# THE HOKKAIDO-NANSEI-OKI EARTHQUAKE
## Preliminary Report of the NZNSEE Reconnaissance Team

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### INTRODUCTION

At 10.17 pm on the evening of 12 July 1993 an earthquake with a magnitude of 7.8 occurred in the Sea of Japan off the south west coast of Hokkaido, the most northerly of the Japanese islands. The earthquake was located at a depth of 34 km with its epicentre about 55 km from the west coast of Hokkaido and some 75 km north of the small offshore island of Okushiri, according to the Japan Meteorological Agency (JMA). At this point the depth of water is estimated to be 3500 m. The location of the earthquake is shown in Figure 1.

The earthquake caused extensive damage and loss of life on Okushiri Island and to a lesser extent on the Hokkaido mainland. Some loss of life and damage was reported on the Russian Pacific coast and in addition fishing boats were lost off the east coast of South Korea. Most of the damage and loss of life was caused by tsunamis generated by the earthquake. In addition major ground damage consisting principally of liquefaction, rockslides and landslides occurred in southern Hokkaido and on Okushiri Island. The damage to structures as a direct result of ground shaking was minimal apart from the collapse of a recently completed snow shelter over a road on Okushiri. Most damage to structures occurred as a result of ground damage.

After reviewing reports of damage received from Japan and after seeking information from people in the region, the NZNSEE decided to despatch a reconnaissance team to investigate the earthquake and to identify lessons of value to New Zealand. From the early reports it appeared that the areas of particular interest would be ground damage, damage to lifelines, fire following earthquake and tsunami, performance of time houses and the effects of tsunami.

Accordingly, a team of four members of the Society spent eight days in Japan during late July observing the effects of the earthquake. Two days were taken up with briefings at universities in Tokyo and Sapporo on the latest situation in the damaged region and six days were spent in the field.

The aim of this Preliminary Report is to provide readers of the Bulletin with up-to-date first-hand information on the event and a brief account of the initial impressions of team members. A detailed Final Report will be published in the December issue of the Bulletin.

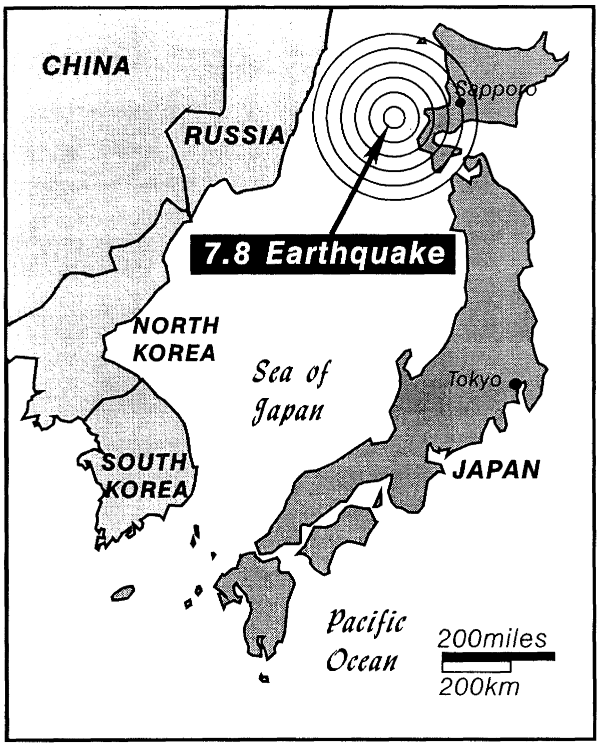


*Figure 1 Map showing epicentre*

### THE GEOLOGICAL AND SEISMOLOGICAL SETTING

The islands of Japan are located on the circum-Pacific "rim of fire" at a point where the Pacific Plate oceanic crust is in collision with the "Asian" continental plate. This has formed a region of complex tectonic activity with several interacting plates and high rates of relative plate movement. In northern Japan, along the eastern coast of Hokkaido and Honshu, the Pacific Plate is being subducted beneath the North American Plate, forming the Japan-Kuril Trench. Here the relative plate motion rate of about 100 mm/year is approximately twice that in New Zealand, and leads to about double the incidence of strong earthquakes (see Figure 2).

