

Geomorphological Accidents caused by the Tokachioki Earthquake

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Geomorphological Accidents caused by the Tokachi-oki Earthquake

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Introduction

At 09:49, May 16th, 1968 occurred an earthquake with the magnitude of 7.8, the epicenter of which was at 41 N Parallel, 144E Meridian to the south of Erimomisaki, the southcentral cape of Hokkaido, and the distribution of seismic intensities is shown in Fig. 1.

The earthquake and aftershocks caused a great disaster in eastern Aomori prefecture and southern Hokkaido. The authors surveyed the disaster, especially, the geomorphological accidents. Mizuno and Hotta surveyed every important point in eastern Aomori prefecture, and intensively, in Hachinohe area. Miura and Tamura joined the Mizuno and Hotta team and collaborated in the investigation of slope failures in Hachinohe-Gonohe area, Akagiri's researches were mainly on the destruction of reservoir dams and consequent flood. Segawa surveyed in Hakodate area, Hokkaido. Nishimura led the project of research and compiled this report.

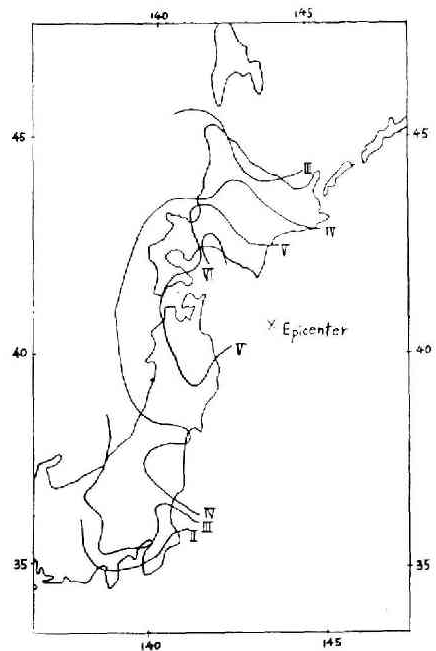


Fig. 1 Epicenter and Seismic intensities

Slope failures

Many slope failures by the Tokachi-oki earthquake in Hachinohe and around (Fig. 3) are not the rejuvenation of the former landslide areas subject to geological

structure such as the landslides observed at the Niigata earthquake (Nishimura *et al.* 1965) and as the landslides at this earthquake in Yamagata prefecture (Yonechi 1968). The sites of failures are not steep hillslopes but rather gentler slopes (5° at minimum). Collapsed materials of these failures are neither waste mantle nor bedrocks but younger pyroclastic fall deposits. The volume of the detritus is small (about $15,000 \text{ m}^3$ at maximum) but the distance of transport is relatively long (310 m at maximum).

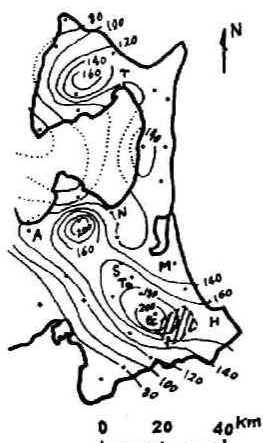


Fig. 2 Rainfall distribution (mm), May 13-15, 1968, in the eastern half of Aomori prefecture
T: Tanabu, A: Aomori, N: Noheji, M: Misawa, S: Shichinohe, To: Towada city, G: Gonohe, H: Hachinohe
Hatched area is shown in Fig. 3.



Fig. 3 Failed zones in the region to the west of Hachinohe
spot: failed zone with Scauper-type erosion area, cross: failed zone with Plane-type erosion area, hatch: upland surface, blank: valley wall, stipple: valley floor and the lowest terrace
Encircled areas with heavy lines are shown in Fig. 4.



Fig. 4 Landform classification maps near Locs. 1 and 3.

1-4: terrace surface (higher to lower), 5: shallow depression excavated in upper convex slope, 6: gentle footslope, 7: valley floor, 8: failed zone (a: erosion area, b: runway, c: deposition area)

Most of slope failures are concentrated in the valleys of small tributaries of the Asamizu river (west of Hachinohe) where there had been the heaviest rainfall amounting to 210 mm (observed at Gonohe) in preceding three days (Figs. 2 and 3). Each failed zone on the slope between the undulating upland surface and the narrow valley floor is composed of erosion area, runway through which detritus passed and deposition area (Figs. 4 and 5). The form of erosion area is apparently classified into Scauper and Plane types (Fig. 5, Photos. 1, 2).

The erosion area of scauper type is situated in small shallow depression excavated in upper convex slope. The lower end of the erosion area looks like a Karboden and is at the boundary between upper convex slope and middle straight slope (Photo. 3).

The erosion area of plane type is generally on a little steeper slope than the slope on which that of scauper type is, and lacks Karboden-like terracette. But the fact that small scaupers are often at the head of the plane-type erosion area may suggest the similarity of the mechanism of the failures of both types.

Stratigraphic sequence of surface materials less than 2 m in thickness are, upper to lower, black surface soil intercalating sandy pumice of Holocene, dark brown subsoil, yellowish brown clayey volcanic ash with yellow pumice grains of the latest Pleistocene, greyish white fine pumice of the latest Pleistocene and whitish coarse pumice of the latest Pleistocene (Fig. 6). Those materials except the coarse pumice were removed.

Runway, regardless to the type of erosion area, is very long in proportion to the whole size of the failed zone (Figs. 4 and 5). This area was free from any erosion but was subject to a little deposition. Surface materials of a few decimeter

