Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.III)

4-3-3

MAPPING LIQUEFACTION POTENTIAL BASED ON GEOMORPHOLOGICAL LAND CLASSIFICATION

Kikuo KOTODA[1], Kazue WAKAMATSU[1] and Masahiko OYA[2]

[1]Science and Engineering Research Laboratory, Waseda University, Shinjuku-ku, Tokyo, Japan
[2]School of Education, Waseda University, Shinjuku-ku, Tokyo, Japan

SUMMARY

A simplified method without the use of boring data is proposed for compiling maps showing liquefaction potential. The geomorphological land classification is conveniently adopted as an index for liquefaction susceptibility, because the classification data are easily available for any area. For each geomorphological unit, the qualitative liquefaction susceptibility is investigated based on the case histories in Japan. Among the various units, the reclaimed land, drained land, river channel, lowland between sand dunes or bars, marginal part of sand dune, natural levee and banking area in swampy lowland are most susceptible to liquefaction.

INTRODUCTION

In recent years, the demand to assess the soil liquefaction potential to some extensive area such as a plain, a prefecture, or a city has increased in Japan. The methods to evaluate the liquefaction based on the SPT N-values have shown their usefulness. However, to estimate liquefaction potential to a wide area, they are not always applicable practically, because they need a large number of boring data covering the area. On the other hand, it is known in general that the geomorphological features of an alluvial plain have good correlations with subsurface ground conditions such as soil type and its density, depth of ground water table and other factors. The geomorphological land classification can be made by interpretation of published aerial photographs and simple field inspection, without expensive geotechnical tests. Therefore, this classification must be a suitable index for practical evaluation of soil liquefaction potential.

In this paper, the correlations between geomorphological conditions and liquefaction susceptibility based on the case histories in Japan was investigated first, and then, liquefaction potential maps were compiled taking three major plains as examples.

<u>Distribution of liquefied sites during the past earthquakes</u> The writers have collected the liquefaction case histories during the past Japanese earthquakes from published earthquake reports and our supplemental interviews to local people. The result shows that the 123 earthquakes for the years, 863-1987, have caused liquefaction. Fig.1 shows the distribution of liquefied sites during the earthquakes which occurred after 1885 when the systematic seismic observation started in Japan. The liquefied sites distributed in most part of Japan. In some areas, such as the plains of Akita, Kanto and Nobi, the liquefaction was observed in more than 5 earthquakes for the last 102 years.

