SEISMIC HAZARD ANALYSIS BASED ON THE GEOLOGICAL, GEODETIC AND ARCHEOLOGICAL STUDY

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SUMMARY

The historical geological, archeological and geodetic observation of past earthquake events along the Nankai trough provides variable information on estimating the earthquake occurrence pattern. The geological observation of crustal movement has shown that the time of occurrence of a great earthquake can be predicted from the amount of the fault slip of the preceding earthquake. Studies of historical earthquake sequences on a subduction zone have shown that the characteristics of recurrence pattern. The systematic interactions between large event have value in the prediction of future earthquake events. The combination of geodetic, geological, and archaeological studies are important to estimate the next great Nankai earthquake with magnitude more than magnitude 7.5.

INTRODUCTION

The destructive earthquake in Shikoku region includes the large M7 level earthquakes that recurred in the Pacific Ocean. The Seismic activity of the South-West region Nankai trough is on the northern boundary of Philippine Sea. Along this trough, many great earthquake events, which were accompanied by the large crustal deformation. recorded in historical documents. In particular the historical, geodetic, and archeological studies are used to estimate the time and space of the next large earthquakes based on the time-predictable model. The ancient liquefaction events along the trough are also used to determine the sequence of the great earthquakes along the Nankai trough in this study. The Nankai trough earthquake is expected along plane D off the Tokai area where the historical, geological, and geodetic observation of past earthquake events along the Nankai trough provides variable information on estimating the earthquake occurrence pattern.

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past earthquakes along the Nankai trough provide variable information on estimating the earthquake occurrence pattern. The geological observation of crustal movements has shown that the time of great earthquake can be predicted from the amount of the fault slip of the preceding earthquake. Also studies of historical earthquake sequences on a subduction zone have shown that the characteristics of recurrence pattern such as systematic mitigation clustering and interaction between large event have value in the prediction of future earthquake event. The combination of geodetic, geological, and archaeological studies are important to estimate the next great Nankai earthquake with magnitude 7.5.

Based on the triangulation and triangulation results after the 1946 event reveal that current inter-seismic strain accumulation is characterized by northwest-southwest contraction of about $3\sim6\times10^{-7}$/yr. in maximum shear strain rate.

Seismic activity in the Chugoku-Shikoku region can be divided onto two types. First are earthquakes that occur near the plate boundary subducting. Second are those occurring in shallow locations on land at depths of 20km or less.

The crustal deformation of Japanese islands, one of the major subduction zone continental margins in the world, has been revealed in detail with the nationwide GPS array in the central and western Nankai region .

