 2 and 3, Block C=Block 4 and 5. It was thought that each block had the following:

Block 1; this block is an abundant underground water. Because there are many spring points in this block and the lower part produced the flowing type slide weathering and weakening the landslide soil mass with underground water. This abundant underground water flowed along the north side of Block A and inflowed into Block C which was a deposit of mud flow.

Block 2; this block is like the surround Block B′ for the supplied underground water from the small crossing valley in the area. The underground water which supplied Block B′ from Block 2 assisted Block B′ in moving.

Block 3; this block is toward the south-east from Block B′ and does not move at present, but in the case of the weathering of the landslide soil mass by underground water from Block B′, this block will have the possibility of landslide movement in future.

Block 4; this block is in the west part of Block B′, supplying underground water from Block A and the small crossing valley. This block is weathered to a considerable depth.

Block 5; this block is toward the bottom of Block 1, and is weathered by underground water to a great depth flowing into and along the north side of the valley from Block 1.

From the above-mentioned it is thought that there are distributed areas of low apparent resistivity values of two kinds; one of these is created by underground water flowing down from the top of the landslide area, the other is created by underground water supplied from the small crossing valley at the center of the landslide area.

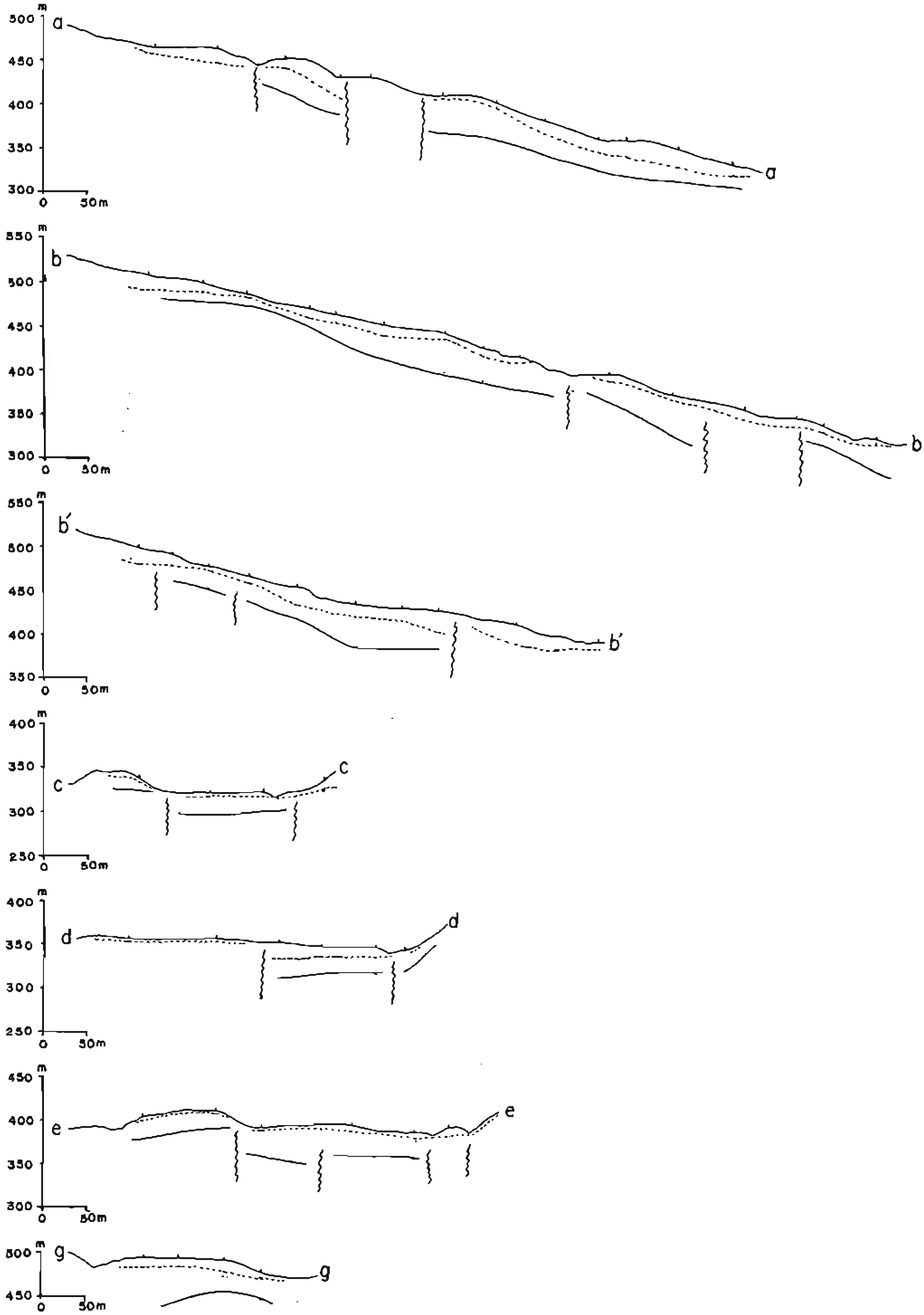

Fig. 7 Assumed underground structure of the Matsukino landslide area. (2)