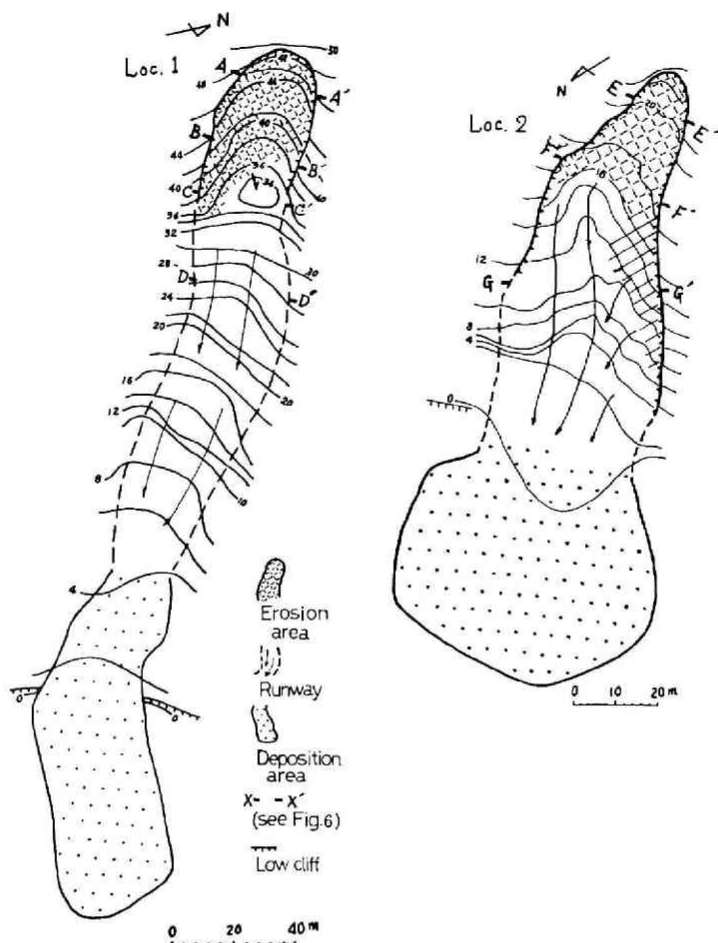


Fig. 5 Detail map of the failed zones surveyed by the authors
 Loc. 1 and Loc. 2 are shown in Fig. 3.

on the ground surface before the failure were mainly smashed materials of black surface soil and subsoil with blocks of yellowish brown volcanic ash removed from the erosion area (Fig. 6). Greyish white milky pumice was deposited directly on the original surface soil at some places of runway. Then it is suggested that this pumice removed at first from the erosion area. Deposits on runway were occasionally left at flow of materials from the erosion area to deposition area. The flow was very fast, seemingly 20 m/sec., an estimation based on several witnesses' observation.

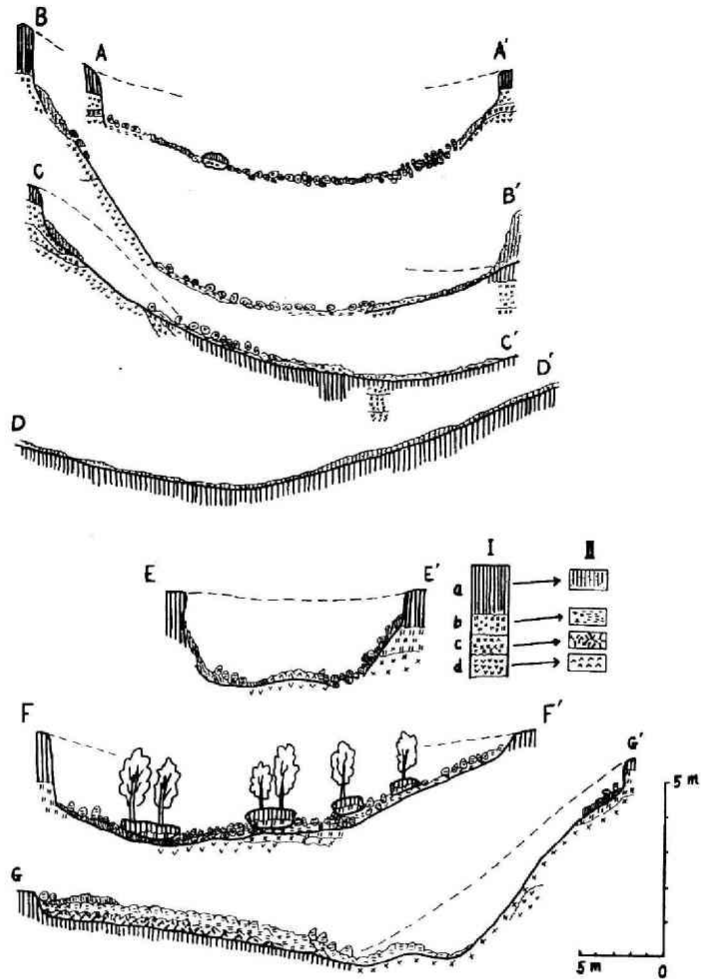


Fig. 6 Cross sections of the failed zones (Locs. 1 and 2)
 from A-A' to D-D': Loc. 1 from E-E' to G-G': Loc. 2 (see Fig. 5)

Surface materials

a: black surface soil and dark brown subsoil, b: yellowish brown volcanic ash with yellow pumice, c: greyish white fine pumice, d: whitish coarse pumice

I: undisturbed materials at this failure, II: deposits removed from upper position at this failure

Deposition area spreads widely on lower concave slope and valley floor like a palm leaf or a tongue where the valley is wide enough (Photo. 4) and elongated downstream where it is narrow. Deposited materials on the area about 1 m in depth are consisted of smashed materials of black surface soil and dark brown subsoil with

large blocks of yellowish brown volcanic ash held by roots of standing trees on them. This area was a mire immediately after the deposition.

There are some compound types of scauper and plane types in erosion area (Fig. 5b). The slope failures observed at Nyûguchi-zawa (Photo 5), to the north of the area shown in Fig. 3, are varieties of plane-type failures fit for the local topographic setting which has small river terraces in front of upper convex slopes. The case seen in the campus of Kitazato College, Towada city, is a scauper-type failure lacking runway because of the gentle (5°) and low (10 m) valley wall (Photo. 6). Collapsed materials of these cases are stratigraphically same as the region to the west of Hachinohe.

The mechanism of slope failures is considered as follows: Surface materials consisted of pyroclastic fall deposits and surface soils originating from them were saturated with water supplied by heavy rainfall (amounting to 211 mm) in three days preceding the earthquake. The depth of such materials changes according to micro-landforms. The small shallow depressions in upper convex slopes might have helped the storage of subsurface water. Those soaked surface materials fluidified at the shock. Greyish white clayey fine pumice at the bottom of the shallow depression fluidified at first and consequently overlying materials began to move. Then scauper-type erosion area were formed.¹⁾ The fine pumice, originally thin, stopped midway but surface soil and subsoil ran as mudflow down to the valley floor. Yellow brown clayey volcanic ash, originally rich in cracks, did not crash but maintained as blocks. Large blocks of them were rooted with standing trees. In general, plane-type erosion area was on a little steeper slope than scauper-type and, unconsolidated surface materials of which had been smaller but were soaked in the same way.

The slope failures were fundamentally controlled by surface geology which depended on micro-landforms and were led by the heavy rainfall immediately before the earthquake. The shock acted as a trigger.²⁾

Those processes, viewed from the forms of the environing slopes, seem to have been taking part in the landform evolution (destruction of the uplands) of the region.

