FEATURE OF THE SEISMIC ACTIVITY IN THE FOCAL AREA ASSUMED FOR THE NEXT TOKAI EARTHQUAKE AND ITS TEMPORAL CHANGE

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ABSTRACT

The Tokai district is one of the most remarkable places in Japan, in the meaning of seismic hazard due to an anticipated Tokai earthquake, so has been kept under intensified monitoring of crustal activities. Recently, unusual signals have been detected in the data obtained from the continuous observation. First, a delicate but clear quiescence was found to start in the seismicity within the subducted Philippine Sea slab since August, 1999. The similar quiescences were also found to progress in other areas, the seismicity within the overriding plate, and the clustered activity beneath Lake Hamana, all of which are considered to be related to the locked subduction. Subsequently, a gradual slipping on the plate interface was found to occur since the latter half of 2000, based on the GPS monitoring respecting the ground surface movement. Such contemporaneous activities deviating from the normal movement attributable to the stable convergence of the Philippine Sea plate lead us to imagine an anomalous change progressing in the locking state between the plates. The degree of the quiescence is very small, and the rate of the slipping is very slow, but they are still going on. Though we cannot yet present any rationalized interpretation that is explainable all the phenomena observed by now, it is important to monitor the following activities, and to make an effort to expose the hidden evidences in order to realize the prediction of the next Tokai earthquake.

1. INTRODUCTION

The Tokai district, located around the central part of the Japan islands is well known as one of the most dangerous places in Japan since 1976, when Ishibashi(1976) gave a warning to the public that a mega-thrust earthquake had been impending around the Suruga bay, that is the next Tokai earthquake. This earthquake is regarded to belong to the historical Tokai earthquake series, the latest one of which was the 1944 Tonankai earthquake. The problem is that the fault area of the latest one did not reach inside the Suruga Bay. Based on this evidence, Ishibashi concluded that the Tokai area around the Suruga Bay was left as a potential seismogenic area, having been accumulating stress since the 1854 Ansei Tokai earthquake, and as a result, had been grown enough to arouse M8 earthquake. However, it has already passed more than 20 years without any occurrence of the focussed one. During the while, various kinds of observation networks have been developed covering the Tokai area in order to monitor and catch any gradual or small signal change. One of representatives is a high sensitive seismic network, which was constructed and has been operated by our institute, the National Research Institute for Earth Science and Disaster Prevention (NIED). Another is the GPS network constructed and managed by the Geographical Survey Institute (GSI). Both networks could provide remarkable results, which led us to a new point of view for the impending Tokai earthquake. The obtained results was utilized for reevaluation of the potential seismogenic zone for the next Tokai earthquake. Furthermore, we have recently detected anomalous movements in the seismic acitivity and in the crustal deformation.

2. REEVALUATION OF THE SEISMOGENIC ZONE

Ishibashi proposed his original prospective view for the seismogenic zone of the next Tokai earthquake by investigating the historical evidences that appeared with the occurrence of the 1854 Ansei Tokai earthquake. This zone has a rectangle shape enclosing the west Suruga Bay and the coastal area of the Shizuoka prefecture (see Fig.1). This was adopted as an official model by the government organization, the Central Disaster Management Council in 1978. Based on this model, various kinds of countermeasure acts had been set up by the government, the local autonomous bodies, and the public offices.