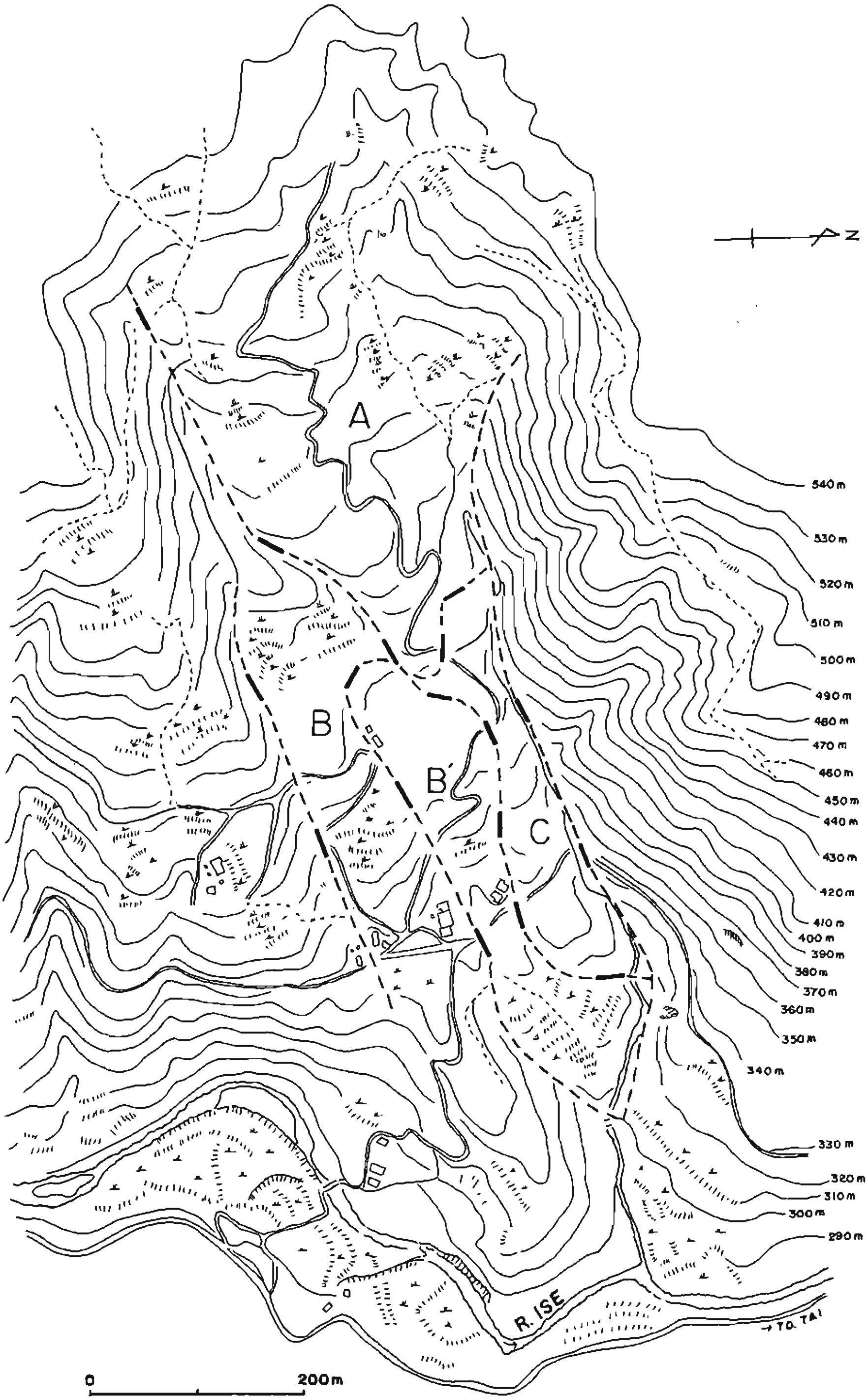

Fig. 8 Distributed diagram of the discontinuity belts at the Matsukino landslide area (block diagram obtained from Fig. 7).

