GROUND DEFORMATIONS AND THEIR EFFECTS ON STRUCTURES IN MIDORIGAOKA DISTRICT, KUSHIRO CITY, DURING THE KUSHIRO-OKI EARTHQUAKE OF JANUARY 15, 1993

by

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ABSTRACT

Midorigaoka is a residential area situated in Kushiro City, Hokkaido, approximately 900 km northeast of Tokyo. It was developed for housing in 1972–3 by cutting and filling a pleistocene terrace with an maximum elevation of approximately 30 meters above sea level. Following the January 15, 1993, M7.8 Kushiro–oki earthquake, various types of ground failures such as slope failures, ground settlements, ground cracks, sand boils, and lateral movements were evident at many locations in Midorigaoka. Buildings (mostly wooden single family residences) and underground utilities such as water supply, wastewater and natural gas networks were seriously affected by these ground failures. This paper presents the ground failures observed at Midorigaoka during the Kushiro–oki earthquake and examines the relationships within ground deformation patterns, subsurface ground conditions, landform changes, and the performance of wood houses and underground utility lines.

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INTRODUCTION

The Kushiro-oki earthquake struck Hokkaido, a northern island of Japan, at 10:06 PM local time, on January 15, 1993. The magnitude was assessed at 7.8 in the Japan Meteorological Agency (JMA) Magnitude Scale. The epicenter was located 15 km south of Kushiro City and the focal depth was 107 km. The earthquake resulted in 2 deaths and as many as 968 injuries[1]. The damage estimated was 55 billion yen (approximately $550 million) within Hokkaido[1].

Strong motion data were recorded at more than 180 sites through the northern half of Japan. Peak accelerations observed at both free-field sites and the ground floors of structures in the epicentral region are plotted in Fig. 1. A peak horizontal acceleration of nearly 1 g was recorded at Kushiro Meteorological Observatory, 14 km north of the epicenter.