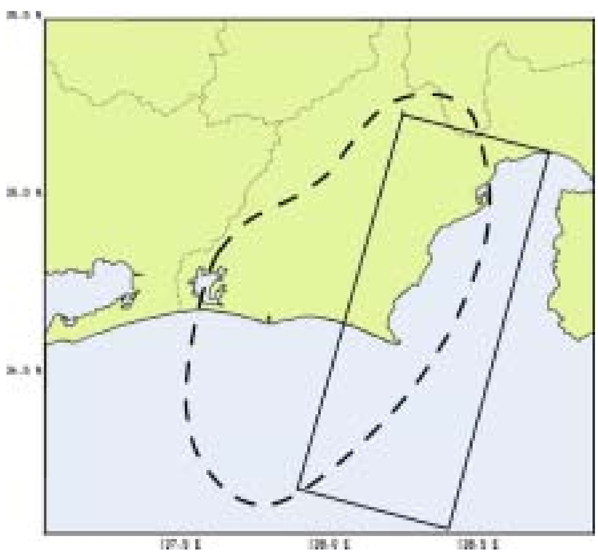

Figure 1: Seismogenic zone assumed for the next Tokai earthquake

During the following two decades, the advanced observations have provided a plenty of data to introduce a new outlook of the Tokai earthquake. At this point, the assumed zone came to be revised into a new version as shown like an egg-plant drawn with the broken line in the figure. These evidences provided from the new observations are the microearthquake distribution and the ground surface deformation. The former is given by the high-sensitive seismic network of NIED, and the latter by the GPS network of GSI. Figure 2 shows an image of the evidence possibly progressing under the western Shizuoka prefecture. The Philippine Sea plate is subducting under the overlying plate in and around the Tokai area, where the subduction must be locked along a part of the plate boundary as indicated in the thick solid line, while the rest of the boundary is slipping (broken line). Then, such a situation should cause a stress concentration surrounding the locked part, and also should cause surface deformation as shown in the figure (arrows). Based on this image, we analyzed the microearthquake distribution and its focal mechanism pattern, which resulted in drawing a map of the locked zone. The map is shown in Fig.3 (gray-shaded area, refer to Matsumura, 1997). On the other hand, the similar map was drawn through the analysis of the surface movements, based on the GPS data (Sagiya, 1997), which is also shown in Fig.3. The distribution of the small arrows indicates movement of the upper plate dragged by the lower plate due to locked subduction (this phenomenon is called a back-slip).

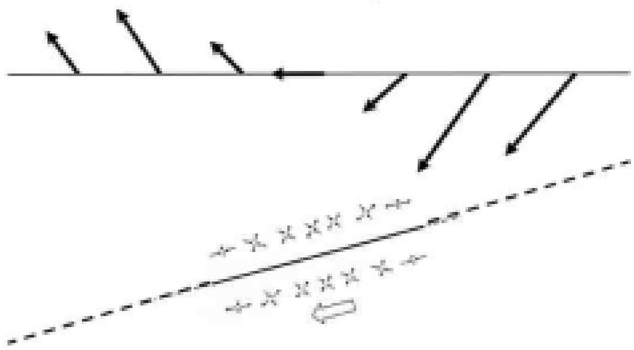

Figure 2: Stress concentration and surface deformation induced from a locked subduction

Here, it must be noticed that both results bring a significant spatial discrepancy between each other. The back-slip distribution definitely deviates toward the ocean side from the shaded area. However, this discrepancy can be resolved by introducing the following explanation. Figure 4 presents two cases of simplified model representing a locked subduction, where the upper plate (the prism-like block) is dragged by the lower subducting plate (the thick arrow) through the point of the small arrow. The left figure shows stress/ strain distribution, while the right one shows distribution of displacement. We consider that the left case reflects the result provided from the microearthquake data, and the right one from the GPS data, because the former one should be essentially related with the stress/strain distribution, while the latter with the

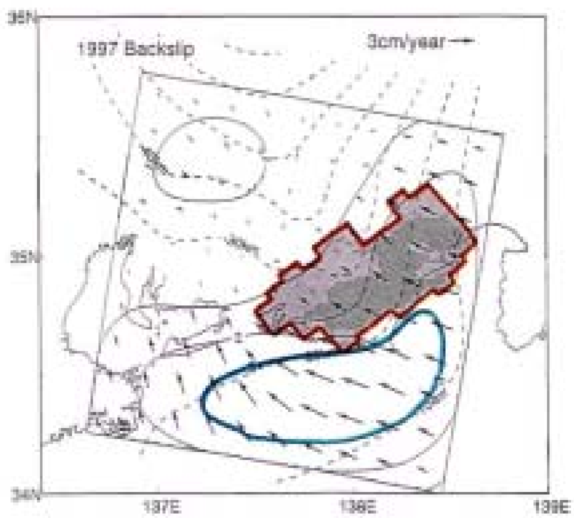

Figure 3: Locked subduction area (shaded zone), and back-slip distribution (arrows)

