31. *Geology of Imaichi District with Special Reference to the Earthquake of Dec. 26, 1949. (II)*

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III. Change of the surface.

Changes of the surface caused by the earthquake which the writer intends to mention in this chapter, include the land slips or rock falls that took place at the time of the two principal shocks in this meizoseismic area. Changes occurred not only of natural surfaces of the ground but also of artificial structures of civil engineering. Damages to the artificial structures are not described here. Of these changes of the surface, there are some that were brought about or were amplified by the earthquake motion of the most severe aftershock of 5:54 p.m., Dec. 27. Most of the damages done to living creatures, roads, forests, and farms are ascribed to these surface changes.

These changes of the surface are described below by grouping them according to the geological and topographical conditions of the lands attacked.

(1) Rock falls or earth falls along steep slopes or cliffs.

Rock falls or earth falls occurred at many points along the upper stream of the Name River. Of them, conspicuous rock falls took place at the rocky cliff of the ridge running through the 527 m peak. As was mentioned in the foregoing chapter, the ridge is formed of the highly silicified hard Palaeozoic slate or shale and of compact biotite-quartz-porphyry intruding the former. The earth falls were observed at many points along the marginal cliff of the fan of Diluvial age, composed almost uniformly of the stratified succession of yellowish pumice (Kanuma-soil), reddish brown pumice (Imaichi-soil), brownish clayey bed called "loam" extensively developed in Kwanto Region, and thick gravel. One of the most typical examples of these earth falls was shown in Fig. 5. These earth falls, all of similar feature, are commonly found along the left side of the Name River from Itagabata to Matsunokiuchi. The underlying rocks exposed along the cliff are thickly bedded Diluvial gravel at the east of Murose-namegawa, and auto-brecciated andesite at the west of Murose-namegawa. Remarkable earth falls are seen near the junction of two tributaries, to the Name River on its upper course (Fig. 14*A*). Falling

of rock fragments or blocks of smaller scale were reported to have taken place at some places, e.g. at the road-side near Shinkyo, Nikko, near Funyu, etc.

(2) Destructive land slips of comparatively large scale near Murose-namegawa, Town Imaichi.

Land slips occurred near Murose-namegawa, about 2 km southeast of the town of Imaichi. One of the most destructive land slips of a large scale occurred at the steep slope, on the northern side of the 527 m peak. A land slip of about the same scale was simultaneously brought about at the southern slope of the same peak, and a smaller one took place along the adjacent gully on the northern side of the ridge. Localities of these land slips are shown in the annexed map (Fig. 9) on an exaggerated scale. All of these slips occurred at the time of the second principal shock of 8:26 a.m., Dec. 26. Two rural houses standing in the valley at the opposite side of the slope were badly wrecked; one was burried *in situ* and the other (*A* in Fig. 15) was pushed down and was carried away by a muddy flow towards the lower stream along the valley. By this accident, four persons were killed (burried alive) and a horse wounded to death. According to the personal account by a survived inhabitant of one of the wrecked houses, a crack was formed on the mountain-side and rock fragments fell at the time of the first principal shock of 8:18 a.m., and the collapse took place about a minute later than he had felt the second shock of 8:26 a.m., and the catastrophe came to the end within about 10 seconds. The mass of rock and earth, being roughly estimated as $3\times10^4\,m^3$ in volume, rushed down along the slope for about 150 m and slipped further on to the opposite side of the valley about 25 m beyond the river (*B* in Fig. 15). The collapsed mass consists of fragments or blocks of compact biotite-quartz-porphyry intermingled with pumiceous earth. A photographic survey of this area was performed by H. Kawasumi and his associates.