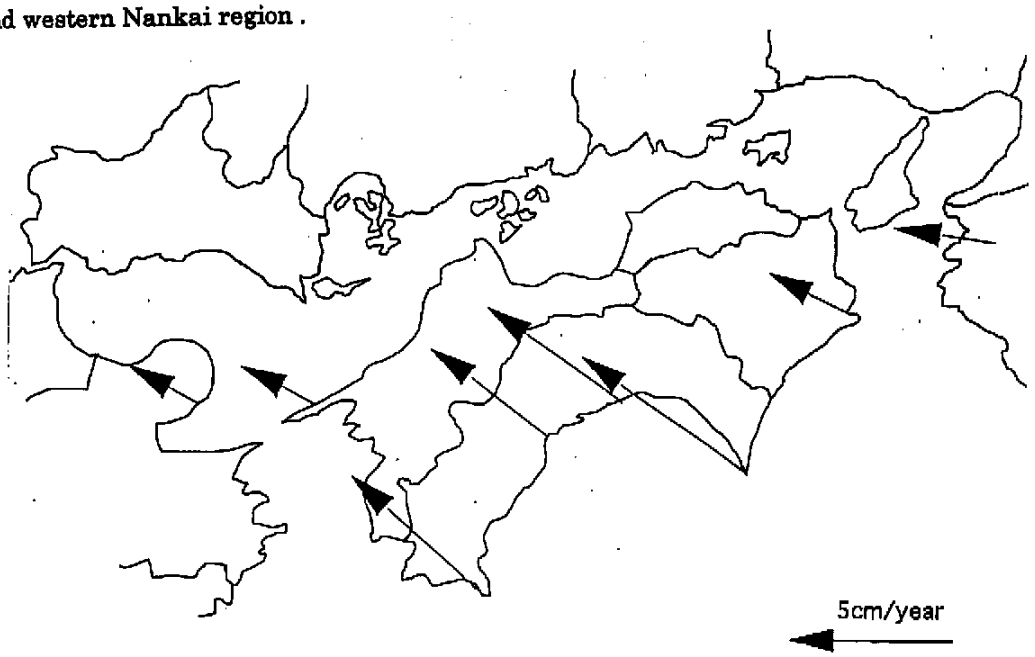


Fig.1 Velocity field of south west Japan

In recent year, the global positioning system GPS , which is a world wide precise positioning system enable us to detect highly-precise three dimension of crustal deformation. 600 observation stations are operated in Japan. GPS originally developed as a satellite-based navigation system by the US Department of Defense has been applied recently to the study of earthquake. With this satellite technology, scientists are able to obtain extremely precise

measurements of motions of the surface of the earth. The earth is continually being deformed by motion of the tectonic plates that make up its crust. This deformation is particularly pronounced in places such as Japan, which lies on the boundary between major tectonic plate as shown in Figure 1.

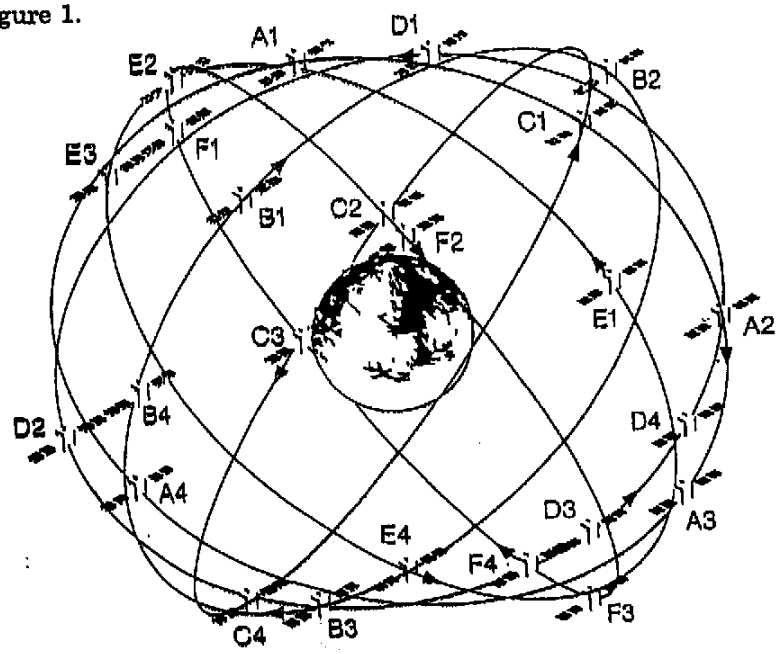
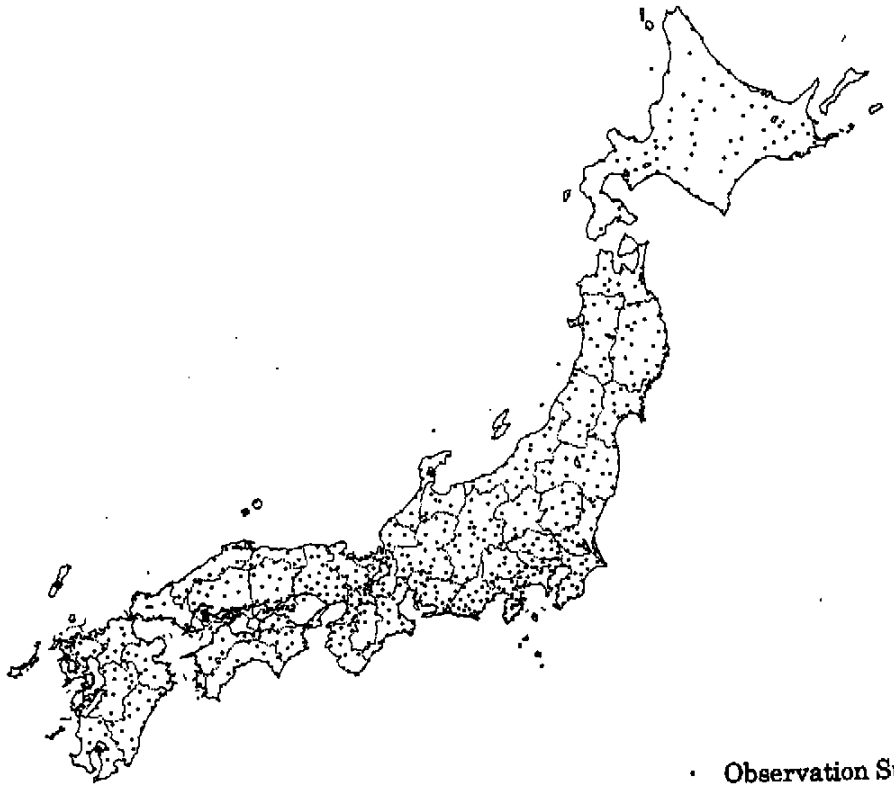