To the west of Hokkaido and northern Honshu, beneath the Japan Sea, lies a boundary where the North American Plate and the Eurasian Plate are in collision. It is along this

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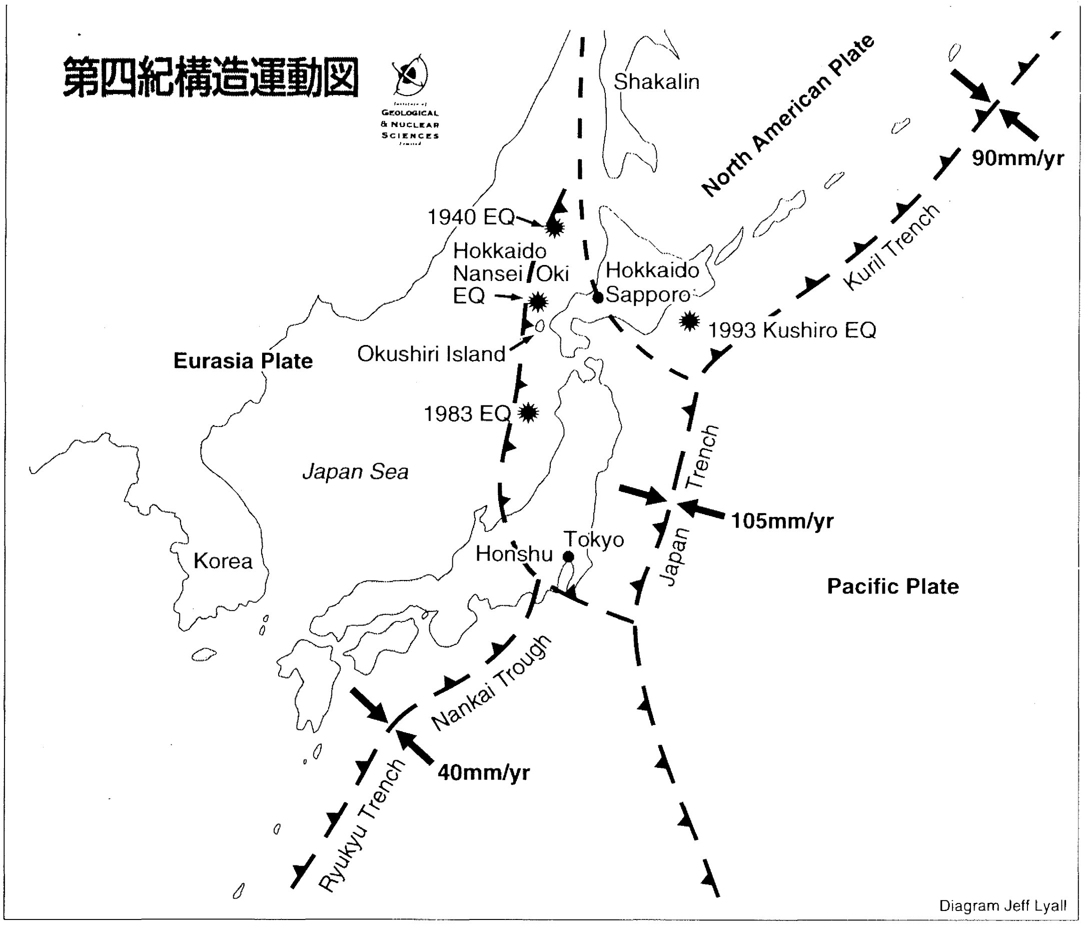


*Figure 2 Map showing plate boundaries.*

collision zone that the Hokkaido-Nansei-Oki and several earlier earthquakes have occurred. Seismologists had considered that large earthquakes along this zone were relatively uncommon, with recurrence intervals of 200 years or more, but the activity this century at least, indicates a far higher incidence of large events.