On the southern side of the same ridge, along dendritically developed gullys, a land slip of about the same scale was brought about simultaneously with the above-mentioned one; slipped rock mass from each head of these gullys rushed down the slope, (about 20°–30° in inclination), and combined together into a larger mass, and this larger mass moved down along the lower ravine and increased its volume more and more combining with collapsed reddish brown pumice deposited on the porphyry. At the foot of the southern slope of the ridge, where the pumice deposits increase in thickness, the mode of occurence of the land slips is some what different from that of the above-mentioned one. It resembles to some

extent that of those described in the succeeding section. The occurrence of the above-mentioned rock or earth falls and land slips, can not be explained to certain geologic structures of the spots where they occurred. One of the favourable conditions in bringing about these surface changes may be that the relief of the surface in these spots was comparatively high as a result of differential erosion, though such topographic features are not peculiar to these spots, but are common in the mountainland of this seismic area. The surface changes along the valley, the upper stream of the Name River, are more remarkable and of larger scale, compared with those in the other parts of this seismic area. It may be considered that the shock of the earthquake was felt more violent there than at the adjacent area.

(3) Slipping of surface soil in the region where granite or Palaeozoic strata are exposed.

In the southwestern mountainland of the present meizoseismic area composed geologically of biotite-granite and compact Palaeozoic rocks, slipping of surface soil took place. The area most severely attacked by the slipping is a granite terrain

Fig. 7. Slipping of the soil along the weathered layer at the surface of the porphyritic granite, near Kusagyu.

Fig. 8. Slipping of the thin soil on the slope of Palaeozoic mountain near Yamaguchi, on the right side of the Kuro River.

between Okurugawa and Kusagyu, the upper stream of the Kuro River and the Ooashi River. There, porphyritic crystals of microperthite are predominant in the biotite-granite. The potash-felspar contained in the granite promoted the rock decompostion and the coarse arkose sand came to coat the surface. The slipping

took place along the bottom of the layer of the surface soil. The thickness of the slipping layer is less than 1 m in most places in this granite region (Fig. 7). At Nakayama, a granite terrain, land slips are not so conspicuous as at the above-mentioned granite terrain. The granite of Nakayama is different in its rock facies from the granite near Kusagyu or Okurugawa; it contains no porphyritic perthite. The occurrence of the remarkable surface changes in the granite terrain near Kusagyu and Okurugawa may be attributed chiefly to the petrographic cause. Slippings of the comparatively thin deposits of surface soil with similar appearance are frequently met with on the slopes of the mountainland in the southwetern part of this meizoseismic area where the compact Palaeozoic rocks are exposed (Fig. 8). The Palaeozoic rocks in this district are shale, slate, sandstone, conglomerate, and hornfels derived from them, and in many cases they are highly silicified into hard compact rocks. In these rocks as well as in the granite, there is no geologlcal discontinuity. The distribution of these land slips which are exclusively of small scale is greatly influenced by the local topography. Some of them were destructive and took place along road cuttings, e.g. those along the Ooashi River.

(4) Land slips characteristic of the region where Diluvial pumice deposits are developed.

Some representative and characteristic changes of the surface brought about in this district by the present earthquakes are a number of land slips found in the region where pumice and clay are uniformly and thickly deposited. The land slips of this type are marked with solid circles in the annexed map (Fig. 9). In spite of the slight difference in the mode of their occurrence owing to the local topography of each place, they always show the same feature in general. This feature is due mainly to the same geological conditions of the Diluvial formation in this district. Before describing representative landslips of this type, a supplementary note of the geology of these Diluvial beds will be given.

As was already mentioned in the foregoing chapter, the Diluvium of this district consists almost uniformly of yellowish pumice bed (the uppermost Kanumazuchi), reddish brown pumice bed (Imaichizuchi) and loam (Kwanto loam), underlaid with gravel beds or a lava flow of augite-hypersthene-andesite. On the comparatively gentle slopes of the mountainland, these beds of pumice or loam are deposited directly on the basal rocks such as granite, porphyry, and Palaeozoic strata. Geologic succession and thickness of these Diluvial beds at many localities in this district are shown