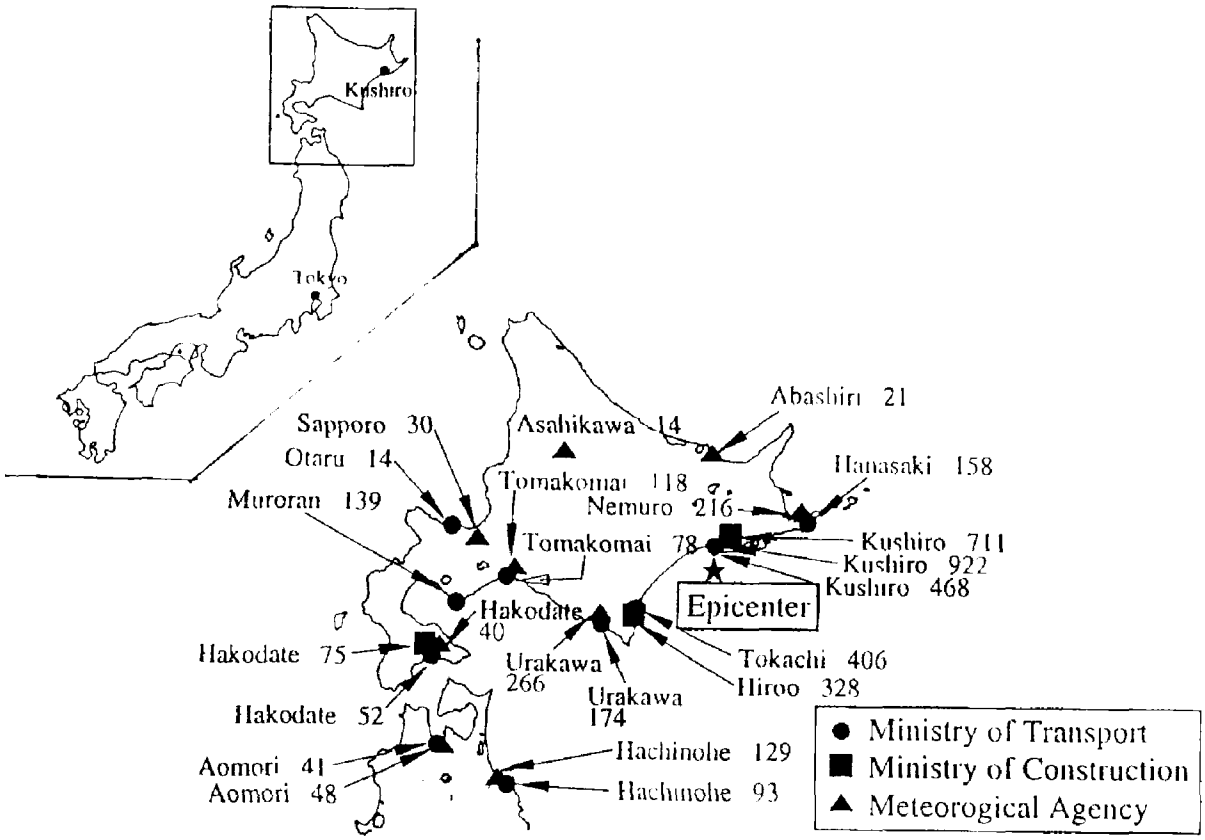

Fig.1 Peak Accelerations in cm/s^2 at Free-field Sites and Ground Floors of Structures during the 1993 Kushiro-oki Earthquake

The earthquake caused ground failures such as land slides, slope failures, and soil liquefaction in the epicentral region. Railways, highways, buildings and underground utilities were affected by these ground failures. The eastern part of Midorigaoka District, a residential area in Kushiro City, was one of the area most seriously affected by the ground failure.

This paper focuses on the damage of the eastern part of Midorigaoka District (simply called Midorigaoka below). At first, a historical review of land reclamation and construction in Midorigaoka is presented. The damage to buried lifeline systems and buildings is evaluated. The lifeline systems include water supply, wastewater and natural gas networks. Geotechnical data were collected and short period microtremor measurements were carried out to determine the subsurface conditions in the area. Photogrammetric analyses were performed to establish the profiles of the landforms before and after the residential development. Furthermore, the effects of changes in landforms, variation in fill thickness and density, subsurface water conditions and intensity of ground motion in concentrating damage in such a local area are evaluated.

GEOLOGY AND HISTORIC DEVELOPMENT OF MIDORIGAOKA

Midorigaoka is located on a pleistocene terrace in the eastern part of Kushiro City, Hokkaido, approximately 900 km northeast of Tokyo. The terrace is comprised of, from upper to lower, volcanic ash known as the Kussharo Pumice Flow Deposit, volcanic sandy soil known as the Otanoshike Formation, and sand, gravel, silt or clay known as the Kushiro Group on a base of Paleogene rock. Photo 1 is an aerial photograph taken in 1947, in which a valley is seen to dissect the terrace around Midorigaoka. The bottom of the valley was underlain by soft and loose soils.

The development of the terrace started from the north-western part of the area around the estuary of Old Kushiro River in the early 1900's and gradually extended toward the north-east. Midorigaoka was developed last, in 1972-73. The area was developed for construction by cutting and levelling the terrace and then filling the valleys with soils from the terrace. Therefore there are two general type of subsurface conditions in Midorigaoka: 1) natural soils associated with the volcanic pumice flow deposit overlying the original or excavated surface of the terrace and 2) fills consisting mainly with the volcanic pumice flow deposit placed on the valleys and hollow parts in the terrace. Typical soil profiles and elastic wave velocities in the terrace and in the valley are shown in Fig.2, respectively. Areas underlain by these different profiles behave differently during the earthquake, as discussed later.