## DETAILS OF THE HOKKAIDO-NANSEI-OKI EARTHQUAKE

An earthquake of Richter magnitude 7.8 shook northern Japan at 2217 hours on Monday 12 July 1993. Located beneath the Sea of Japan, the depth was estimated at 34 km by JMA and at 15 km by the University of Tokyo. Based on the surface evidence, the depth is more likely to be closer to the shallower estimate, i.e. about 20 km, and the distance from the epicentre is also likely to be closer to Okushiri Island than to the south-west coast of Hokkaido. The earthquake triggered devastating tsunamis that were the cause of much of the loss of life and damage. An intensity of MM 8-9 was felt on Okushiri Island, the nearest landmass lying some 75 km to the SSE of the epicentre, while an intensity of MM 7, reducing with distance away from the epicentre was felt across Hokkaido (but almost reaching MM 8 on the closest parts of the western coast of Hokkaido). The epicentre is located between the epicentres of two past large earthquakes. The one to the north occurred in 1940, and that to the south was the 1983, magnitude 7.7 Nihon-Kai-Chubu earthquake. All three earthquakes, plus two additional earthquakes located further to the south, have occurred below the bed of the Japan Sea, on a north-south fault line where the two continental plates meet (i.e. the North American and Eurasian Plates). According to the Sapporo Meteorological Observatory, 103 strong aftershocks were recorded up to 900 hours, 20 July 1993. The largest aftershock of M 6.3 occurred at 0101 13 July, after two and a half hours after the main shock. The main shock and its aftershocks were focused in a rectangular area about 100 km north to south and 50 km east to west in and around Okushiri Island. Preliminary reports indicate that Okushiri Island has subsided by 500 to 900 mm. However, raised beach platforms on the island indicate an overall past trend of tectonic uplift.

Strong ground motions from the earthquake were recorded in many places by the Japan network. Peak ground accelerations were 0.216g in Suttsu (epicentral distance 70 km), 0.17g in Sapporo (160 km), 0.05g in Asahikawa (260 km), in Hachinohe (310 km), 0.05g in Wakkanai and 0.14g in Akita (both about 350 km).

## SUMMARY OF CASUALTIES AND DAMAGE

- 195 people killed, 47 missing (presumed dead), 42 badly injured, 198 slightly injured (mainly by tsunami, then landslide).
- 540 houses completely destroyed by tsunami and/or fire, 154 badly damaged, 1,826 partially damaged.
- 31 public buildings were (slightly) damaged.
- Railways were disrupted in 124 places.
- Roads were damaged in 365 places.
- 5 bridges were slightly damaged.
- 14 major slope failures occurred.
- 14,600 households temporarily lost their water supply.
- 33,000 households temporarily lost their power supply.
- 1,460 households temporarily lost their gas supply.
- 270 vessels along the Sea of Japan coast were sunk or swept away by the tsunami.

(from INCEDE Newletter of July 1993)

## GROUND DAMAGE

The damage to ground caused by the Hokkaido-Nansei-Oki earthquake extended over a wide area of south west Hokkaido. The principal forms of ground damage were landslips and liquefaction, with the former generally confined to the west coast of Hokkaido and the island of Okushiri, while the liquefaction damage was more extensive in areas of deep alluvial soils as far away as Hakodate Port (160 km).

The coastal landslips observed by the team generally consisted of joint-controlled rock slides on the steep coastal cliffs. The rock types are mostly of volcanic origin with granites and volcanic breccia forming the major part of the cliffs with areas of tuff breccia and tuffaceous sandstones. A major earthquake induced landslide in the weathered tuffaceous sandstones at the Okushiri Ferry Port buried the Yoyoso Hotel causing many deaths (Figure 3). The landslide/avalanche protection systems which have been constructed along the coast roads provided a variable performance. The mesh systems were heavily damaged, being torn by large rock blocks, while the unreinforced concrete gravity walls at the base of cliffs were overturned or smashed and were only partly effective in containing landslide material. The shelters generally performed adequately but one section of a shelter at Motsuta (west coast of Hokkaido) collapsed and resulted in an extended period of road closure. The benefit/cost analysis of such structures would be of interest but there is a long history of use of those structures along the coast road.

There were few landslides observed in natural soil slopes. In Toya, a volcanic ash deposit of saturated uncemented sands failed at the edge of an irrigated celery garden. A road embankment on Route 5 Highway also failed but there is clear evidence of previous creep and marginal instability.

A large sidling embankment failure occurred on a new section of road at Horonai on the west coast of Okushiri Island. The weathered granite soils were also involved in a bridge abutment failure and several large shallow based landslips also occurred in the nearby natural slopes. The surface of the disturbed soils had been quickly eroded indicating a sensitive soil type.