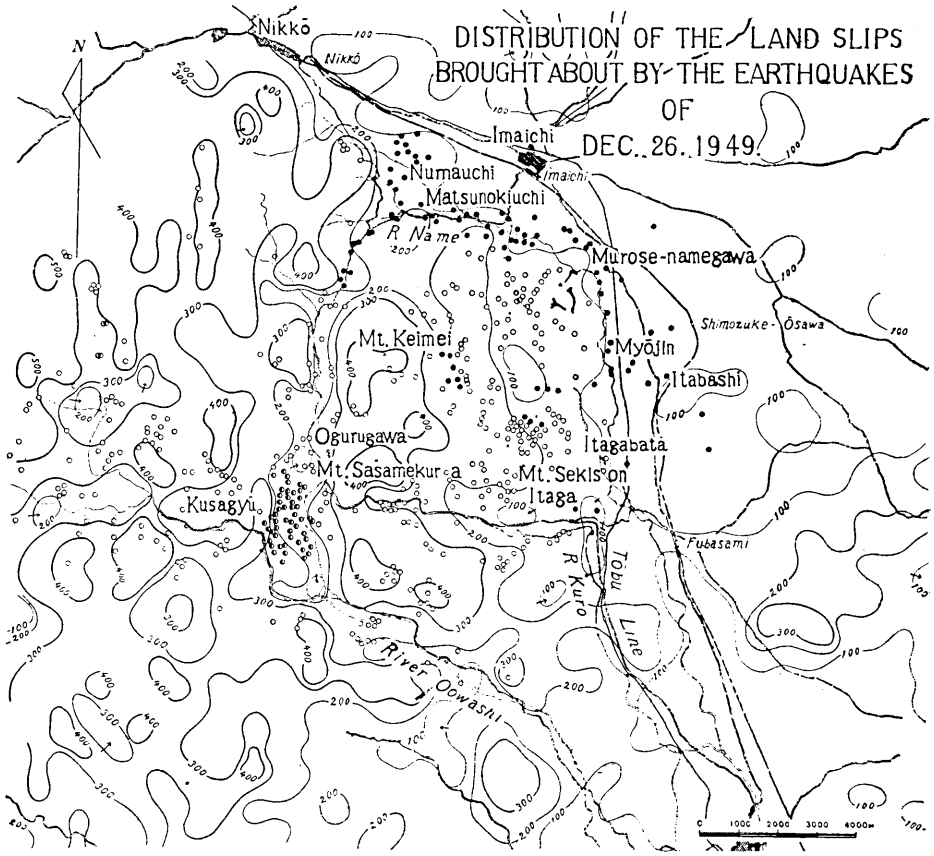

Fig. 9. The surface changes which occurred in the region where the Diluvial pumice deposits are distributed and those which took place on the porphyritic granite are marked as solid circles and half solid circles respectively. The curved lines designated by figures such as 100, 200, 300 etc. (in m), are contour lines for the difference in height between the highest and lowest points, within each of 1 km^2 into which the whole area is divided.

diagrammatically in Fig. 10. Damages done to forests and farms in the present seismic area are mainly due to the collapse of these pumiceous beds. Earth falls or land slips are remarkedly found in the northeastern part of the macroseismic area where these deposits are developed; especially conspicuous in the area between the Namegawa valley and the Daiya River (Fig. 14 *C*). These changes in the area where such pumiceous beds are distributed, occurred not only on the steep slope or on the cliff, but also on the quite gently sloped surface. Of these changes, the