Fig. 2 Global positioning system for observing crustal deformation



· Observation Station

Total 600 station

Fig.3 Crustal deformation observed by global positioning system

2. Observation

The Shikoku district is one of the most seismically active regions in Japan and is one of the most historically active area The carats deformation GPS observation of deformation. For highly precise baseline determination with GPS, precise satellite ephemeredes are indispensable even in local network analysis shows length changes in three baselines of approximately equal length.

Great earthquakes occur along the Nankai Trough in the Pacific Ocean. Seismic activity in this area is seismically active. The Philippine Sea Plate is subducting toward the Chugoku-Shikoku region from the Nankai Trough, which lies in the Pacific Ocean off the coast of Shikoku. The earthquake that occurs near the plate boundary.

3.Curustal deformation observation

With regard to horizontal base line components, the standard deviation in each observation was roughly from 10 to 20mm in 1990 and 1991. Figure shows base length changes in three base line change rate are approximately equal length.

Global Positioning System (GPS) ,which is a world-wide precise positioning system operated by the U.S. Department of Defense, has become a popular and useful device for geodetic survey and crustal deformation observation. For precise positioning system operated by the U.S.D Department of Defense ,has become a popular and very useful device for geodetic survey and crustal deformation observation .A dense and wide permanent GPS station network has been established in Japan.

4.Seismity in Shikoku

The Philippine Sea Plate is subducting toward the Chugoku-Shikoku region from the Nankai Trough, which lies in the Pacific Ocean off the coast of Shikoku.The earthquakes that occur near the plate boundary off the coast of Shikoku are classified as Interplate earthquakes that occur due to the slipping movement at the boundary between the subducting Philippine Sea Plate and the land plate and earthquakes that occur in somewhat deeper areas within the subducting Philippine Sea Plate.

The great earthquakes have occurred along the Nankai Trough., which lies in the Pacific Ocean off the Trough. The earthquakes that occur near the plate boundary off the coast of Shikoku.The earthquakes that occur near the plate boundary off the coast of Shikoku are classified as Interplate earthquakes that occur due the slipping movement at the boundary between the subduction Philippine Sea Plate and the land plate and earthquakes that occur in deeper area.. The great earthquake s of this type have occurred along the Nankai Trough. The seismic ground motion from these earthquakes caused damage in a

5.Types of earthquakes near the plate boundary off the coast of Pacific Ocean

The Philippine Sea Plate is subducting toward the Chugoku-Shikoku region from the Nankai Trough, which lies in the Pacific Ocean off the coast of Shikoku. The earthquake occurred near the plate boundary off the coast of Shikoku. The earthquake occur near the plate boundary off the coast of Shikoku. The earthquakes that occur near the plate boundary off the coast Shikoku are classified as interpolate earthquakes that occur near the plate boundary off the coast of Shikoku. the slipping movement at the boundary between the subducting Philippine Sea Plate and .the land plate and earthquakes that occur in deeper areas within the subducting Philippine Sea Plate.

6.Earthquake caused by subduction

Great earthquakes of this type have occurred along the Nankai Trough. Some of the largest earthquakes in Japan have been of this type. An example is the 1707 earthquake (M=8.4) with a broad source region from the western part of Suruga Bay to Western Shikoku.Th Earthquake One of these older earthquakes occurred in 684. In addition to damage caused by the seismic ground motion throughout the region. Historical records indicate that many ships were sunk by the tsunami at Tosa Later earthquake occurred in 887,1096 and 1099,1361,1498,1605, 1707,1854, 1944 and 1946. Therefore, great earthquakes of M8 or so have recurred at interval of 100 to 150years along the Nankai Trough..