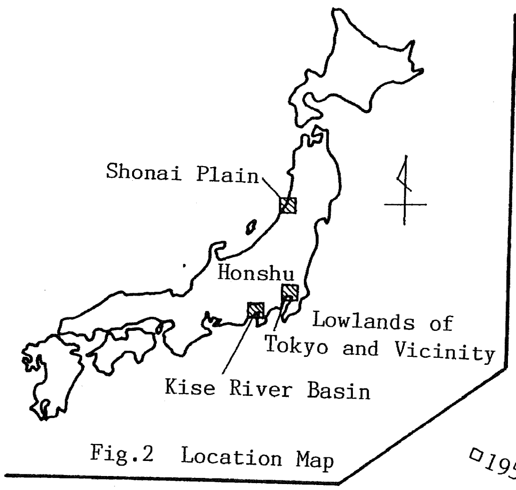

Fig.2 Location Map

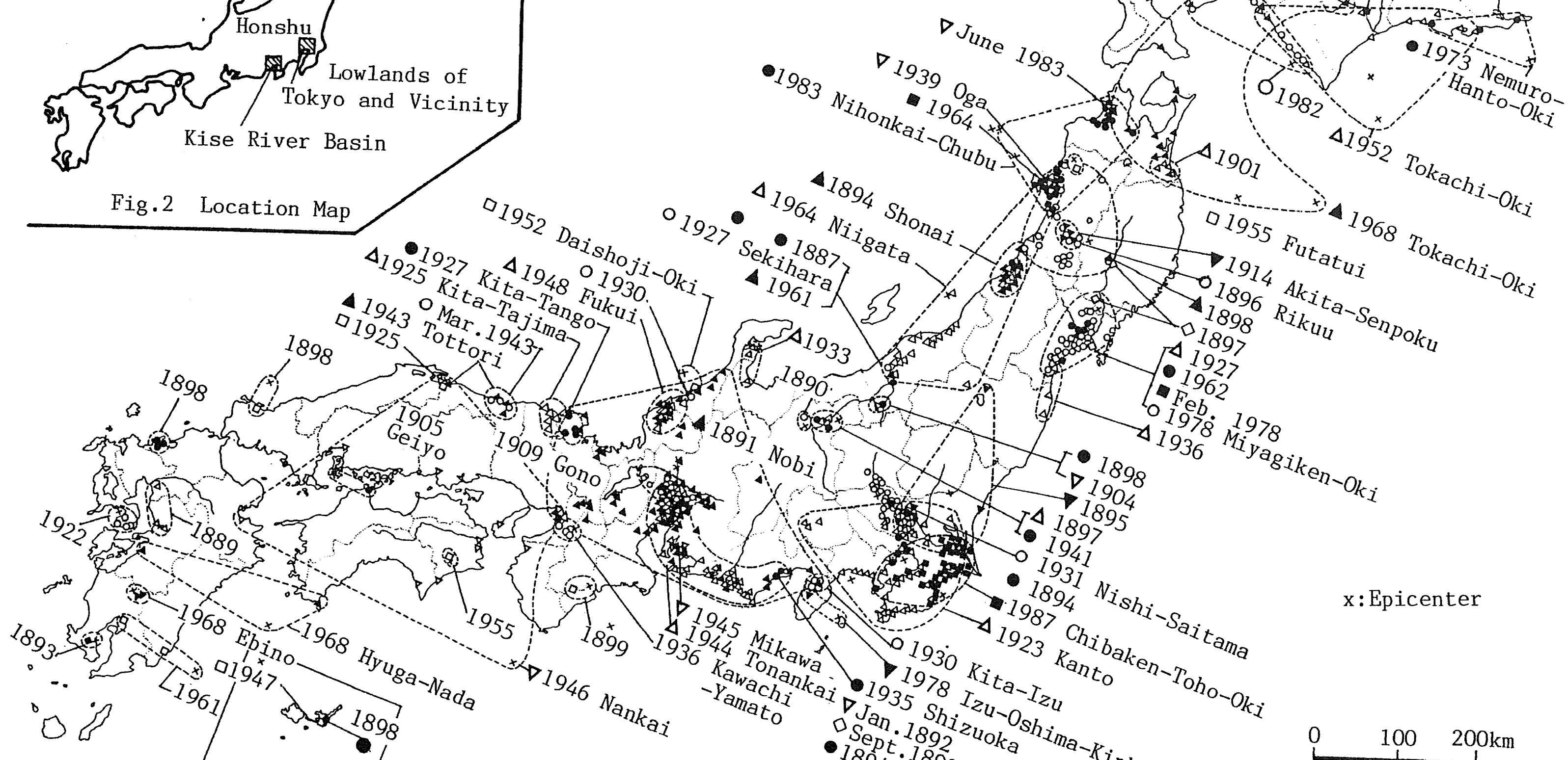

Fig.1 Distribution Map of the Liquefied Sites in Japan (1885-1987)

Liquefaction susceptibility for each geomorphological unit The writers have investigated the geomorphological settings of the areas where liquefaction had occurred and have examined the correlation between the geomorphological conditions and liquefied sites. As a result, the following matters became clear. The *liquefaction was observed in numerous cases in natural levee, river channel,* reclaimed land and drained land, and in few cases in sand bar, delta, back marsh and valley plain. In sand dune zone along coast, liquefaction was frequently observed. In these cases, the liquefaction occurred along inland margin of a dune and in lowland between dunes . In an alluvial fan, liquefaction was seldom observed. Even if it occurred, it tended to appear on the gentle slope of the fan with vertical gradient of less than about 5 in 1000. In these cases, the liquefaction concentrated in the lower edge of the fan where the underflows of the fan spring out to the ground surface .

To clarify the intensity of earthquake ground motion which caused liquefaction, seismic intensity data by the Japan Meteorological Agency (JMA) at the liquefied sites were examined. The results showed that the liquefaction generally occurred with the ground motion of intensity 5, or higher, in the JMA scale, as pointed out by Kuribayashi and Tatsuoka (1975). But, in reclaimed land, drained land, natural levee, river channel or marginal part of sand dune, the liquefaction occurred even at intensity 4. The JMA intensity 5 and 4 correspond to about the Modified Mercalli intensity 8 and 7, respectively. As a result, the criteria of the qualitative susceptibility to liquefaction for various geomorphological units of Japanese alluvial lowland is summarized in Table 1.