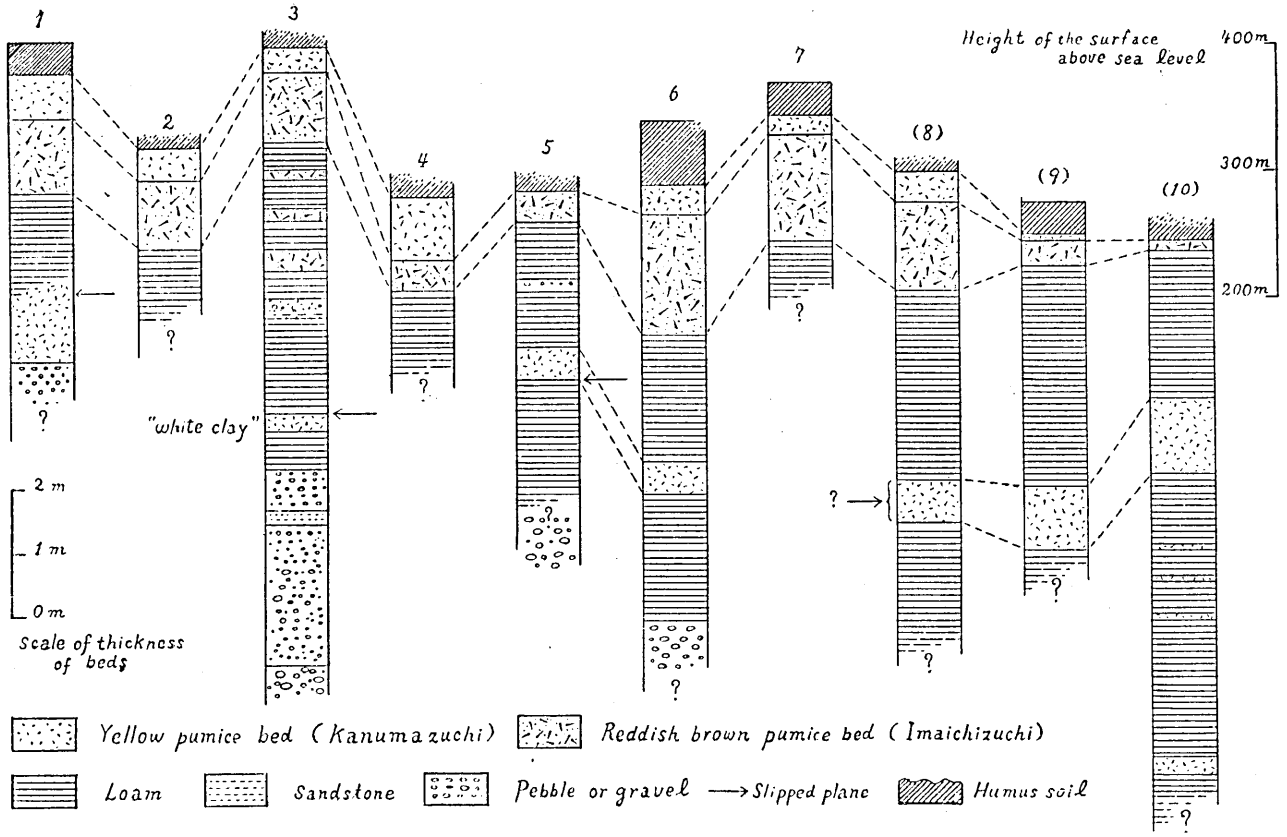

Fig. 10. The main geological columns of the Diluvial beds in this district. 1: Yamakubo, 2: Takachiya-Ochata, 3: Imaichi, 4: Shimagane, Itaga, 5: Ushiroyama, Myojin, 6: Itabashi, 7: Jukkokuzaka in Oosawa village, (8): Oosawa, (9): Shimokojiro, (10): Fubasami. The columns (8), (9), and (10) are quoted from Kawamura and Harada (K. KAWAMURA & M. HARADA, *Jour. of Sci. of Soil and Manure* **6** (1932) 414.); all others 1, 2, ..., 7 are based on the writer's observations.

two land slips which took place at Numauchi near Yamakubo and at Oosawa, 1 km north of Itabashi, respectively are representative.