7. Monitoring of crustal deformation

Achieving real time mitigating and improved precision of measurement are essential for progress of earthquake prediction studies. But real time monitoring by GPS enables us to observed precision to large earthquakes in real time. During the last few years the application of the Global Positioning System (GPS) to geodesy has been a major development area This technique now uses the Monitoring of crustal deformation.

8. Nation wide network

Nation-wide continuos GPS observation network is established in Japan. This network is designed for crustal deformation observation network by GPS spacing between the stations and deformation observation and a new control point network by GPS . Because of the different purpose of establishment, spacing between the station and station. Spacing of net work is about 100 km for the nation wide network., and this network is connected with the global GPS site.

9.Curustal Deformation

With regard to horizontal baseline components, the standard deviation each campaign was about 10 to 20 mm between 1990 to 1991. While a standard deviation in each campaign was roughly from The rates of change are roughly comparable deviation in 1990 and 1991. The rates of change are roughly comparable approximately 15 to 19 mm/yr. convertible to strain approximately 15 to 19 mm/yr. Figure 3 shows horizontal strain rates are characterized by a contraction of $2.2\sim3.4\times10^{-7}$/yr. in a northwest to southeast direction.

These strain are in good agreement with the average interseismic strains drived from long-term triangulation and triateration surveys conducted after the 1946 event. The southeastern part of Shikoku provides a good observation field for monitoring the earthquake deformation cycle.

10.Earthquakes in Shikoku

The earthquakes within the subducting Philippine Sea plate. The depth of earthquakes within the subducting Philippine Sea Plate is about 30km near the Pacific Ocean coast in central Shikoku.

(1)Great earthquakes along the Nankai Trough

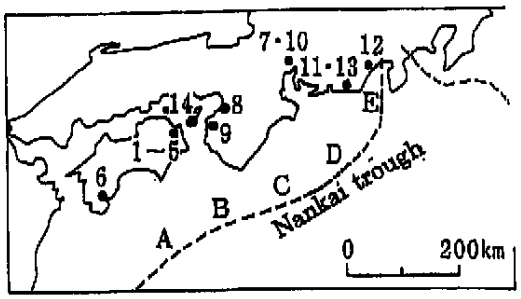
The Ansei Nankai Earthquake	December 24 1854.	M=8.4
The Nankai Earthquake	December 21 1946	M=8.0

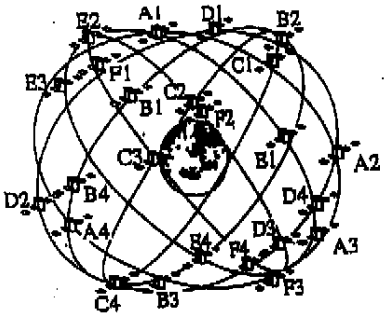
The Ansei Nankai Earthquake was plate earthquake with a source region in an area along the Nankai Trough. The great earthquakes along the Nankai Trough have occurred either simultaneously or in series in adjoining source regions. Many of those that have continued in a series have started on the eastside (Tokai Earthquake) and later moved to the westan side. The great earthquakes along the Nankai Trough have occurred either simultaneously or in series. Many have started on east side and later moved to the west side (Nankai earthquake) .The seismic ground motion and size of the tsunami differ considerably with each occurrence For example the 1605 earthquake generated a tsunami that struck the Pacific Ocean coast from the Kanto region to Kyushu,, however ,there was almost no recorded damage from seismic ground motion. It is suggested that this was a tsunami earthquake (slow earthquake whose fault slipped more slowly than that of a normal earthquake.