Liquefaction potential map based on the geomorphological land classification

Liquefaction potential maps can be readily compiled based on the published geomorphological land classification maps in reference to the criteria in Table 1. More precise prediction taking the local site effect into account is possible by making supplemental geomorphological surveys. The writers have tested such type of predictions for three areas of special interest. They involve typical geomorphological settings, and also, they are located in the areas of high seismic risk in Japan (Fig.2). In the following, our procedure for compiling the liquefaction map of the Shonai Plain in Yamagata Prefecture is demonstrated.

Liquefaction potential map in Shonai Plain The Shonai Plain is located in the northern part of Honshu, Japan, and faces the Japan Sea. Geomorphologically, the plain consists mainly of the swampy delta and the belt of sand dunes along the coast. Such a type of plain can be seen in Niigata City and its vicinity which is famous for the liquefaction damages in the Niigata Earthquake of 1964.

At first, the geomorphological land classification map in a scale of 1 to 50,000 was made. During the geomorphological studies, the following items were taken into account for the purpose of estimating the risk of liquefaction:

Table 1 Estimated Susceptibility for Liquefaction in Geomorphological Units subject to Ground Motion of the J.M.A. Intensity 5

Geomorphological Unit	Susceptibility
(A) Reclaimed Land, Drained Land, River Channel, Sand Dune(Margin)[1)], Lowland between Sand Dunes or Bars, Natural Levee[2)], Banking Area in Swampy Lowland	High
(B) Sand Bar, Delta, Back Marsh, Valley Plain, Gentle Slope Alluvial Fan[3)]	Rather Low
(C) Lowland excluding (A) and (B),	Low