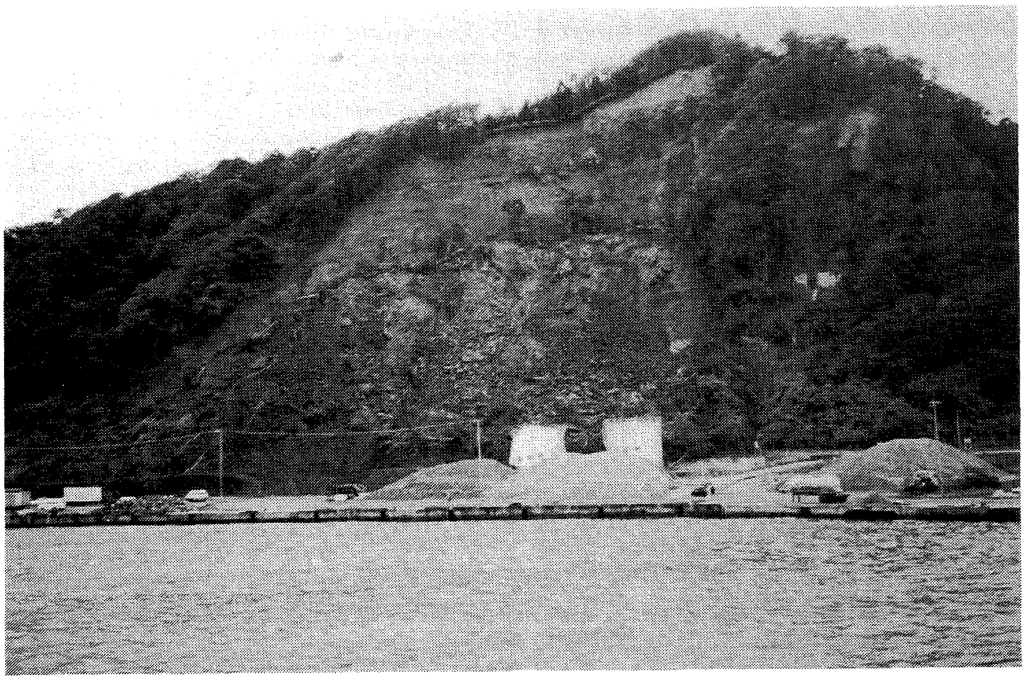

*Figure 3 Okushiri Ferry Port - landslide which buried the hotel causing 19 deaths*

Liquefaction induced ground damage occurred in areas of deep alluvial deposits. The main damage observed by the Team were in five locations viz:

- Shiribetsu River Valley, 2.5 km damaged stopbank, minor structural damage
- Shiribeshi-Toshibetsu River Valley, 8.5 km of damaged stopbanks, lateral displacement of roading and ground rupture, minor structural damage
- Esashi - Stopbank damage, bridge bearing damage, flotation of storage tanks (Figure 4)
- Osyamanbe - Ground rupture and slumping, lateral displacement causing damage to building foundations, roading embankments and pavements
- Hakodate Port - Major liquefaction induced consolidation overturning of sea walls, tilting of cement silo, damage to wharf structures and pavements (Figure 5).

The damage to stopbanks was principally limited to lateral spreading causing cracking of the embankment fills, surface slumping and damage to facings. However, extensive slumping and shear failures were reported along some 4 km of stopbank on the Shiribeshi-Toshibetsu River. The construction history of the embankments is of progressive development with previous requirements to reconstruct sections of poor quality construction. However, failures are considered to be principally due to foundation instability. Remedial measures were well progressed within two weeks of the earthquake, with temporary repairs and protection works undertaken immediately and sheet piled temporary stopbanks being constructed along the most heavily damaged sections.

At Hakodate Port, where the soft alluvial deposits are up to 100 m deep, the amplification due to site response characteristics resulted in settlement of reclamation fill of up to 1.5 m at the dry dock areas.

While damage to structures is limited, the facilities are effectively inoperable with major reconstruction works required. This may need to include densification of the reclamation soils to reduce the potential for repeat damage.

## THE MAIN IMPRESSIONS

- Landslip failures were generally limited to areas of high risk steep rock faces and embankments of apparent poor quality construction. Few failures were observed in weathered soil slopes.
- Stopbank failures were located in areas of foundation liquefaction or swamp zones. The quality of construction of the embankment was secondary but may have determined the extent of failure i.e. extent of slumping.
- Liquefaction damage to reclamation fills caused extensive damage in areas up to 160 km from the epicentre. While building structures had been designed on deep piles the facilities are generally inoperable and will require major works before they will be functional.