Chasms were formed on the wheat corn field at Numauchi, 3 km west of Imaichi, and 3 km southeast of the town of Nikko, at the time of the earthquake of 8:18 a.m., December 26. The gently sloped surface of the corn field changed into an amphitheatre-like topography, about 100 m long in EW-direction and about 5 m deep (Fig. 11) at the time of the succeeding earthquake of 8:26 a.m. The

Fig. 11. A northward view of the amphitheatre-like land slip at Numauchi, about 100 m across in the E-W direction.

original dips of the surface and of the strata were gentle, not attaining to 10 degrees southwards. Displacement of the slipped land mass was not uniform; larger in the central portion of the collapsed area, smaller in the marginal portion, attaining to 30 m or more in the remarkedly slipped portion. The area of the corn field damaged is roughly estimated as 4×10^3 m^2. The mass which slipped or collapsed into mosaic aggregate of blocks consists mainly of reddish brown pumice. The slipped plane was not recognized here.

The surface changes, which are similar in form and comparable in scale to the just-mentioned land slip, were conspicuously observed side by side on the hill between the Akahori River and the valley of the upper stream of the Name River. Nowhere the slipping attained to the depth of 5 km from the surface. From this,

it appears that the slipping was caused in the loamy bed. For, in this neighbourhood, pumice beds (the uppermost Kanumazuchi and Imaichizuchi) of 2-3 m in thickness uniformly and conformably cover the so-called loam. The latter, consisting mainly of volcanic glass stained with iron, intercalates thin beds or laminae of other material such as fine pebble, sand, lappili, pumice etc., somewhere.

Fig. 12. The geologic succession of the strata near Itabashi. (Cf. Figs. 9 and 10. Photo. by H. Kawasumi.)

Fig. 13. An exposure along the road-cutting through Ushiroyama. Notice the slipping along the lower boundary of a white clay bed intercalated in the loam beds. (Cf. Figs. 9 and 10, Photo. by H. Kawasumi.)

Slipping is apt to be brought about along the boundary plane with these intercalated beds. Near Numauchi, a compact clayey loam bed, overlaid conformably with the above-mentioned aeolian pumice beds, such as the uppermost "Kanumazuchi" and "Imaichizuchi", suddenly grades into a coarse undecomposed pumice bed at the depth of 3.7 m from the surface, and further into a coarse sandy bed at 5 m. There is no evidence to show that any displacement of the strata under this compact loam took place.

At Oosawa, 1 km north of Itabashi, corn fields and forests of about 25,000 m^2 in area were attacked by land slips; a portion of the upper beds of the strata occupying a semicircular area of about 18,000 m^2, and another portion of about

7,000 m² slipped to southwest and to northeast respectively, toward a common line, resulting in heaving up of the surface. The strata of this area are as a whole nearly horizontal. Locally, however, they are slightly dipping in parallel with the surface. Dip of the strata is about 7 degrees here. The plane along which the overlying strata slipped down could not be directly observed at this place. A white pumice bed, so-called "white clay",[8] intercalated in the compact loam, is exposed at Itabashi and at Myojin (Figs. 12 and 13). It must have played an important rôle in causing such low-angled land slips, the strata overlying this greasy bed being easily movable along it by the earthquake shock. In fact, the slipping of the strata along the lower boundary of the "white clay" was observed at the road-cutting through the hill between Myojin and Ushiroyama (Fig. 13). T. Honda and his pupils of the Imaichi Middle School[9] found the regional slipping of the strata along this "white clay" from observing dislocations on the walls of water wells in the town of Imaichi and its adjacent area. The dislocations observed at Oosawa coincide in the direction of their slip with the movement of the strata on the surface.

The so-called "white clay" consists mainly of natural glass of volcanic origin. Porphyritic crystals of plagioclase, hypersthene, magnetite etc., are contained. The glass is altered mostly into hydrated halloysite;[10] montmorillonite is also found, and the latter is remarkable in some parts. As compared with the natural glass in the loam bed in which the bed of this white clay is intercalated, the volcanic glass in this "white clay" is more advanced in alteration (kaolinization). The white bed which contains much water forms a kind of impermeable bed. It may mainly be due to this mineralogical composition of the bed that the land slips were brought about remarkably in this seismic area, in spite of low-angled inclinations of the strata and of rather unsevere shocks of the present earthquakes[11]. In short, of the changes of the surfaces in the region covered with these Diluvial deposits, it

8) Correlated to the "1st Kanumazuchi" of Kawamura. K. KAWAMURA and M. HARADA, *Jour. of Science of Soil and Manure*, **6** (1932), 411–434. (in Japanese)

9) T. HONDA, *Bull. Earthq. Res. Inst.*, **28** (1950), 449–455.