- 1) It is noticeable that each erosion area is not at the center of shallow depression but on its steeper side. Karboden-like terracette may suggest piping.
- 2) Small seismographs set after the main shock on several locations by the Earthquake Research Institute, the University of Tokyo, recorded that after-earthquake shocks were heavier along the line from Towada City to Gonohe (NNW-SSE) than at other locations (personal communication of Kamikita Research Group). The line coincides with one of the severe damage zones, but it is difficult to separate the meaning of the heavy shock zone, even if that of the main earthquake shock had coincided with that of the aftershocks, from the effects of the heavy rainfall zone or the densely populated zone.

The slope failures above mentioned are different from Landslides in the meaning of Japanese usage represented by Koide (1955) and, at the viewpoint of phenomenal classification of mass-movements, for example by US Highway Research Board Landslide Committee (Leopold et al. 1964), they are recognized as Debris slides combined with Mudflows.

Collapse of artificial embankments

Recent progress in civil engineering made many artificial landscapes. Urgent need for land to build the establishments for industries, communication and residence or to enlarge the agricultural field, is now resulting in the artificial change of landform all over Japan.

But it is proved at the Niigata earthquake (Tanabe and Hasegawa 1964, Tanabe 1965, Nishimura et al 1965) and at this Tokachi-oki earthquake that the artificial land is very fragile to the earthquake.

The most miserable disaster was caused by this earthquake at the Kenyoshi Junior Highschool, where the school campus artificially made slid down and gave four pupils the death.

Newly reclaimed paddy fields at the flank of uplands were damaged here and there, especially heaped soils collapsed, and the irrigation became out of work.

1. Damages of railroads and highways

The Tokachi-oki earthquake brought severe damages to railroads and highways in the eastern part of Aomori prefecture (Fig. 7).

The destruction of railroads and highways at more than two hundred places in Aomori prefecture were caused by the collapses of artificial embankments such as railroad basements or highway roadbeds across the dissected valleys. They were generally filled with dark-brown loamy volcanic ash (Photo. 7).

In particular the connecting slopes of embankments to railroad or highway bridges subsided in many places though the bridges were undamaged.

The heavy rainfall just before the earthquake had prepared the collapses of embankments, that is, the heavy rainfall above 160 mm in three days made the embankments fragile, and the earthquake itself was no more than the motivation of collapses.

Therefore, the water-proof and earthquake-proof technology of artificial embankment will come into argument in the civil engineering works.

2. Damages of reservoir dams and consequent inundation

More than 100 irrigation reservoirs were damaged by the Tokachi-oki earthquake

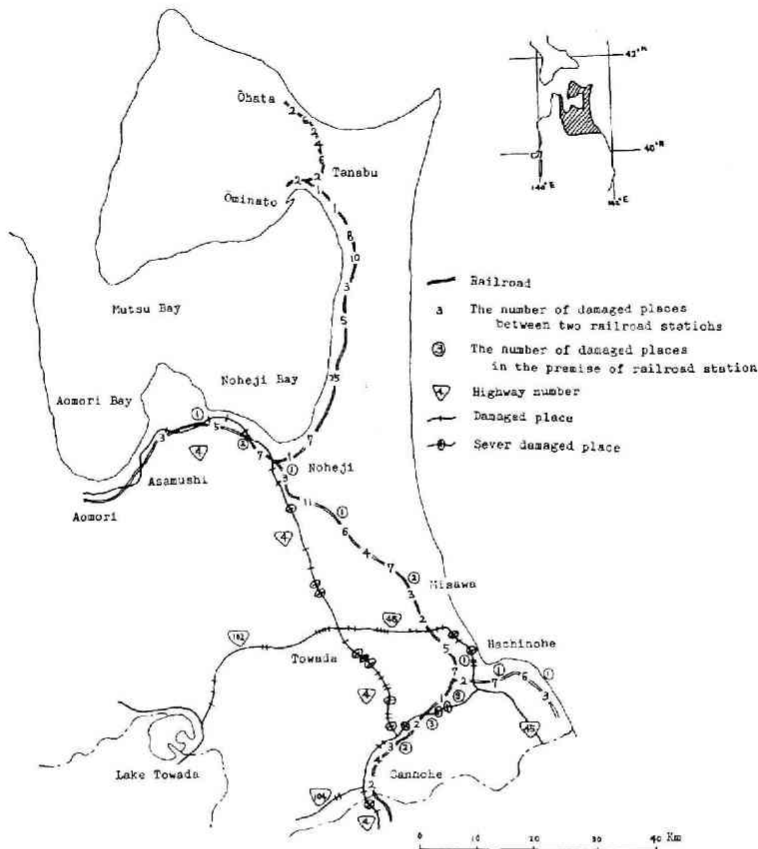


Fig. 7 Damaged places of railroad and highway in the eastern part of Aomori prefecture

in eastern Aomori prefecture. Damages were (1) destructions of sluices or spillways, (2) cracks and failures of earth embankments, (3) breaks of embankments and consequent floods. Most of reservoir dams suffered (1) and (2), but (3) occurred at about 10 reservoirs, the heaviest damage of which was at Hayakake-numa reservoir north of Mutsu city in Shimokita district.

At Hayakake-numa the earthquake caused several cracks parallel to the length of the dam and broke it at two places. Total width of the breaks reached about 150 m (Photo. 8). Consequently a flood happened and it flowed with full strength eastward to the Tanabu river, and it washed away the roadbed of the Ohata line railroad (Photos. 9, 10). Then the flood flowed down southward along the Tanabu river, when the flood-flow was weakened and controlled by micro-landforms, and formed a temporary lake at the upper side of Akasaka bridge east of Mutsu city.