## PERFORMANCE OF STRUCTURES

In general, all types of structures performed well, as would be expected in an earthquake with a maximum intensity of MM 8 to MM 9 in a seismically well prepared country like Japan.

*Figure 4 Liquefaction and uplifting of 20 $m^3$ storage tank (one third full)*

*Figure 5 Hakodate Port - Liquefaction damage*

The nuclear power station at Tomari on the west coast of Hokkaido and about 70 km from the epicentre, was reported to be undamaged (Figure 6). On Tuesday 13 July, the Ministry of International Trade and Industry reported that all the nuclear power stations in Hokkaido and northern Honshu were functioning normally.

The major buildings on Okushiri Island were the four storey, reinforced concrete apartments and barracks of the Japan Self-Defence Force. Although the Team was unable to inspect these buildings, they were reported to be undamaged.

The major prestressed concrete Horonai No. 2 Bridge on Okushiri Island was undamaged. However, the expansion joint gap at the south abutment had reduced from 40 mm to 10 mm as a result of the earthquake. In addition the approaches to the bridge were damaged and retaining walls displaced.

Structures on Okushiri Island which suffered severe damage from ground shaking included the three pin arch precast concrete snow tunnel over the highway near Aonae, and the steel framing to the concrete batching plant also near Aonae.

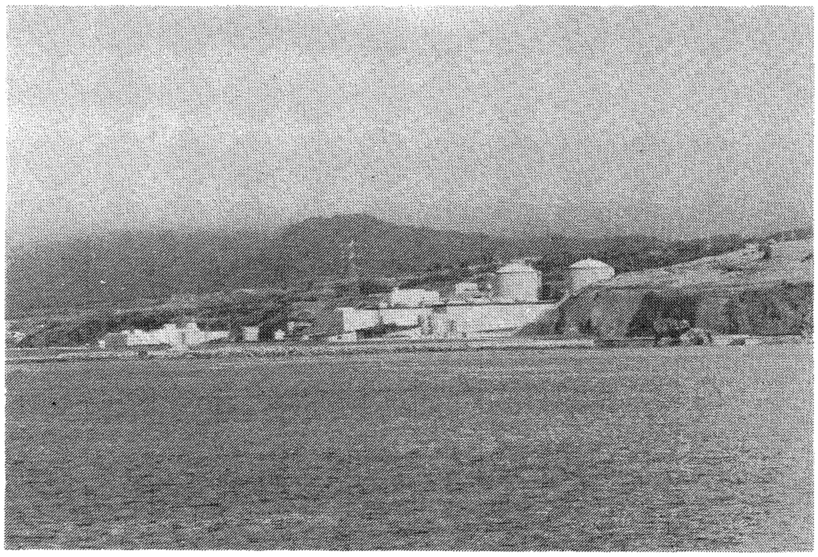

*Figure 6 Nuclear power station at Tomari 70 km from epicentre, apparently undamaged.*

The snow tunnel arch footings and retaining walls were not tied and relied on piles to provide stability. Part of the tunnel collapsed (Figure 7) and the footings of the remainder spread. There is some evidence to indicate that the piles were either not provided or were not connected to the footings. The Team was unable to carry out a detailed inspection of the steel framing to the batching plant to determine why the main columns had buckled at the bracing nodes. It would appear however, that the oustand to thickness ratios of the angle forming the column was excessive.

Well built timber framed houses (Figure 8) similar to those constructed in New Zealand, performed well, even when exposed to the tsunamis (Figure 9). Much of the damage to houses which resulted from ground shaking was due to rotting of framing caused by poor weather protection, failure of rigid external cladding and poor construction practices. Features of the framing, not practised in New Zealand, was the use of mortice and tenon joints between studs and plates and the use of studs and plates 100 mm by 100 mm in cross section.

## TSUNAMI

Okushiri Island and the south western coast of Hokkaido were battered by a series of tsunamis which claimed almost 85 percent of the lives lost in the earthquake [1]. Tsunami warnings were issued five minutes after the earthquake occurred but the first tsunami arrived soon after on Okushiri some 69 km from the epicentre. The reduced water depths and shoaling sea bed attenuated the speed of the waves and delayed the arrival time of the tsunami on the west coast of Hokkaido.