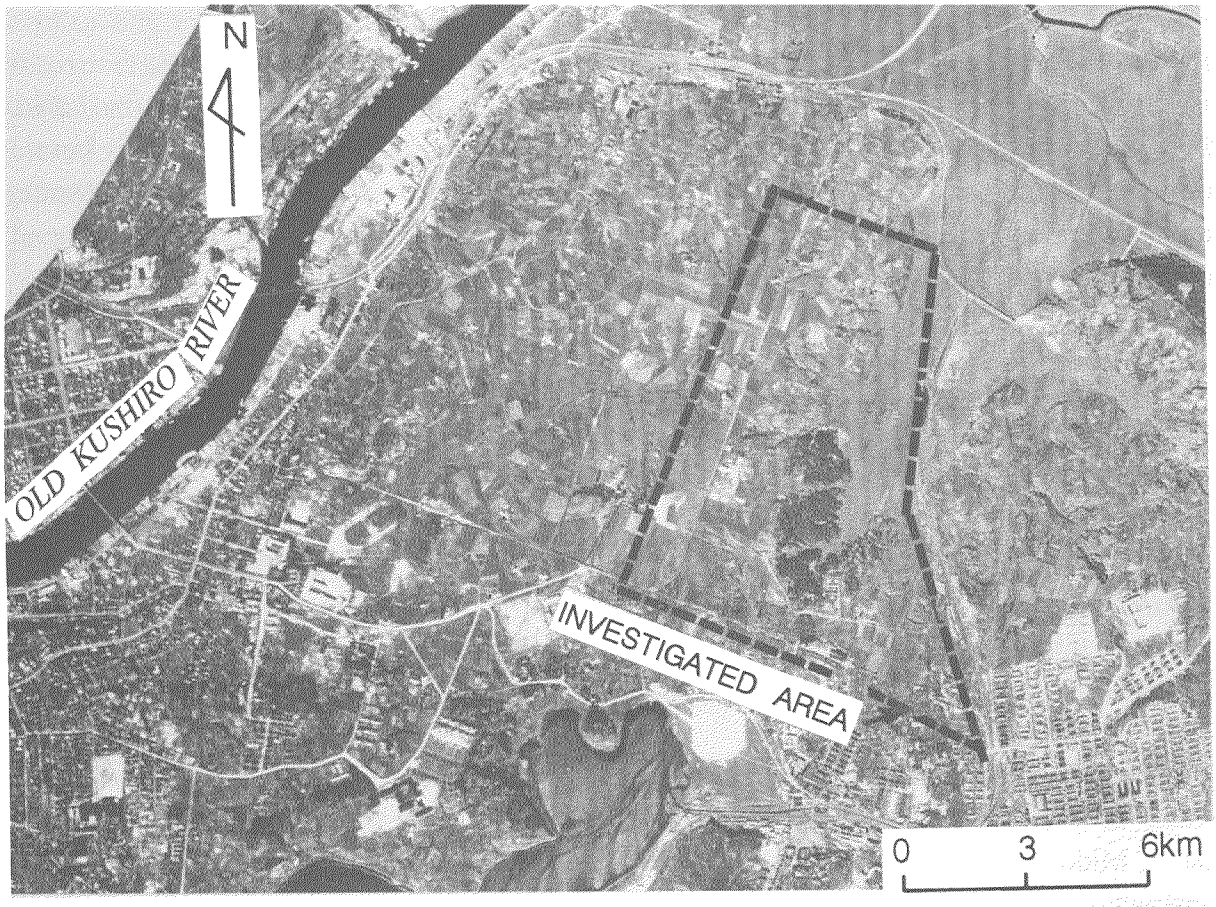

Photo 1 Aerial Photograph of the East of Kushiro City Taken in 1947

a) Pleistocene terrace

b) Filled valley

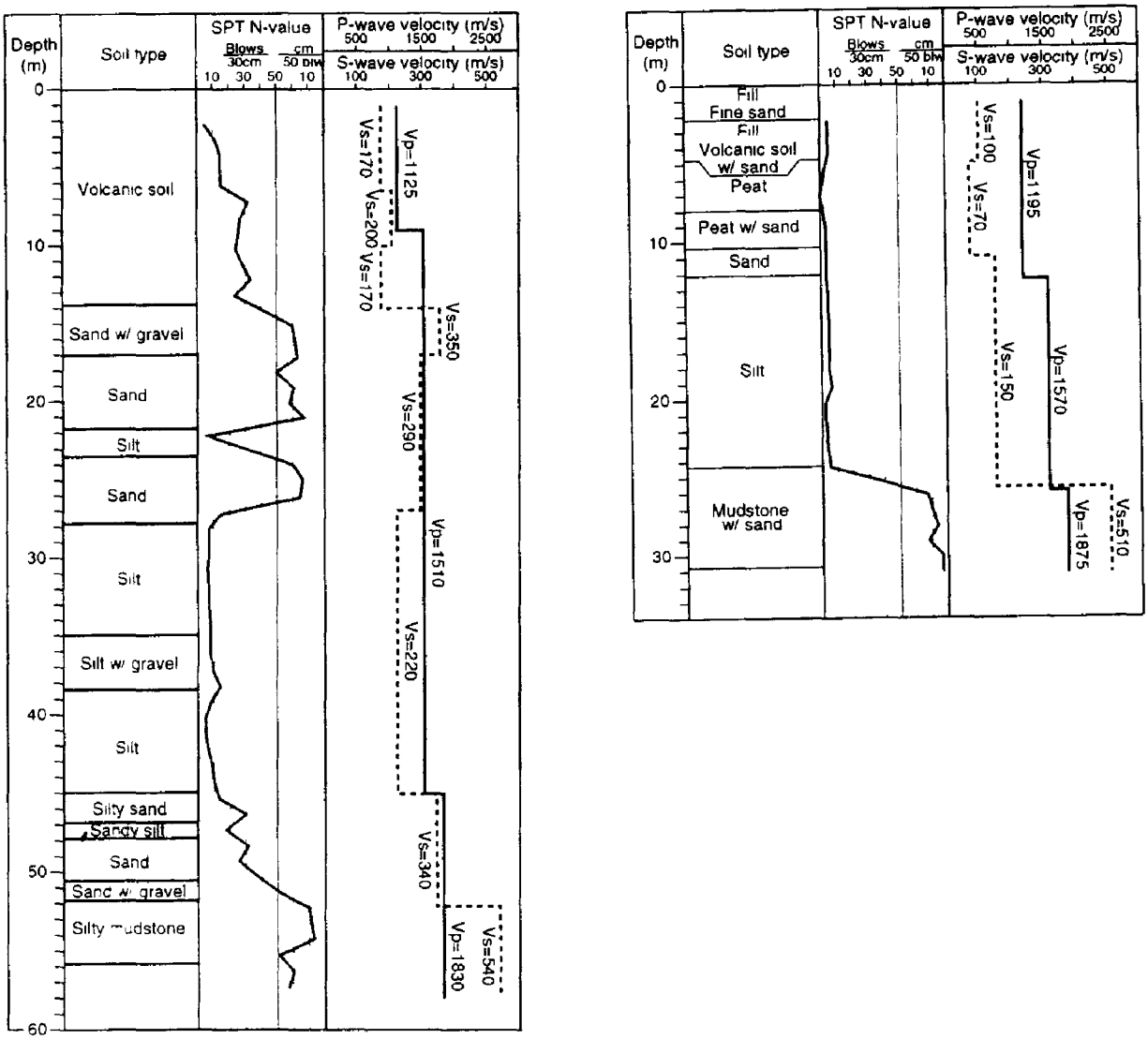

Fig.2 Typical Soil Profiles and Elastic WaveVelocities in Terrace and Valley[2)]

LIQUEFACTION EFFECTS AND OTHER GROUND DEFORMATIONS

Figure 3 shows locations of major ground failures and damage to structures in the eastern part of Kushiro City. The ground failures include slope failures, collapses of retaining walls, ground cracks, ground settlements and sand boils. The locations of damaged structures coincided with these of ground failures, which implies that most of the structural damage was caused by the ground failure. The damage was heavily concentrated in the zone investigated in this paper.