10) Identified by X-ray powder photgraph as follows:

$2L$ (cm)	I	d (Å)	
17.4	10	10.3	
39.6	8	4.54	Cu $K\alpha$ $\lambda=1.5374$ Å
53.0	7	3.33	3.2 kV, 15 mA, 3.5 hr.
69.0	4	2.57	Radius of camera: 5.68 cm
106.8	2	1.70	
123.8	5	1.48	
146.5	2	1.28	
152.5	2	1.24	

may be said as follows: The loose aeolian deposits of pumice such as the uppermost "Kanumazuchi" and "Imaichizuchi" were easily collapsed by the earthquake shocks and the strata easily slipped along the greasy intercalated beds, especially of "white clay" in the "loam".[12]

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31. 今市地震地域の地質 (2)

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昭和 24 年 12 月 26 日の，栃木縣今市町附近に起つた地震の震域の地質の概要と，地變について述べた。この地方の基盤岩石は，少しくホルンフエルス化され，著しく珪化された古生層の砂岩，頁岩，礫岩，それを貫く黒雲母花崗岩，花崗斑岩，石英斑岩などの酸性岩類からなり，石英斑岩は所によつて噴出岩的岩相(石英粗面岩)を伴ふ。これらの基盤岩石は差別浸蝕によつて，珪化された古生層は山稜を，花崗岩類，特に加里長石に富む斑狀花崗岩は低地を形成した。以上の先第三紀乃至第三紀岩石を削つて，大冶川の扇狀地が形成され，その上に日光火山群の比較的古期の熔岩(おそらくは女峯——赤薙の)が，ほゞ，いまの行川上流の谷に沿ひ室瀬近くまで流れた。この熔岩噴出の時代をも含めて，引續いて，ロームをつくつた火山物質が堆積し，更に今市土，鹿沼土をつくつた浮石が，比較的緩やかな山地斜面やこの扇狀地一帶に堆積した。現在の大冶川その他の河川及び行川は，更に，これらの洪積層を削つて流れてゐる。今回の地震で，烈しい地變が集中した行川上流の谷は少くとも洪積紀の扇狀地の形成及び上記安山岩噴出以前からあつた地形に基いてゐる。地變は，地震の規模が小さかつた割合に著しく起きた。これは，この地域に廣く厚く分布してゐる洪積紀の火山性堆積物の性質に歸着するものである。なかでも，地辷りの絶好な辷り面になつたものはロームに夾まれた，一部粘土化した浮石層であつた。この地變に關與した，火山性堆積物については，また稿を改めて述べたい。

11) H. KAWASUMI, *Bull. Earthq. Res. Inst.*, **28** (1950), 364.

12) The writer's sincere thanks are due to Prof. Seitaro Tsuboi of this institute for his reviewing this chapter of the present paper in manuscript, to Prof. Hiroshi KAWASUMI for his kind instruction during investigation of the surface changes, and to Mr. A. Zitukawa for the loan of his photographs.