11 Archeology study

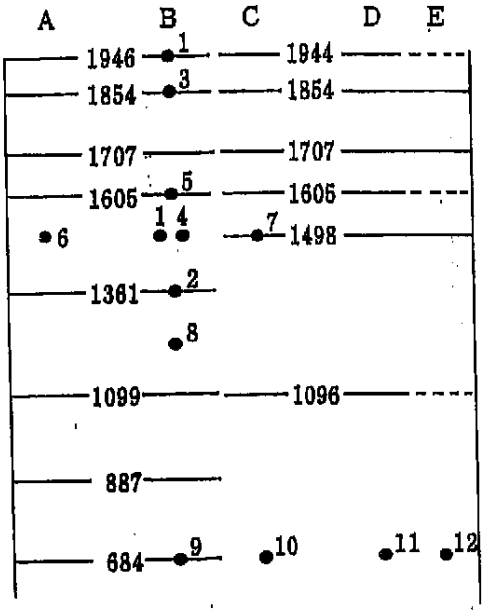
Liquefaction of old earthquake events along the Nankai trough is used to understand the time and location of liquefaction area. Archeology study is used to understand the time and space of liquefaction events of old earthquakes can used to determine the time and space of old

earthquake trace. Along the Nankai Trough many liquefaction trace can find by archeology study. Based on this study we can determine the time and space of large earthquake events. Fig 11 and Fig 22 show old ancient liquefaction remains event along the Nankai trough based on liquefaction events

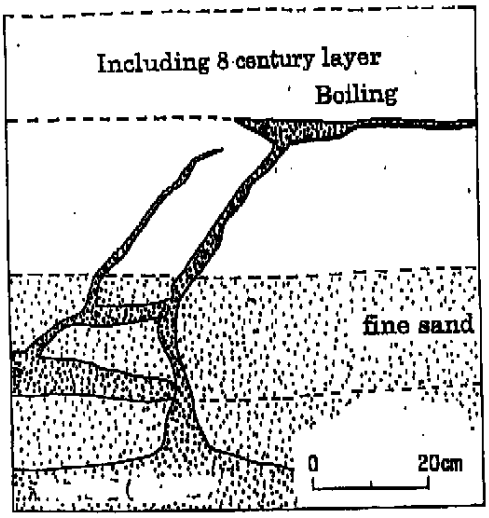


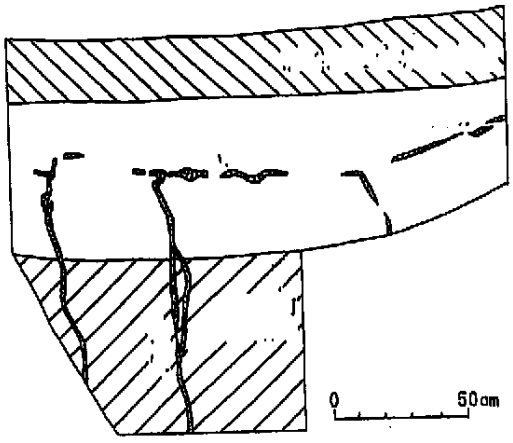


GPS Nabster



Great Nankai earthquakes





Miyanomae liquefaction

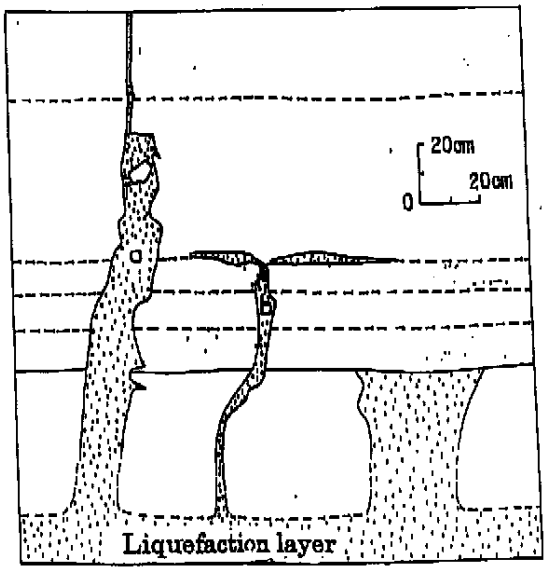


Fig.4 Time and space earthquakes and liquefaction along the Nankai trough

13 Conclusion

1. The geological observation of crustal movements has shown that the time of occurre great earthquake can be predicted from the amount of the fault slip of the p earthquake.
2. Studies of historical earthquake sequences on a subduction zone have shown characteristics of recurrence pattern such as systematic mitigation clustering and int between large event have value in the prediction of future earthquake event.
3. The combination of geodetic, geological, and archaeological studies are important to the next great Nankai.
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