The Meteorological Agency reported that the tidal wave's speed reached 652 km/hr [2], while some other reports [2] say that the speed was about 500 km/hr.

Tsunami heights were measured from the sea level at the beach at the time of investigation to the traces of Tsunami found clearly. Figure 10 shows the results obtained by Professor Y. Tsuji, Tokyo University, where the maximum height of tsunami is recorded as 30.5 m.

In Korea, a 3 m high tidal wave was observed along the east coast and about 60 fishing boats were destroyed. In the Russian Far East, a tidal wave measuring up to 3 m in height, struck about an hour after the earthquake at Nakhodka, a coastal town near Vladivostok [2].

## LIFELINES

The number of households for which water, power and gas supplies were disrupted reached, at one time, about 14,600, 33,000 and 1,460 respectively [1]. However, those supplies were resumed within a day in most areas.

On Okushiri Island the electric power supply to about 2,300 houses was cut after the earthquake but it was restored to about 930 houses by the evening of 14 July [3]. A power generation truck from the Hokkaido Power Co. Ltd started supplying power to Aonae, the most severely damaged area in Okushiri Island, at 5 pm on 15 July. A large parabolic antenna installed by the Nippon Telegraph and Telephone (NTT) restored telecommunication services. Water was supplied by tanker trucks of the Self Defence Force after the earthquake [1] but the water supply was fully restored by the time of the Team visit on 29 July.

Railways were disrupted at 124 places and highways damaged at 365 places. Five bridges were slightly damaged and major slope failures took place at 14 sites [1]. However, most of the damaged roads and railways were reopened within a few days except for a few severely damaged places. A section of National Highway Rout 5 near Oshamanbe-cho and the adjacent Hakodate Line of Japan Railway Hokkaido was severely damaged over 300 m length but had been restored by the day of our visit, 28 July. The Shiraito tunnel in National Highway Route 229 along the west coast of Hokkaido, and the road along the west coast of Okushiri Island were not reopened but had been cleared to allow working parties to pass through by the time of our visit, 29 July.

## FIRE

The tsunami caused a large fire in Aonae, Okushiri Island. Several fires seem to have occurred simultaneously. One possible cause of the fire is the 450 to 500 $\ell$ kerosene tanks installed outside most houses supplying fuel for heating and LPG cylinders used for cooking. These may have overturned and have been damaged due to ground shaking and leaked the contents [1].

According to two residents in Aonae, fires also broke out on board three fishing boats at anchor in Aonae port. It seems possible that these boats collided and the lines of lights short-circuited. The boats, with a significant amount of fuel on board were swept ashore and probably set fire to houses [4].

Dr E. Itoigawa, Building Research Institute, Ministry of Construction, investigated the fire in the Aonae area. He reported that it was not possible to stop the spread of fire earlier due to the large amount of flammable debris and a strong on-shore wind blowing at more than 20 km/hr which fanned the flames.

## REFERENCES

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2. 1993 Daily Yomiuri, 14 July.

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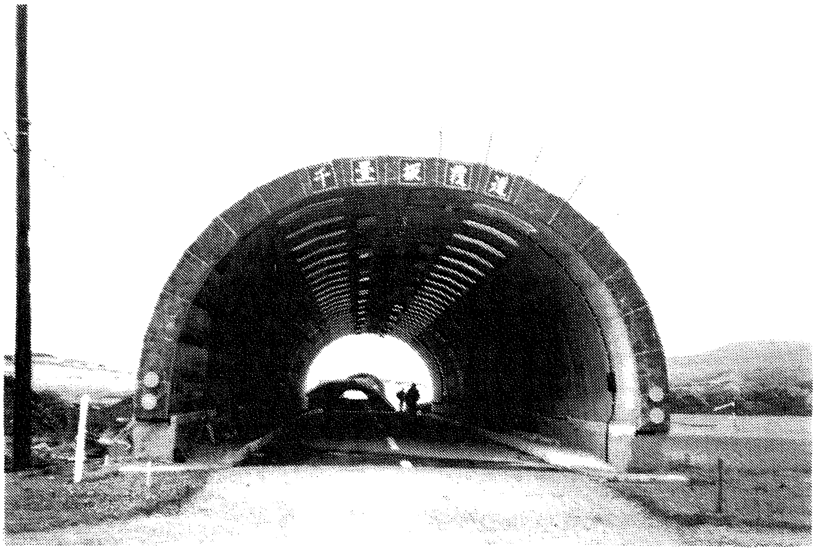