displacement. As a result, it seems reasonable that both figures drawn from the seismic analysis and from the back-slip analysis have a discrepancy between each other. Taking such an interpretation and all the other knowledges respecting plate configuration, thermo-dynamic structure, and etc. into account, the new model of the potential seismogenic zone for the next Tokai earthquake was formulated as shown in Fig.1.

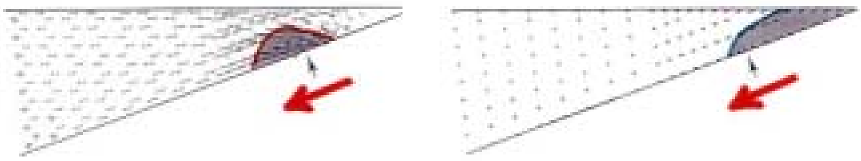

Figure 4: Model representing stress distribution (left) or displacement (right) induced from a partially locked subduction.

3. ANOMALOUS ACTIVITY

We have been maintaining a consistent condition for microearthquake observation during almost two decades, and were impressed on that the

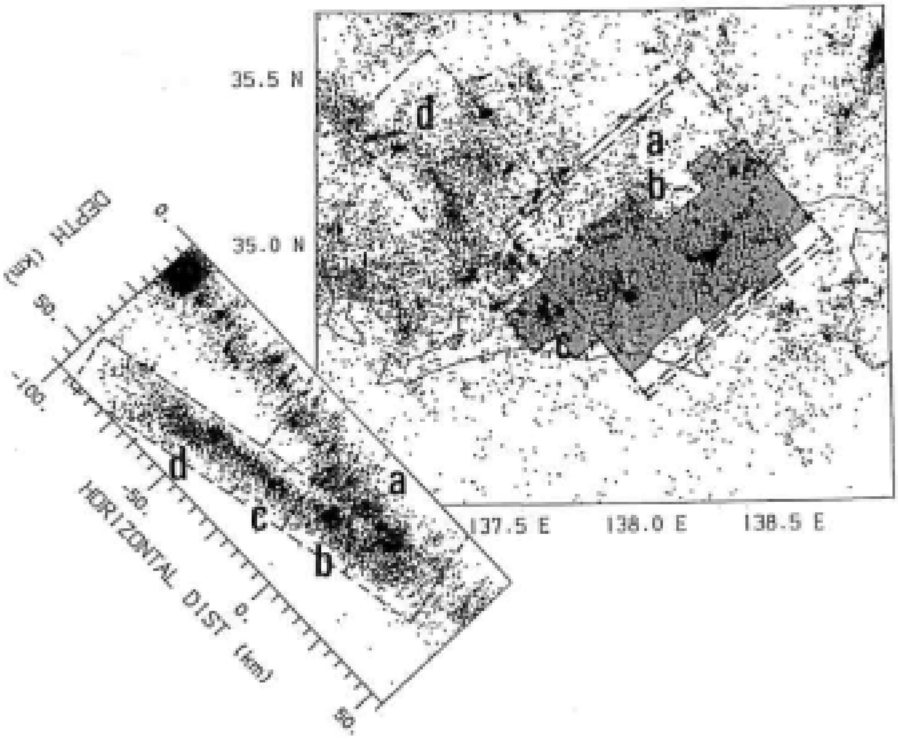

Figure 5: Hypocentral distribution of microearthquakes in the Tokai district obtained by the Kanto-Tokai observational network of NIED

seismicity rate in and around the Tokai area was very much stable for a long period. Under such a circumstance, unexpected changes have commenced to make us strained. Figure 5 shows the hypocenter map and its vertical section viewed along the subduction direction in and around the Tokai area, where the subducting structure and the configuration of the Philippine Sea plate is clearly recognized. From