Fig. 8

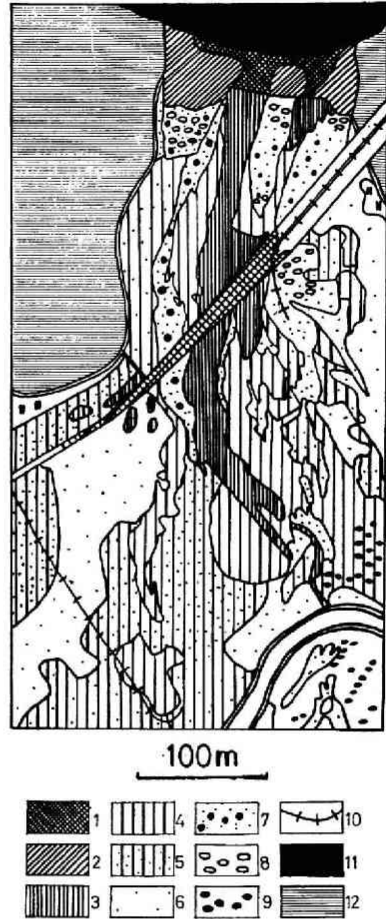


Fig. 9

- Fig. 8 Inundation area and flood current risen from Hayakake-numa reservoir
 1. Upland, 2. Inundation area, 3. Direction of flood current, 120 = Depth of inundation (cm), r=inundation of agricultural road, 2d=Stagnation period (2d=2 days)
 H Hayakake-numa reservoir, D Doteuchi, Y Yanagi-cho, A Akasaka bridge, O Ohta bridge, S Shinanoki, F Flood control channel, OM Omagari lowland
- Fig. 9 Landform modified by the flood just downstream of Hayakake-numa
 1. Area where embankment or railroad was washed away, 2. Failure of embankment slope, 3. Deep erosion, 4. Area where surface rich soil was washed away, 5. Area where deposition and erosion were done, 6. Erosion area, 7. Thick deposition, 8. Plant blocks with earth, 9. Plant-root blocks in floating islands of Hayakake-numa reservoir, 10. Railroad which was washed away, 11. Hayakake-numa reservoir, 12. Upland

The water flowed down again and drained mostly through the flood control bypass channel to Mutsu bay, and some flood water was drained through the lower Tanabu river and the rest of flood water flowed southward into the Kanamagari lowland and augmented the stagnant water level due to the rainfall (Fig. 8).

Landforms changed apparently at the section between the dam and the Tanabu river. Two holes like the waterfall basin were dug just downstream of the two breaks. An erosion trough (width 5–15 m, length 350 m, max depth, 2 m) was scooped out downstream of the bigger hole. Then the area of deposition and erosion belts follows from the roadbed to the Tanabu river. Three deposition belts are clearly distinguished, west (width 5–20 m, length about 300 m, thickness 1 m), central (30 m, 90 m, 2 m) and west of remained part of roadbed (30 m, 110 m, 1.9 m). Deposited materials are coarse sands and gravels near the dam, fine sands increase gradually to the lower part of the roadbed and brown clay near the Tanabu river. Many plant-root blocks originated from the floating islands on Hayakake-numa were transported to paddy fields 500 to 800 m distant from the dam (Fig. 9).

In Shimokita district the break-points of the dams coincide with the site of stream channel before construction. Aspects of the breaks of the reservoir dams in Shimokita district are similar in all the reservoirs. In general the flood currents were very powerful in the valley several hundred meters long from the breaks, and the floods eroded the valley floors, although the valley areas were not so large. When the floods arrived at the lowlands they spread over the paddy fields on the lowlands and lost their power. But at Hayakake-numa reservoir facing directly to the lowland, the flash flood hit the lowland with strong power and caused damages. In case of other reservoirs mostly in the upper reach of small valleys, the floods were already weakened at the paddy fields on the lowlands, although the paddy fields in the narrow valleys were severely damaged.

Causes of breaks of the dams in Shimokita district are as follows: 1) dams were made of earth and constructed over 20 years before, 2) capacity of reservoirs were large and every reservoir was filled fully with the rain water of the preceding heavy rainfall, 3) the shock of the earthquake was too strong.

Table 1. Ratio of reservoir capacity to inundation area

	reservoir capacity (A)	inundation area (B)	A/B
Hayakake-numa r.	1200000t	468ha	0.25
Ichirigoya r.	195000t	39ha	0.50
Kattaizawa r.	21000t	107ha	0.02

Damages in urban areas

In urban areas are concentrated many buildings and population, and there any disaster would cause severe damages.

At the Tokachi-oki earthquake, Hakodate in Hokkaido, Aomori, Mutsu, Noheji, Misawa, Towada and Hachinohe in Aomori prefecture were the cities which suffered the damages. Collapse of buildings, destruction of water and gas supply, cracks or depressions of road or factory site were the main items. Fire was small in number and slight. Fortunately the casualties were negligible.

1. Hakodate city

Hakodate is the city at the gate of Hokkaido and is situated on a tombolo and the coastal plain to the north of it at the southern end of Oshima peninsula. The coast zone is extended by many reclaimed lands.

Landform dislocations caused by the Tokachi-oki earthquake in Hakodate city are classified into cracks, horizontal and vertical dislocations mainly in the reclaimed lands (Photo. 12, 13).

The directions of cracks are NW-SE and NE-SW, which are the direction

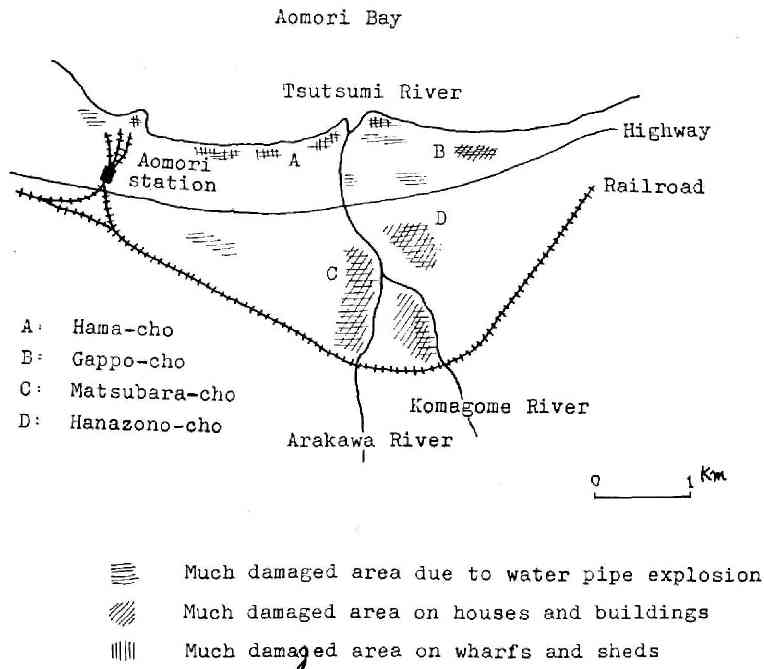


Fig. 10 Distribution of damaged area in Aomori city

from the seismic epicenter and the direction at the right angle. Sand sprouted out from the cracks. Vertical dislocations occurred solely or combined with horizontal ones. These are subsidence; subsidence with inclination; subsidence and uplift; subsidence with horizontal dislocation; and uplift.