1):including outer margin of dune

2):including outer margin of levee

3):vertical gradient is less than about 5 in 1000

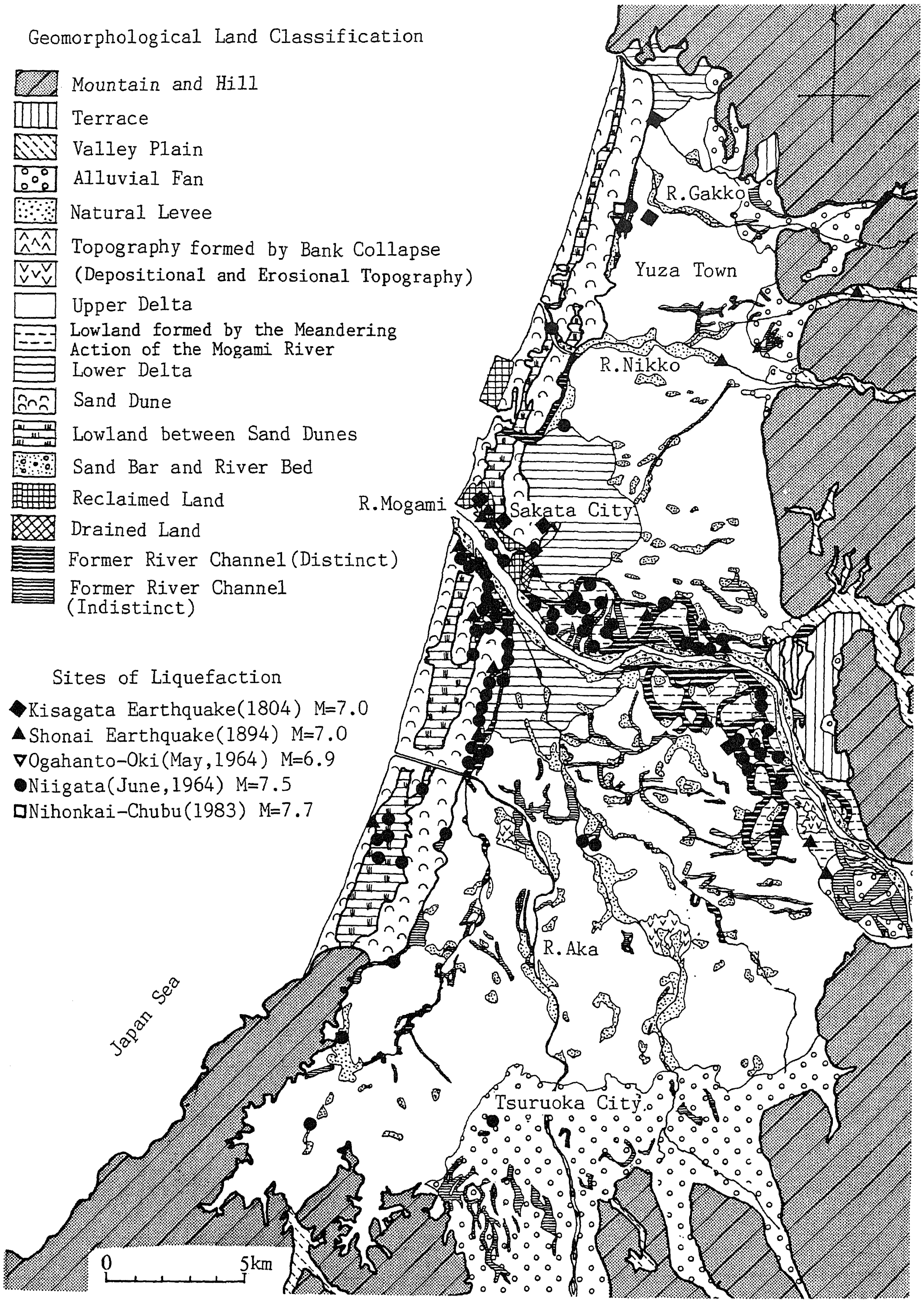

Fig.3 Geomorphological Land Classification Map and Liquefied Sites in Shonai Plain

Table 2 Possibility of Liquefaction subject to Seismic Ground Motion of the J.M.A. Intensity 5 in the Shonai Plain

Geomorphological Unit	Possibility of Liquefaction
Valley Plain	Low
Alluvial Fan	Low in general, but exists to some degree in the spring-zone lying along lower edge of fan
Natural Levee	Exist to some degree
Upper Delta	Low in general, but exists to some degree in the marginal part of former river channel, former pond, lower edge of fan, sand dune or natural levee
Lowland formed by the Meandering Action of the Mogami River	High
Lower Delta	Low
Sand Dune	High except top of dune
Lowland between Sand Dunes	Exist, but is high around the springs
Sand Bar and River Bed	Exist to some degree
Reclaimed Land	High
Drained Land	Low
Former River Channel (Distinct)	High
Former River Channel (Indistinct)	Exist to some degree
Springs	High around the springs in every geomorphological unit