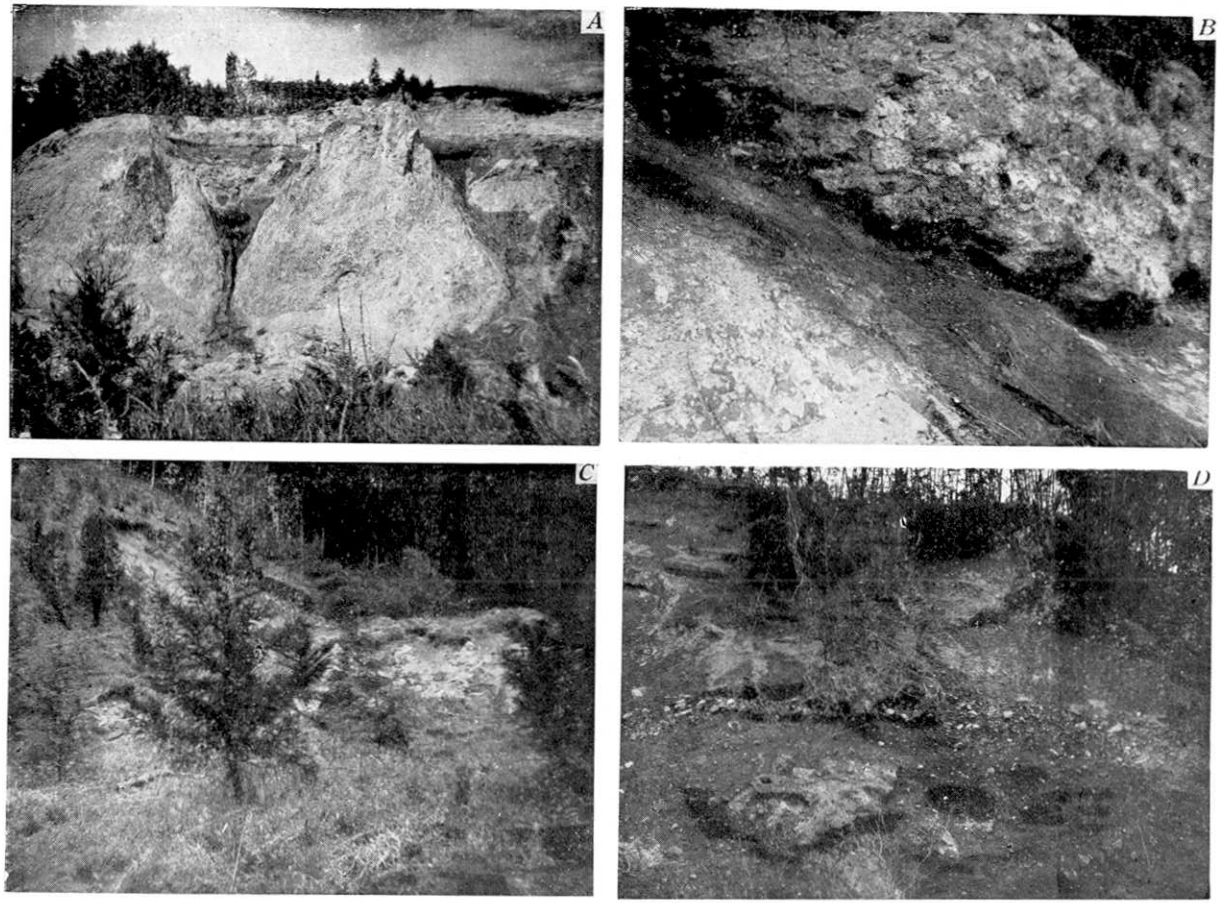

Fig. 14. (*A*) A large-scale collapse of the cliff, on the left side of the upper stream of the Name River, near the joint of two tributaries, at Matsunokiuchi, Nikko-machi. (*B*) The base of an auto-brecciated lava flow of augite-hypersthene-andesite underlaid with hornblende-bearing vitric tuff deposited on an erroded surface of the Palaeozoic sandstone and granite-porphyry. (*C*) A small-scale landslip which occurred on the hill-side covered by aeolian pumice deposits, 500 m northwest of Shimagane, Ochiai-mura. Loose pumice deposits collapsed. (*D*) Terminal front of the auto-brecciated lava flow of augite-hypersthene-andesite, overlaid with gravel, loam, and pumice beds, at Murose-namegawa, Imaichi-machi.