The reclaimed lands can be classified into two. The one is reclaimed with the sea sand, the other is reclaimed with sand and gravel. The former was weak and the latter was resistant against the earthquake.

These accidents are almost always found in the land reclaimed from the sea. The collapse of the Hakodate college on the coastal terrace surface is the only exception, which is perhaps due to the architectural faults (Photo. 11)

2. Aomori city

The earthquake brought much damage to Aomori city, the capital of the

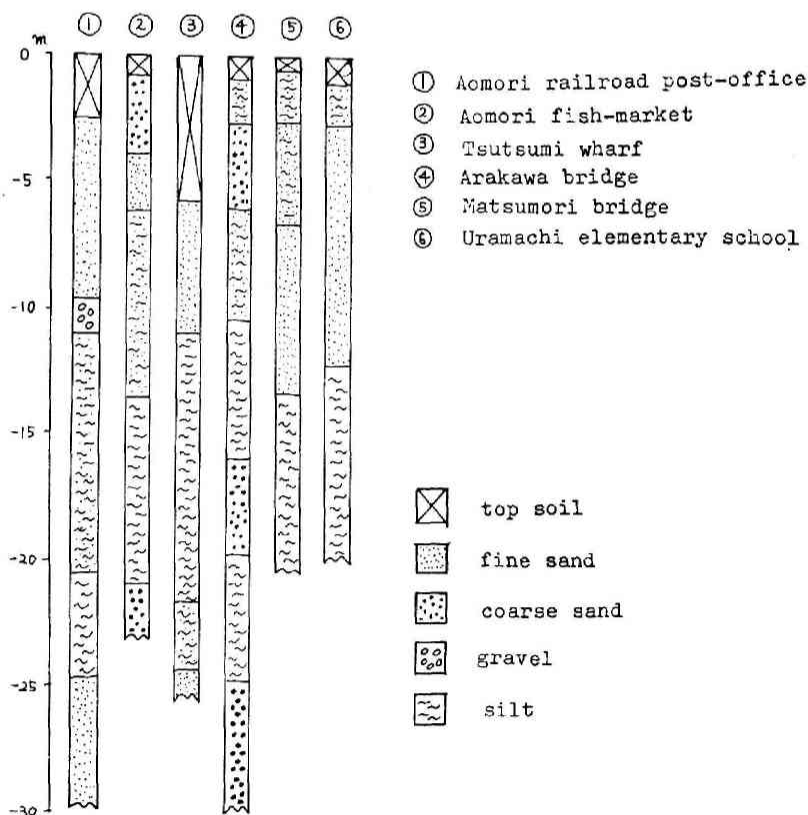


Fig. 11 Boring data near the damaged area in Aomori city

prefecture, which is situated on the coastal lowland along the Aomori bay. Many houses and buildings were completely or partially destroyed in the urban area of Aomori city, moreover water pipes exploded everywhere and wharves and sheds in coastal zone collapsed (Fig. 10).

The distribution of damages is concentrated in two areas, one is the coastal area along the Aomori bay including Hama-cho and Gappo-cho, and the other is on both sides of the Tsutsumi river including Matsubara-cho and Hanazono-cho.

In the coastal area the land had been graded for the purpose of constructing factories, wharves and sheds. Unconsolidated lands which once had been back-marshes among beach-ridges were depressed unequally and jetted out water, and then many factories, wharves and sheds were damaged there (Photo. 14).

In the Tsutsumi river area the damages occurred on the reclaimed land from the former river courses and former back-marshes of the Tsutsumi river, as many cracks, depressions and water-jettings. As the result, many houses and buildings were slanted in various degrees.

According to the boring data (Fig. 11) in and around those damaged areas, it is proved that weak-kneed dark-blue silt layer (-10 m. to -25 m. in depth) is buried there. The damages in Aomori city were mainly caused by the quicksand phenomena as in Hakodate city shocked by the earthquake in the weak-

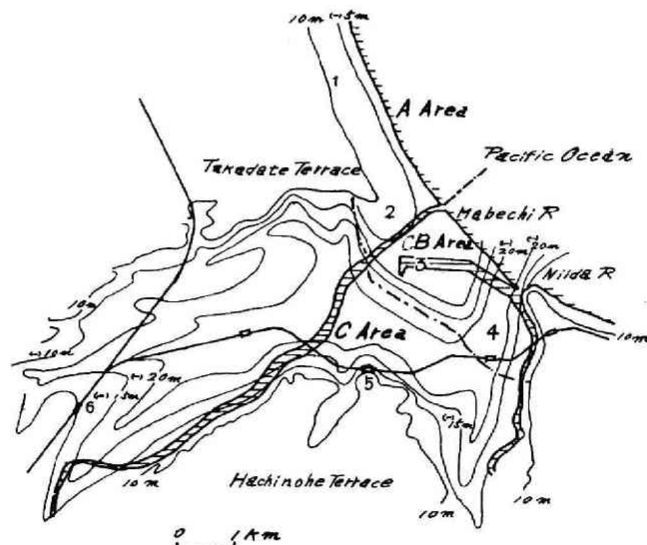


Fig. 12 The lowland of Hachinohe city

1: Kitanuma, 2: Hattaro, 3: Industrial harbor, 4: Konakano, 5: Hachinohe station,
(-): Underground contour line of alluvium.

knead ground due to former landforms such as old river courses or back-marshes.

3. Hachinohe city

Hachinohe city is a prosperous harbor and an industry city on the Pacific coast of Aomori prefecture. The urban area of Hachinohe city is situated on the alluvial lowland in the north and on the upland in the south, which is coastal terraces (10–30 m above sea level).

Alluvial lowlands are divided into 3 areas, northern coastal lowland (A), alluvial delta (B) along the Pacific Ocean and the valley plains along the Mabechi river and the Niida river (C) (Fig. 12).