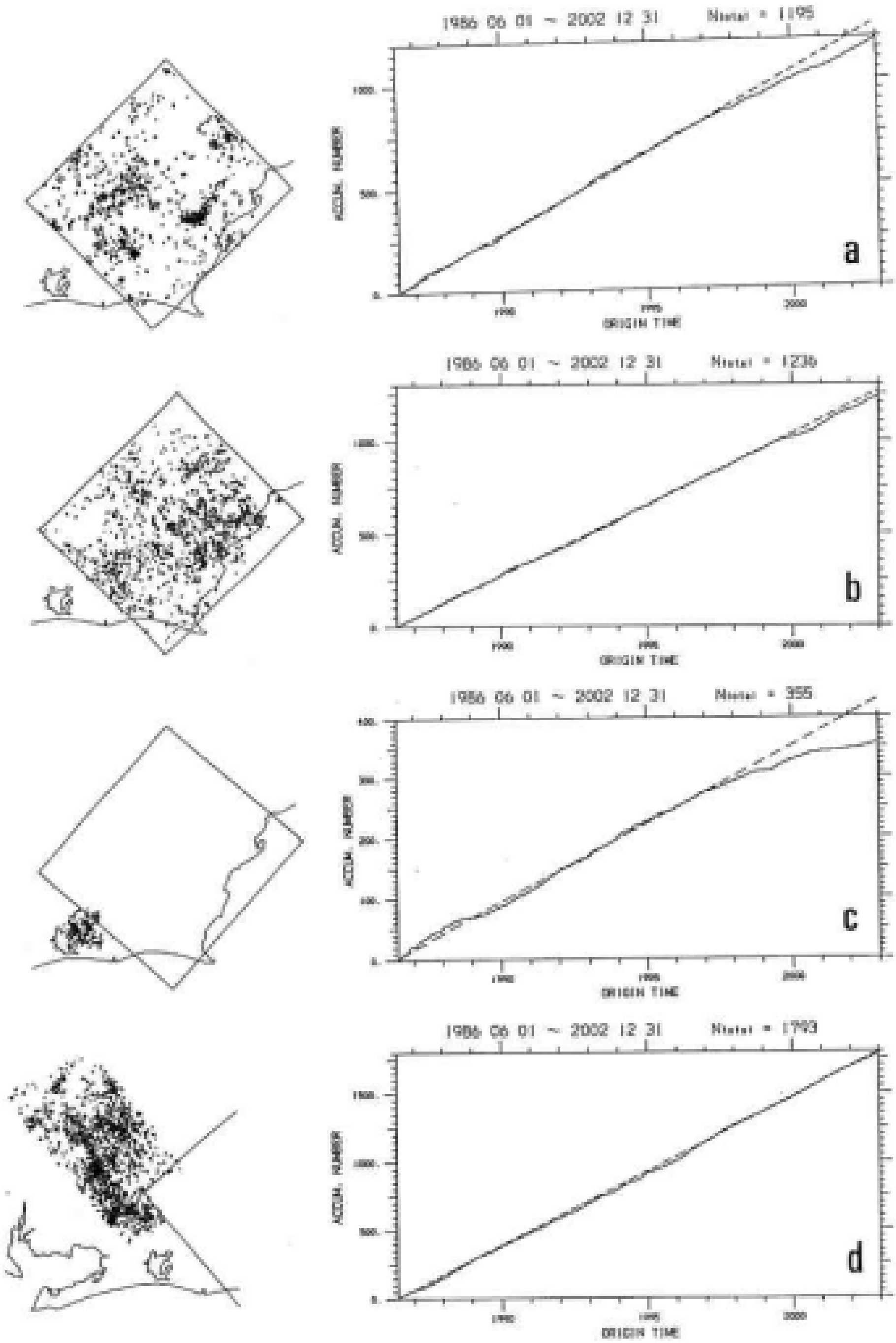

Figure 6: Graphs of accumulated number of earthquakes

this, we selected four parts of the seismicity in order to monitor the movement of the plate, and to check the state of the locked subduction. The four regions are (a) the upper layer above the locked zone (within the crust), (b) the lower layer beneath the locked zone (within the subducted slab), (c) a small clusterized zone just beneath Lake Hamana (within the slab), and (d) a tail-like seismic zone extended from Lake Hamana (within the slab). Then the next step is to examine each sesimicity rate on a temporal axis. The number of earthquakes of M1.5 or greater is drawn as accumulated graphs in Fig.6, where the time scale is from June 1986 till December 2002. The most noticeable feature in these graphs is that a slight but significant decreasing trend of the seismicity happened in the later period of 1990s for the upper three cases, (a), (b), and (c), excepting the bottom one (d). The difference between them is that the former ones are all belonging to the zone of the locked subduction, while the last one is not. We consider that the stress origin for the last case can be attributable to the deformation of the subducted slab (refer to Matsumura, 1997), so that it can faithfully reflect the plate motion. This implies that the plate motion must be constant during the entire period, so should not be the origin of the seismicity change. Then, the change of the seismicity should be attributed to some change of the locking state, which happened in the later 1990s, and was still going on.

Delaying a little after the seismicity change, another anomalous evidence was found. The surface ground movement measured by GPS happened to indicate a clear deviation from the secular trend in the latter half of 2000. This was interpreted as that a part of the locked plate boundary came to be unlocked, and a slow reverse slipping is progressing.