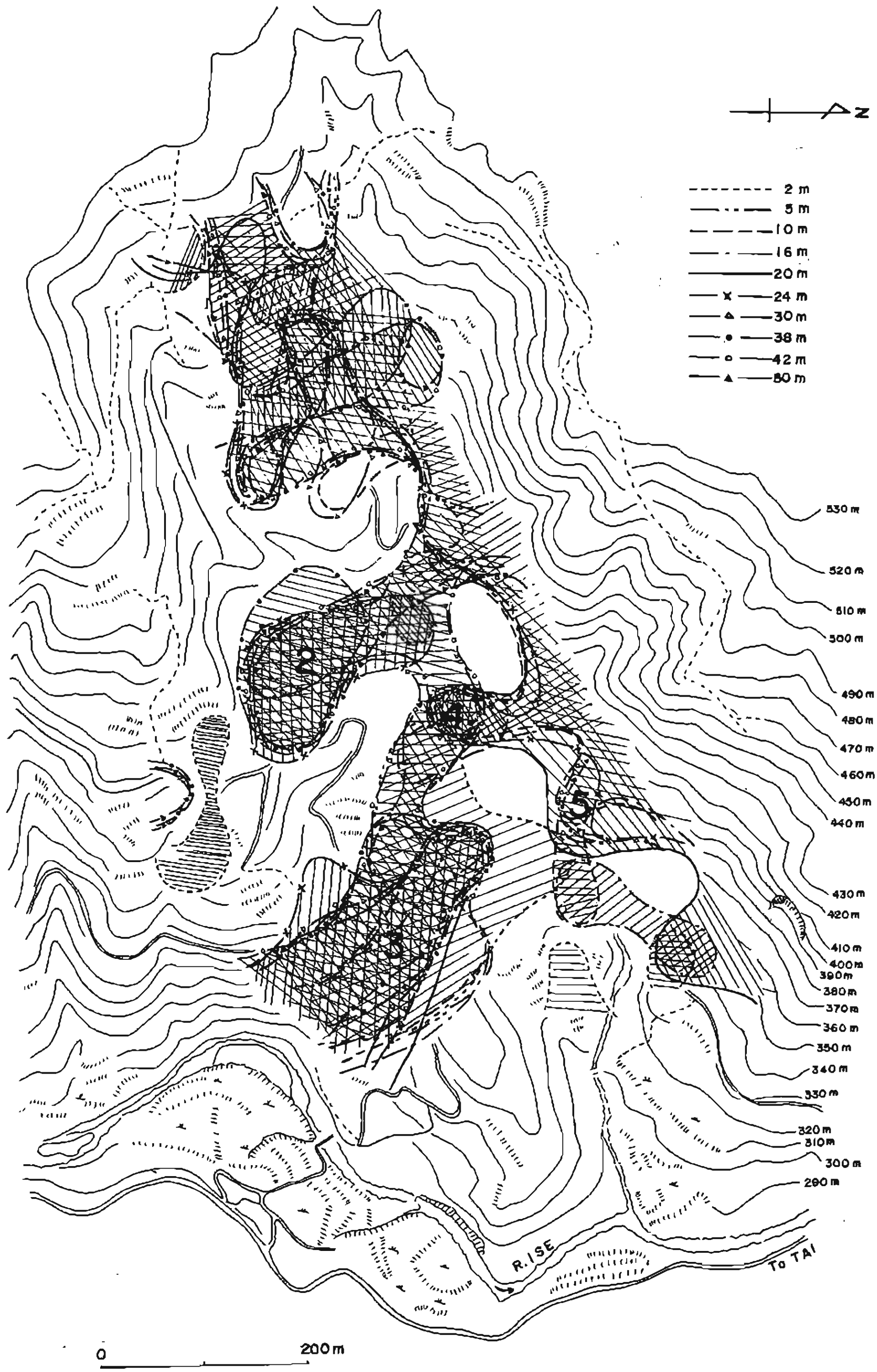

Fig. 9 Distributed condition of low apparent resistivity values at the Matsukino landslide area ($\rho a = 20$ kΩ–cm or less than 20 kΩ–cm).

5. Difference in resistivity values at each tectonic zone.

Table 1 was prepared in order to examine the difference in the resistivity values of the surface layer, slide layer and bedrock layer in the landslide areas between each tectonic zone. The resistivity values shown in this table are the average resistivity values obtained from calculations of the resistivity values including the one continuous layer in cross section. It seems to require examination that the resistivity values obtained by using the above-mentioned method were regarded as the general value of one layer. But here the general values for each layer were tentativley decided by this method. Using the obtained values examination was made disregarding the difference in the resistivity values between each tectonic zone. (Table 1) In this table the general boring profile of the landslide area beside the assumed general underground structure obtained by the electrical resistivity survey is shown.

As is evident from Table 1, it is recognized that the resistivity values for each layer are similar to landslide areas belonging to the same tectonic zone, but that resistivity values at each layer are different at landslide areas belonging to a different tectoneic zone. Comparing the resistivity values with the goelogy at each tectonic zone.