(A) is a new industrial area and several factories are newly built. Beach ridges, back-marshes and lagoons have been graded some years ago. The maximum

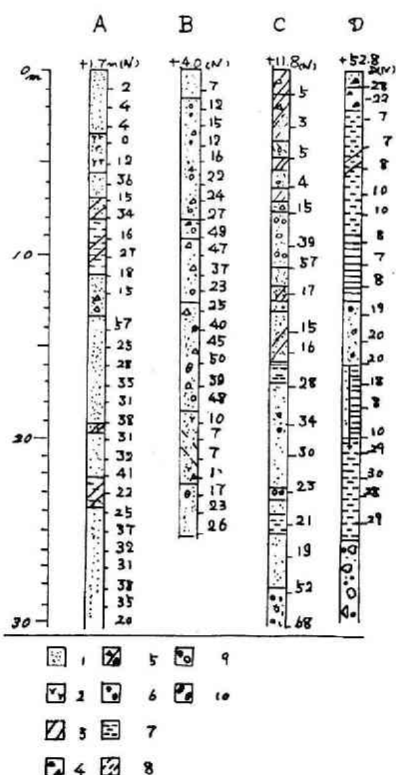


Fig. 13. Boring Columns around Hachinohe city

A: Kitanuma, B: nearby Industrial harbor, C: Kashiwazaki, D: Hachinohe Technical College, (N): N Value, 1: Sand, 2: Humus, 3: Muddy, 4: Pumiceous, 5: Pumiceous Loam, 6: Gravel, 7: Silt, 8: Silty, 9: Conglomerate, 10: Shell.

acceleration of the earthquake was recorded in N-S direction 235 Gal, E-W 188 Gal, Up-Down 80 Gal with the seismometer (SMAC-B2 Type) at the center on the area, and there occurred many cracks, unequal depressions, and sand-jettings. The damages in (A) area were many tilts and depressions of the factory sites and cuts, ruptures, or bendings of the pipes for processing and water supply buried under the ground 2-3 meter in depth. High ground water table, unconsolidated alluvium about 5 m in thickness, and newly graded land, made the damages more severe (Fig. 13).

The much damaged area within (B) was the industrial area along the industrial harbor, which was the former channel of the Mabechi river. The nature of the damages in (B) area was the same as in (A) area, but much slighter. It is noteworthy in (B) area that the embankment of the Mabechi river crossing the former channel collapsed widely at some places. Konakano, residential and shopping quarter in (B) area nearby the mouth of the Niida river was nearly undamaged. The deep alluvium 20-60 m in thickness from the Niida seemed to act as absorber of the shock.

In (C) area, a few steel-concrete buildings on back-marsh of the Mabechi river

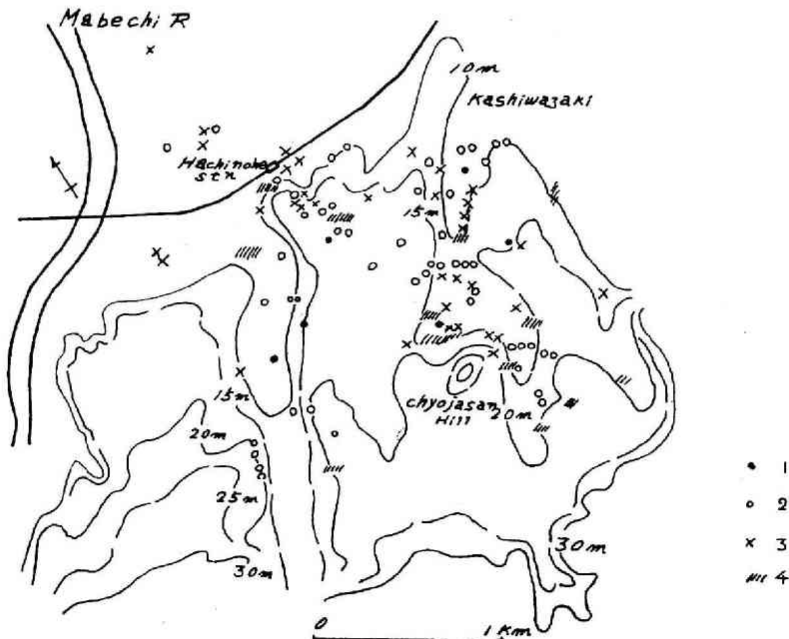


Fig. 14 Damages on the Hachinohe terrace

1: Steel-concrete building, 2: Gas pipe, 3: Water pipe, 4: House

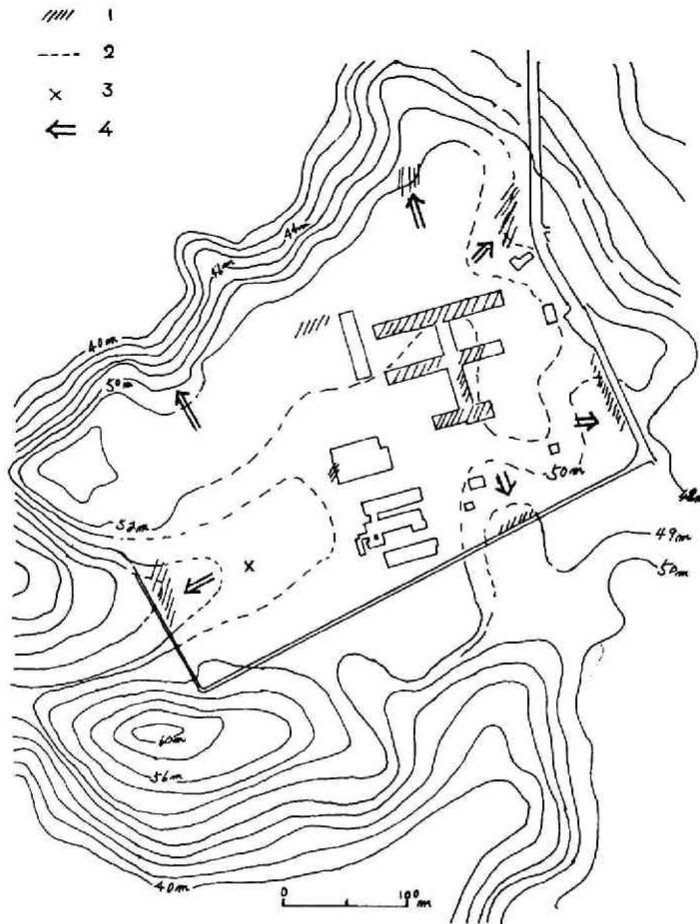


Fig. 15 Damages in Hachinohe Technical College

1: Damaged part, 2: Contour line recopied with previous topographical map and aerophotograph, 3: Mud-jetted position, 4: Depressed part.

below the upland called Hachinohe terrace were damaged, for example, the municipal gymnasium (Photo. 16).

On the lowlands, generally speaking, the degree of the damages was determined with the character of the alluvium 5 m under the land surface. The most heavily damaged area was the recently reclaimed back-marsh or lagoon area. Next to was the deltaic area, and little damaged area was the floodplain area.