*Figure 7* *Part collapse of snow tunnel near Aonae on Okushiri Island. Structure was a precast concrete three pin arch.*

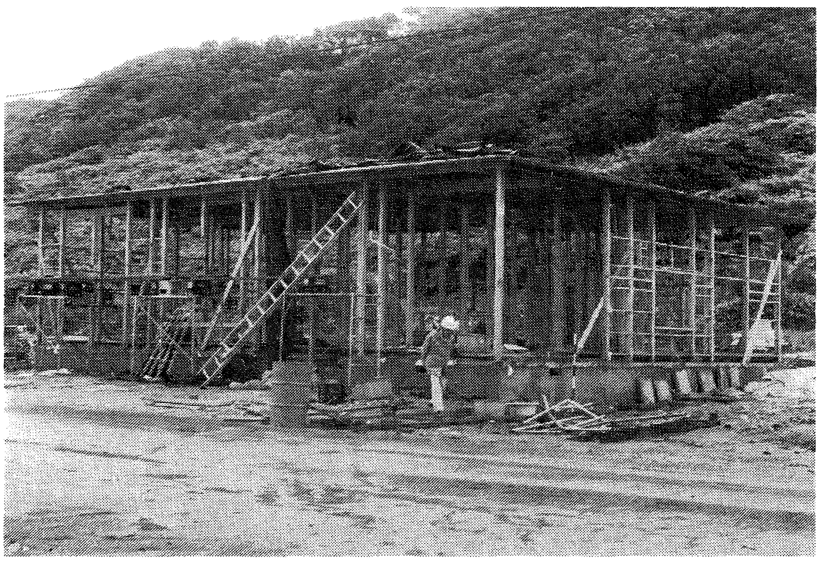

*Figure 8* *Well built timber framed house under construction near Inaho at northern end of Okushiri Island.*

*Figure 9* *Timber framed house near Inaho which survived the tsunami which appeared to be about 3-4 m high. Note the puncture damage to the external sheathing due to debris.*

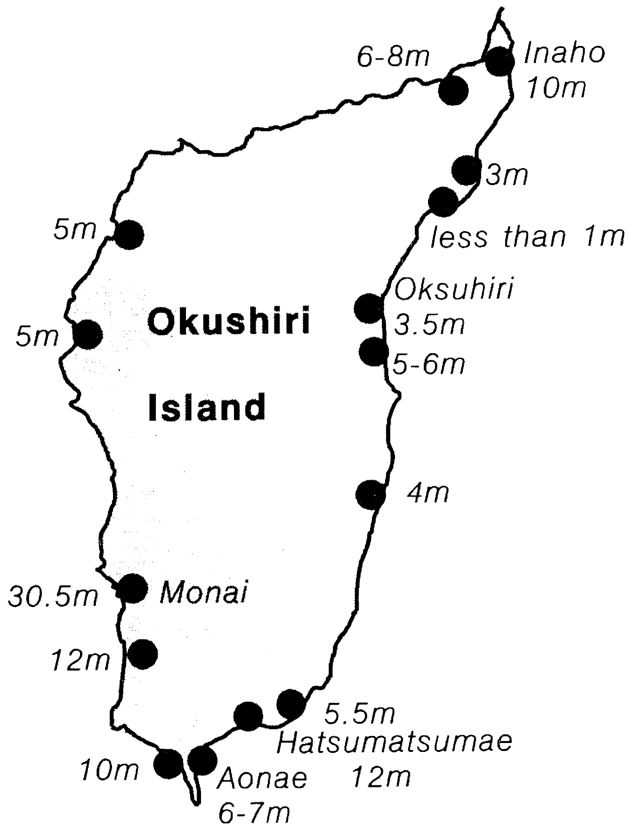


*Figure 10* *Tsunami heights in Okushiri Island, estimated by Prof. Y. Tsuji, University of Tokyo*