The landslide areas which belong to the Sambagawa crystalline schist zone Kiyomizu tectonic zone; the surface layer shows 105 kΩ–cm in resistivity values, and it consists mainly of debris. The slide layer shows 171 kΩ–cm in resistivity values and consists of clay with gravel of crystalline schist rocks. The bedrock layer shows 18 kΩ–cm in resistivity values and consists of the non-weathering rock of crystalline schist rocks.

The landslide areas which belong to the Sambagawa crystalline schist zone south shore zone; the surface layer shows 115.5～166.3 kΩ–cm in resistivity values and consists of debris. The upper slide layer shows 165.6～285.5 kΩ–cm in resistivity values and consists of clay with gravel crystalline schist rocks. The lower slide layer shows 35.7～71.1 kΩ–cm in resistivity values and consists of fractured matter of crystalline schist rocks. The bedrock layer shows 4.9～7.7 kΩ–cm in resistivity values and consists of hard and non-weathering rock of crystalline schist rocks.

The landslide areas which belong to the Mikabu green rocks zone; the surface layer shows 55.6～73.5 kΩ–cm in resistivity values and consists of green rocks debris. The slide layer shows 13.3～28.7 kΩ–cm in resistivity values and consists of clay of weathered green rocks. The bedrock layer shows 74.3～163.4 kΩ–cm in resistivity values and consists of hard and non-weathering green rocks. In order to determin the Chichibu terrain's rocks in the deep part of the Gotokudanigawa and Souzu, both landslide areas belonging to the south shore of the Mikabu green rocks zone, the resistivity values of the bedrock layer shows a value nearer to the resistivity values of the Chichibu terrain that to that of the Mikabu green rocks. The resistivity values of the surface layer at the Gotokudanigawa landslide area show a high value for mud flow deposit movement.