On the Hachinohe terrace (Fig. 14), where there is the urban center of Hachinohe city, the damage occurred selectively. Hachinohe terrace is covered with

thick volcanic ash and volcanic loamy ash (3–4 m in thickness), and underlying deposits are sand and gravel (2–3 m in thickness). The terrace surface is cut by open, shallow valleys which are also buried with the above mentioned volcanic ashes (Fig. 13), and the most damages occurred in these valleys. One runs from Kashiwazaki to Chojasan hill, and another runs just under the civic center where are located newly buildings and houses. Here, steel-concrete buildings, many houses, water pipes, and gas pipes suffered severe damages, because of the alluvial character in the buried valley areas and the insufficient condition of drainage. Out of these buried valley areas, at the smaller valleys and at the margin of the terrace, heavy damages occurred.

The three-storied steel-concrete building of Hachinohe Technical College on another terrace 50–53 m above sea level suffered severe destruction by the earthquake (Photo. 17). The subsurface geology of the ground of the building is almost the same as the Hachinohe terrace. Before the College was built, there had been a few open, shallow valleys cutting the terrace surface as on the Hachinohe terrace (Fig. 15). In the college campus there occurred cracks on paved road, and depressions and mud-jetting on the ground. Especially, in the first floor of the college building many parts of wall cracked, many pillars and windows broke. It is dangerous to build steel-concrete building on the very position of the above mentioned valleys buried with thick volcanic ashes which absorb water easily.

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Photo. 1 Erosion areas and runways of six failed zones at Temmatai.
Two erosion areas, the left and the right sides, are of Plane type and the central four erosion areas are of Scauper type.

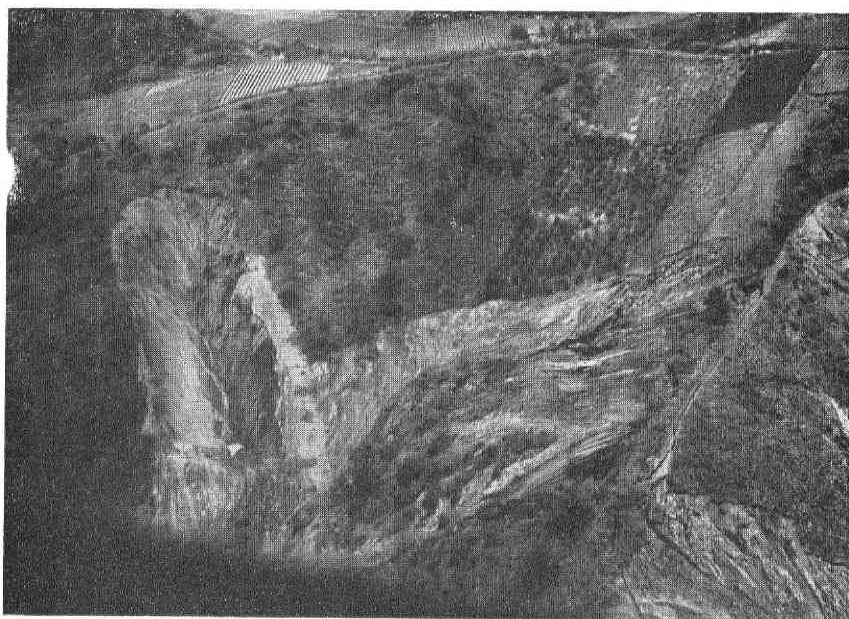
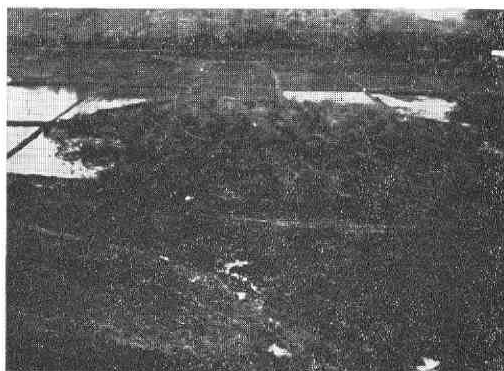
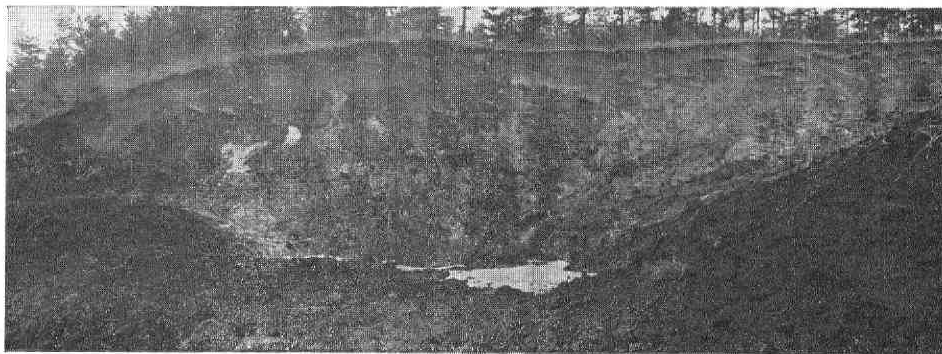


Photo. 2 Scauper-type erosion areas formed on one side of the shallow depressions in the upper convex slope.



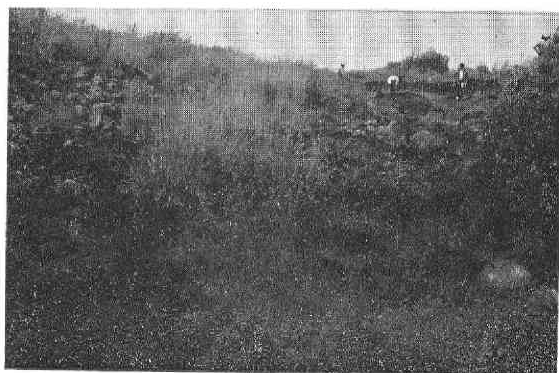
↑
 Photo. 3 The erosion area and the Karboden-like terracette at the lower end of it at Daibutsu (Loc. 1 in Fig. 3). See Figs. 5 and 6 also.

←Photo. 4 The deposition area of the failed zone at Eifukuji (Loc. 2 in Fig. 3). See Fig. 5 also.



↑
 Photo. 5 Failed zones at Nyuguchizawa.

Erosion areas of varial Plane type, straight (relatively steep) runways and deposition areas are seen. There are many large blocks with standing trees on runways and deposition areas.