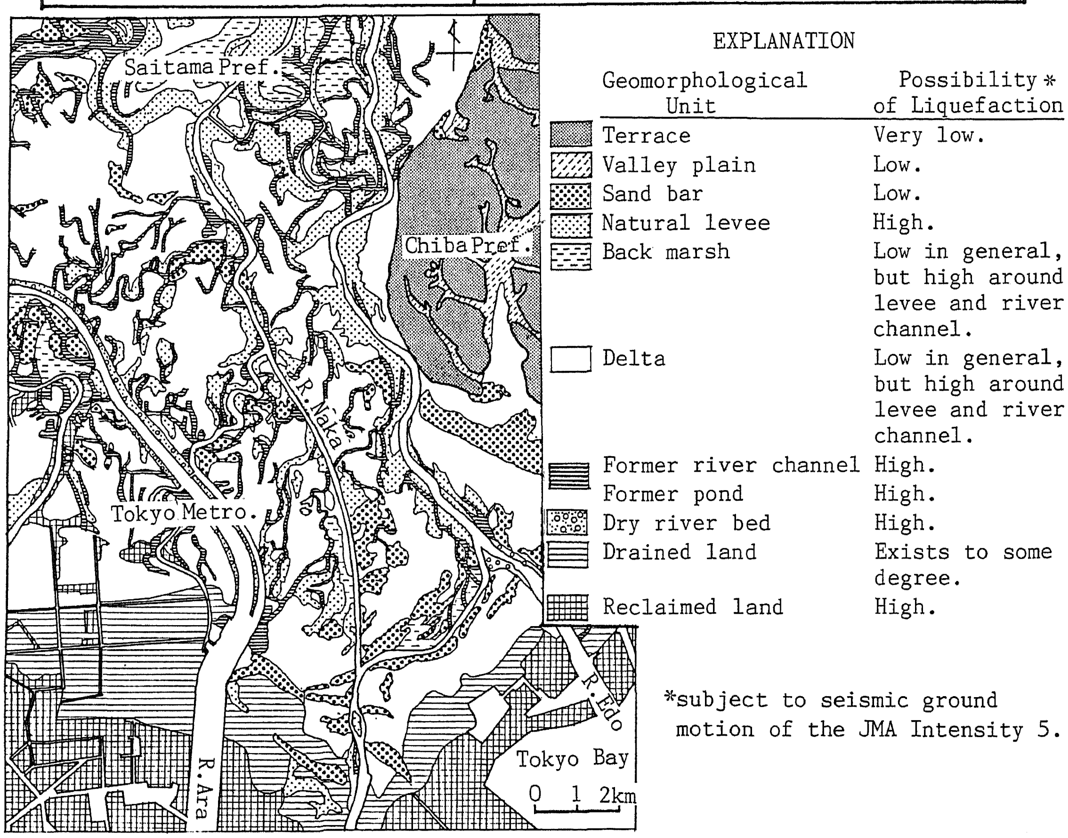

Fig.4 Liquefaction Potential Map of the Lowlands of Tokyo and its Vicinity

Correlation between the geomorphological unit and subsurface geotechnical ground condition; Interpretation of the former river channels; Date, materials and method of the reclamation; Ground water conditions such as the depth of the ground water table, the distribution of the springs, the artesian condition and etc.

On the other hand, the distribution map of liquefied sites in the past earthquakes was compiled. In the plain at present, soil liquefaction was observed in the earthquakes of 1804, 1894, May 1964, June 1964 and May 1983 as shown in Fig.1. Among the earthquakes, the last one named the Nihonkai-chubu Earthquake occurred after our compilation of the liquefaction potential map.

In Fig.3, liquefied sites in the five shocks are plotted on the compiled geomorphological land classification map. In the map, the deltaic lowland lying along the main river Mogami, in which the network of the former river channels are seen, is one of the geomorphological characteristics of the Shonai Plain. We named it the lowland formed by the meandering action of the Mogami River. In the figure, it can be noticed that the liquefied sites concentrated commonly in the four geomorphological units, in spite of the differences of the earthquake conditions such as the earthquake magnitude and location of epicenter. They are, the inland margin of the sand dune, the lowland between dunes, the lowland formed by the meandering action of the Mogami River and reclaimed land lying in the estuary of the Mogami River. Therefore, these geomorphological units would be the most susceptible to liquefaction among the various units of the plain. In Table 2, the estimated possibility of liquefaction for main geomorphological units of the Shonai Plain is listed.

By the method as mentioned above, the maps for the other two areas have been compiled in a scale of 1 to 25,000. In Fig.4, the map of the lowlands of Tokyo and its vicinity is shown. In compiling a map, data of geomorphological settings and correlations between geomorphological conditions and liquefaction susceptibility in a given area are needed. If the records concerning liquefaction in an area are insufficient for evaluation of liquefaction susceptibility in a given geomorphological unit, the susceptibility in other areas which have similar geomorphological setting could be adopted.

CONCLUSION

The criteria of liquefaction susceptibility for various geomorphological units composing the alluvial plains in Japan was proposed, and the liquefaction potential maps were compiled for three sample plains. Half a year after the writers published the map of the Shonai Plain, the liquefaction actually occurred in the Nihonkai-chubu Earthquake of 1983 at the sites which were estimated as having high possibility of liquefaction.

To predict the quantitative liquefaction potential at a particular site in an area, more precise geotechnical investigations and analyses are required. However, this paper suggest that the map of the present level is still useful for preliminary assessments of liquefaction hazard and proper selection of site or route of structures. Additionally, the map provides us with another useful geotechnical information because it visualizes the geomorphological land classification.

REFERENCES

1. Kuribayashi, E. and Tatsuoka, F.,"Brief Review of Liquefaction during Earthquakes in Japan," Soils and Foundations, 15-4, 81-92, (1975).
2. Oya, M., Kotoda, K., Wakamatsu, K. and Kubo, S.,"Geomorphologic Land Classification Map of the Shonai Plain Illustrating Features of Flooding and Soil Liquefaction," Sakata Work Office, Ministry of Construction, (1982).
3. Oya, M., Kotoda, K. and Wakamatsu, K.,"Geomorphological Land Classification Map of the Kise River Basin Located near the Mt. Fuji," Numazu Work Office, Ministry of Construction, (1985).
4. Oya, M., and Haruyama, S.,"Geomorphologic Land Classification Map of the Katsushika Ward(Tokyo) and Its Vicinity," Board of Education of Katsushika Ward, (1987)