The landslide areas which belong to the Chichibu terrain north zone; the surface layer shows 98.8 kΩ–cm in resistivity values and consists of a clay layer with gravel of serpentine and clay slate. The slide layer shows 16.4 kΩ–cm in resistivity values and consists of weathered clay slate. The bedrock layer shows 371.7 kΩ–cm in resistivity values and consists of non-weathering rock of clay slate.

The landslide areas which belong to the Chichibu terrain Kurosegawa tectonic

Table 1. Comparison of the assumed general underground structure with the general boring profile at each landslide area.

Zone	Subzone	Name of the landslide area		surface layer	slide layer	slide layer	bedrock layer	utilization of ground
Sambagawa crystalline schist zone	Kiyomizu tectonic zone	Nagabuchi	A	105.0	171.0		18.0	field
			B	4–20	6–30		10–45	
			C	clay with gravel	weathered deposit of Quartz schist		non-weathering rock of quartz schist	
	south shore zone	Kawai	A	115.5	165.6	35.7	4.9	field
			B	6–10	10–20	10–30	25–40	
			C	clay with gravel	weathered deposit of black schist	fractured material of black schist	non-weathering rock of black schist	
		Nakauchi	A	166.6	285.5	71.1	7.7	field
			B	1–3	2–10	5–20	9–34	
			C	gravel with clay	clay layer with gravel of black schist	fractured material of graphite schist	non-weathering rock of graphite phyllite schist	
Mikabu green rocks zone		Tatewari	A	57.6	13.7		74.3	rice field
			B	1–22	1–35		5–40	
			C	debris of green rocks	weathered material of agglomerate-green rock		non-weathering rock of agglomerate-green rock	
		Nishikawa	A	55.6	16.2		125.6	rice field
			B	1–20	1–25		5–37	
			C	debris (green rocks)	weathered material of phyllite-green rock		a little fractured rock of green rocks	
		Matsukino	A	73.5	13.3		156.2	rice field
			B	2–25	8–40		10–50	
			C	debris (green rocks)	weathered material of green rocks		non-weathering rock of green rocks	
		Wada	A	71.7	19.7		163.4	rice field
			B	1–15	3–50		10–50	
			C	debris (green rocks)	weathered material and gravel of green rocks		non-weathering rock of green rocks	
	ancient mud flow	Gotokudanigawa	A	116.7	26.5		357.7	waste land
			B	2–30	2–25		30–40	
			C	debris (ancient mud flow) mainly green rocks	weathered material of green rocks		non-weathering rock of green rocks	
	south shore	Souzu	A	178.3	28.6		587.2	field and rice field
			B	5–20	10–50		20–50	
			C	debris (green rocks)	weathered material of phyllite-green rock		non-weathering rock of clay slate	
Chichibu terrain	north zone	Tokoroyama	A	98.7	16.4		371.7	field
			B	4–25	2–30		more than 20–25	
			C	weathered material of serpentine and clay slate	weathered material of clay slate		non-weathering rock of clay slate	
	Kurosegawa Tectonic zone	Taketani	A	131.2	17.4		357.0	field
			B	4–13	1–20		6–30	
			C	debris of serpentine and clay slate	weathered material of serpentine		non-weathering rock of clay slate	
		Engyōji	A	281.6	27.4	7.2	390.3	field
			B	1–16	1–20	6–37		
			C	debris	clay with gravel of sand-stone and clay slate	weathered material of serpentine	non-weathering rock of clay slate	
		Chōja	A	67.6	16.0		63.7	field
			B	2–15	3–30		7–30	
			C	clay layer with gravel of serpentine and clay slate	weathered material of serpentine and clay slate		non-weathering rock of clay slate	
		Kusugami	A	137.1	31.1		4.5	field
			B	3–18	6–30		23–35	
			C	debris (schalstein)	weathered material of schalstein		non-weathering rock of schalstein and serpentine	