←Photo. 6 The failed zone in the campus of the Kitazato College. Erosion area adjoins to deposition area to this side and runway is lacking.

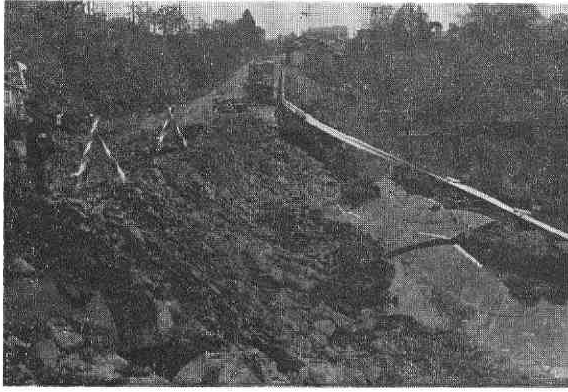


Photo. 7 Roadbed destruction of National Highway Rt. 104 near Kita-takaiwa



Photo. 8 Dam destruction of Hayakake-numa Reservoir

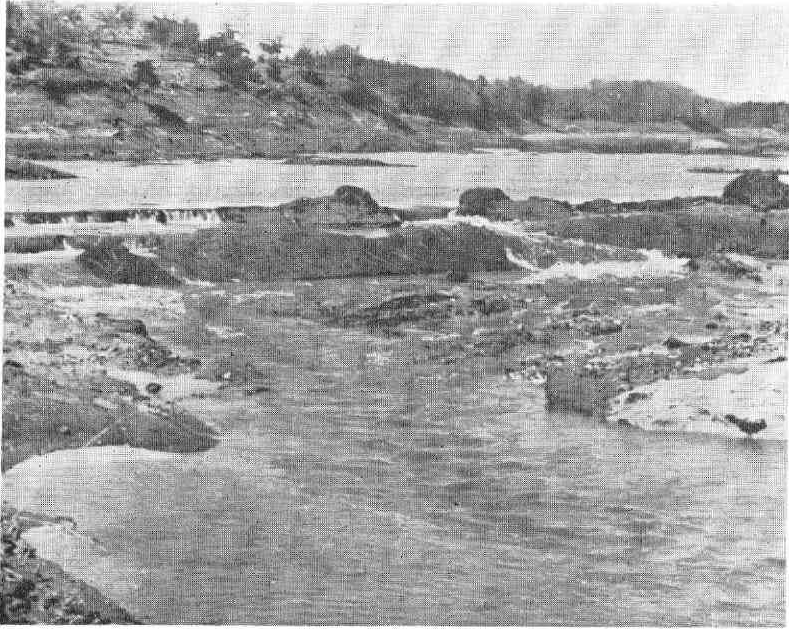


Photo. 9

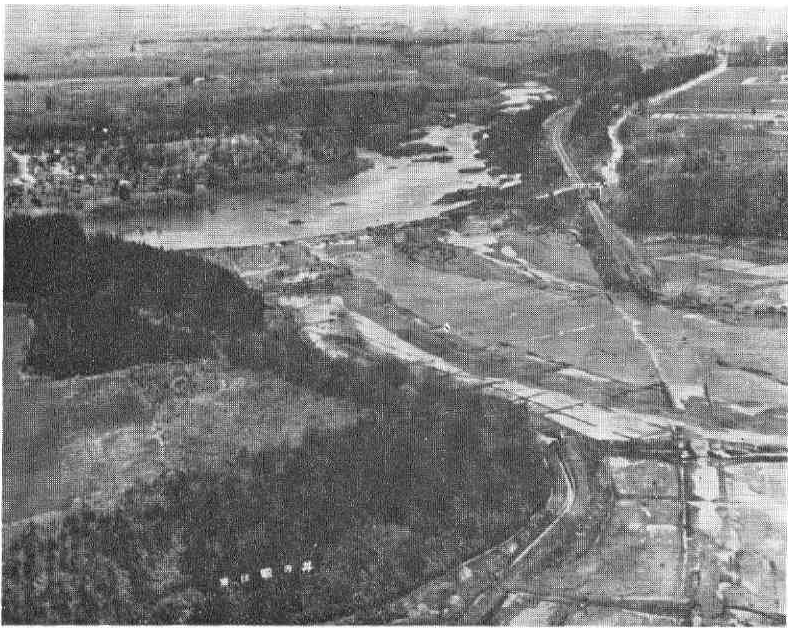


Photo. 10

Photo. 9, 10 Hayakake-numa immediately after the destruction

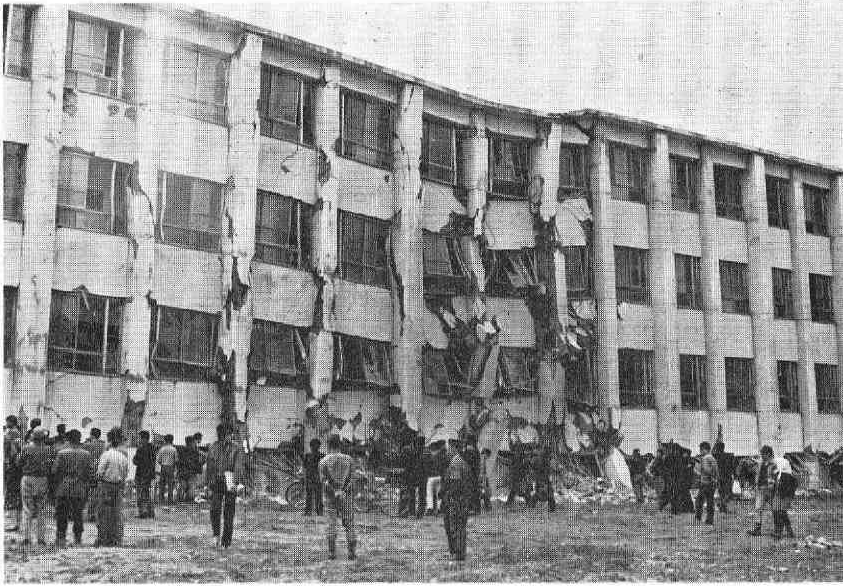


Photo. 11 Hakodate College severely destroyed



Photo. 12 Fissured yard, Mitsubishi Petroleum Co., Hakodate City



Photo. 13 Subsided Wharf in Hakodate City



Photo. 14 Subsided Wharf in Aomori City



Photo. 15 A godown in Noheji Town



Photo. 16 Hachinohe Municipal Gymnasium



Photo. 17 Hachinohe Technical College