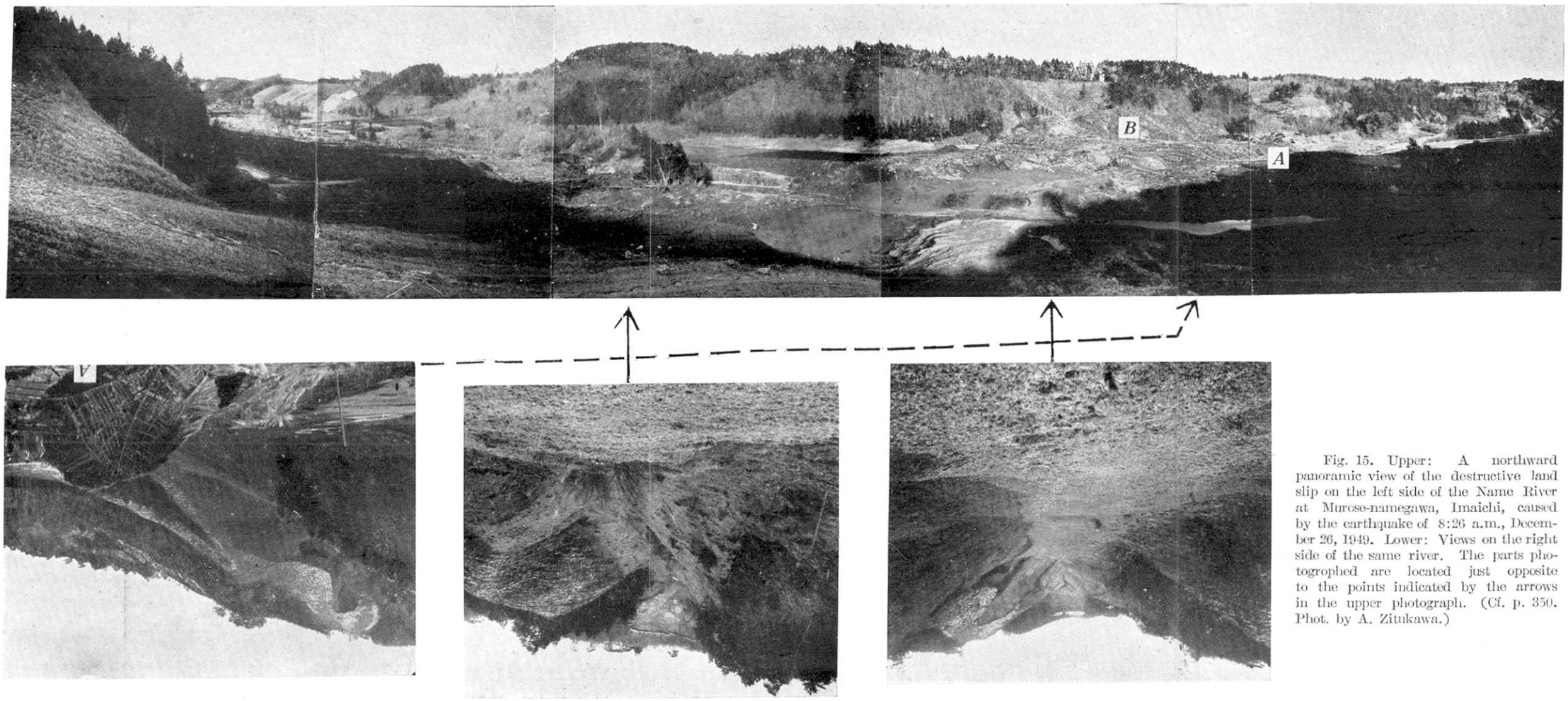

Fig. 15. Upper: A northward panoramic view of the destructive land slip on the left side of the Name River at Murose-namegawa, Imaichi, caused by the earthquake of 8:26 a.m., December 26, 1949. Lower: Views on the right side of the same river. The parts photogrophed are located just opposite to the points indicated by the arrows in the upper photograph. (Cf. p. 350. Phot. by A. Zitukawa.)