A.....general values of the resistivity (unit of numbers = kΩ-cm),
B.....thickness of each layer, and depth of bedrock surface in the section of the bedrock layer (unit of numbers = meters),
C.....general geology obtained by boring profile.

zone; the surface layer shows 67.6~281.6 kΩ-cm in resistivity values and consists of clay with gravel of serpentine and clay slate. The slide layer shows 16.0~27.4 kΩ-cm in resistivity values and consists of clay of the weathered serpentine and clay slate. The bedrock layer shows 357.0~390.3 kΩ-cm in resistivity values and consists of non-weathering rock of clay slate. However the bedrock layer of the Chōja landslide area shows low resistivity values of 67.3 kΩ-cm because the bedrock layer consists of little fractured clay slate. The Kusugami landslide area which belongs to the Kurosegawa tectonic zone is different geologically from the other landslide areas which belong to the same tectonic zone, the difference therefore appearing in the resistivity values. The surface layer shows 137.1 kΩ-cm in resistivity values and consists of debris (clay and gravel of schalstein). The slide layer shows 31.3 kΩ-cm in resistivity values and consists of clay of the weathering schalstein. The bedrock layer shows 4.5 kΩ-cm in resistivity values and consists of the hard and non-weathering rock of serpentine and schalstein.

Table 2 shows the above mentioned collectively.

The author divided four groups of Fractured zone type landslide areas in resistivity values as shown in Table 2.

A type; the landslide area which belong to the Sambagawa crystalline schist zone are included in this type. Surface layer — slide layer — bedrock layer consist of L — LL —(M)— SS in resistivity values and with debris — clay layer with gravel of crystalline schist rocks — non-weathering layer of crystalline schist rocks in geological face. A type is divided into A_1 and A_2.

B type; the landslide areas which belong to the Mikabu green rocks zone are inclued in this type. Surface layer — slide layer — bedrock layer consist of M — SS — L in resistivity values and with debris of green rocks — clay of the weathered green rocks — non-weathering rock of green rocks on the geological face.

C type; the landslide areas which belong to the Chichibu terrain north zone and Kurosegawa tectonic zone are included in this type. Surface layer — slide layer — bedrock layer consist of L (LL)— S (SS)— LL in resistivity values and with clay layer with gravel of serpentine and clay slate — clay of the weathered serpentine and clay slate — non-weathering rock of clay slate on the goelogical face. C type is divided into C_1 and C_2.

D type; some landslide areas belonging to the Chichibu terrain Kurosegawa tectonic zone are included in this type. Surface layer — slide layer — bedrock layer consist of L — S — SS in resistivity values and with debris — clay of the weathered schalstein — non-weathering rock of serpentine and schalstein.

As in Table 2, the resistivity values of bedrock layer show very different values for each rock even in same Fractured zone type landslide area. Accordingly, in cases of the interpretation on the assumed underground structure which was obtained by the electrical resistivity survey, it is necessary to observe the geological condition of the investigated landslide area sufficiently before the electrical resistivity survey is carring out. Moreover, in each type ,when the bedrock was weathered, there are two kinds of variation in the resistivity values. One of these, as seen in A and D types, the resistivity values of the weathered bedrock increase more than the values of the bedrock. The other of these, as seen in B and C types, the resistivity values of the weatherd bedrock decrease rapidly less than the values of the bedrock.

It is clear that a sharp difference exists in the resistivity values from the difference

Table 2. Relation between the resistivity values and the geology at landslide areas which belong to each tectonic zones

Tectonic zone	Surface layer	Slide layer	slide layer	bedrock layer	classification by the electrical resistivity survey
Sambagawa crystalline schist zone Kiyomizu tectonic zone	L	LL		SS	A_1 } A
	(debris of crystalline schist rocks)	(clay layer with gravel of crystalline schist rocks)		(non-weathering rock of crystalline schist rocks)	
Sambagawa crystalline schist zone south shore zone	L	LL	M	SS	A_2 } A
	(debris of crystalline schist rocks)	(clay layer with gravel of crystalline schist rocks)	(fractured material of crystalline schist ricks)	(non-weathering rock of crystalline schist rocks)	
Mikabu green rocks zone	M	SS		L	B
	(debris of green rocks)	(weathered layer of green rocks)		(non-weathering rock of green rocks)	
Chichibu terrain north zone	L	S		LL	C_1 } C
	(clay layer with gravel of serpentine and clay slate)	(weathered layer of serpentine)		(non-weathering rock of clay slate)	
Chichibu terrain Kurosegawa tectonic zone A	LL	SS		LL	C_2 } C
	(clay layer with gravel of serpentine and clay slate)	(weathered layer of serpentine)		(non-weathering rock of clay slate)	
Chichibu terrain Kurosegawa tectonic zone B	L	S		SS	D
	(debris of schalstein)	(weathered layer of schalstein)		(non-weathering rock of schalstein and serpentine)	

LL, L, M, S, SS.....degree of general resistivity values.
LL.....more than 150 kΩ-cm, L.....150–100 kΩ-cm,
M.....100–50 kΩ-cm, S.....50–20 kΩ-cm,
SS.....less than 20 kΩ-cm.
( ).....general geological condition of each layer.

of the geology and rocks in the same Fractured zone type landslide areas and that there are two kinds of variation in the resistivity values when the bedrock is weathered. Some of these facts can not always be explained by the difference in the rocks and geology and the relation between rocks and the underground water.

6. Summary

Carring out the electrical resistivity survey in the Fractured zone type landslide area and the usefulness of such a survey has been examined in various ways. From the results it is clear that the electrical resistivity survey offers much useful information concerning landslide areas.

A. The following information is obtained from the assumed underground structure of the investigated landslide area.

1. An outline of the underground structure of the landslide area can be determined.
2. Fairly exact information can be obtained on the existing depth of the bedrock surface and the slide surface. Especially, when the bedrock surface is at a shallow depth or the different rock characteristics existent between the bedrock and the slide layer.
3. When the bedrock layer is at a very great depth, it is very difficult to estimate the existing depth by using the electrical resistivity survey. But the shallow slide layer or slide surface which give great damage to fields and houses can be sufficiently detected.
4. The discontinuity belts of the underground structure in resistivity values can be divided into blocks of the investigated landslide area by making the belts into a landslide topographic map.

B. The following information is obtained from the results of the horizontal electric profiling in the investigated landslide area.

1. It is assumed that the distributed areas of low apparent resistivity values belong to one of the following areas; an area of abundant underground water, an activity area of landslide movement at present, a weathering promoting area of a landslide soil mass or an area of which may produce landslide movement in future. It is necessary to assumed carefully which areas belong to the distributed areas of low apparent resistivity values considering topographical factors, geological factors, other investigated results and each landslide phenomena in the investigated landslide area.
2. Combining the distributed areas of low apparent resistivity values and the discondinuity belts of the resistivity values which are obtained from the assumed underground structure, the landslide area can be divided into blocks and the meaning of each block can be decided by considering the results of each investigation.
3. Coordinating the above-mentioned in A and B, an outline of the landslide movement mechanism can be assumed.

C. Examining the resistivity values of each landslide area the following is clear.

1. The Fractured zone type landslide areas can be divided into four groups according to the difference in resistivity values for each layer. (Table 2)
2. The resistivity values of the assumed bedrock layer have a sharp difference

oue to the difference in geology and rock.

crystalline schist rocks ..... 5–20 kΩ-cm
green rocks .... 70–160 kΩ-cm
clay slate .... 300–500 kΩ-cm
schalstein .... 4–5 kΩ-cm

3. When bedrock is weathered the variation in resistivity values are of two kinds.
   a. the resistivity values of the weathered bedrock increase about ten times more than the values of the bedrock. (as A and D types)
   b. the resistivity values of the weathered bedrock decrease about one tenth or one twentieth less than the vlaues of the bedrock. (as B and C types)

In the future when the electrical resistivity survey is carried out at the landslide area and the results are interpreted, it will be necessary to interpret them with regard to the above-mentioned.

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