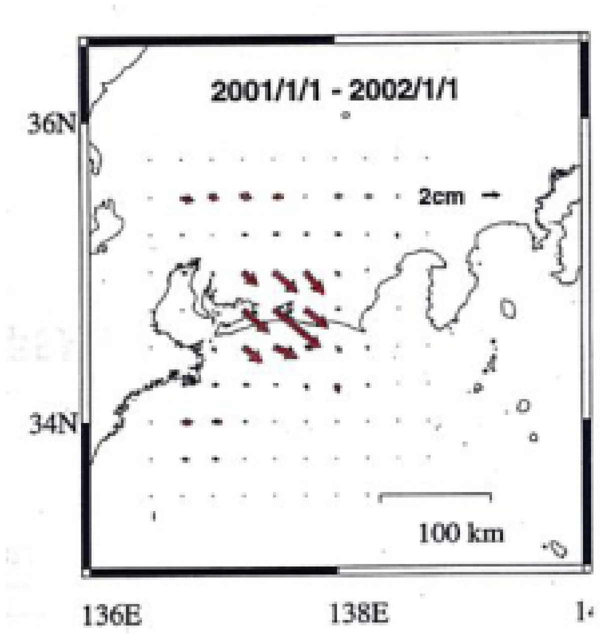

Figure 7: Slow slip (forward-slip) on the plate boundary (cited from Ozawa et al., 2002)

The center of the slow slipping was placed just beneath the Lake Hamana in the early stage of the anomaly (see Fig.7). At a later period, the center of the slipping moved its center northwestward, and is still continuing by now.

4. DISCUSSION

The problem is "What is going on the plate boundary and how is it going to change?". Although we never get any information directly describing the truth, it is necessary to construct some assumptions and interpretations in order to understand the present situation, and if possible, in order to make a prescription for its future state.

Figure 8 shows a spatial pattern of the seismicity rate change now progressing inside the subducted slab. The anomaly commenced in the latter half of 1990s. Then, regarding the first 10 years from June 1986 till May 1996 as a regular period, we compared the seismicity rate of the anomalous period from August 1999 till December 2002 with that of the regular one. Though the rate averaged for the entire zone indicates a decreasing trend, the overall pattern is not uniform. The black area in the figure corresponds to where the rate has decreased (less than 100%). On the other hand, the white area is where the rate has increased (more than 150%). What does this mean? It is proposed that the seismicity rate may represent the rate of the stress accumulation (Dieterich, 1994). Viewing the pattern of Fig.8 and taking Dieterich's assumption into consideration, we propose the following assumption.

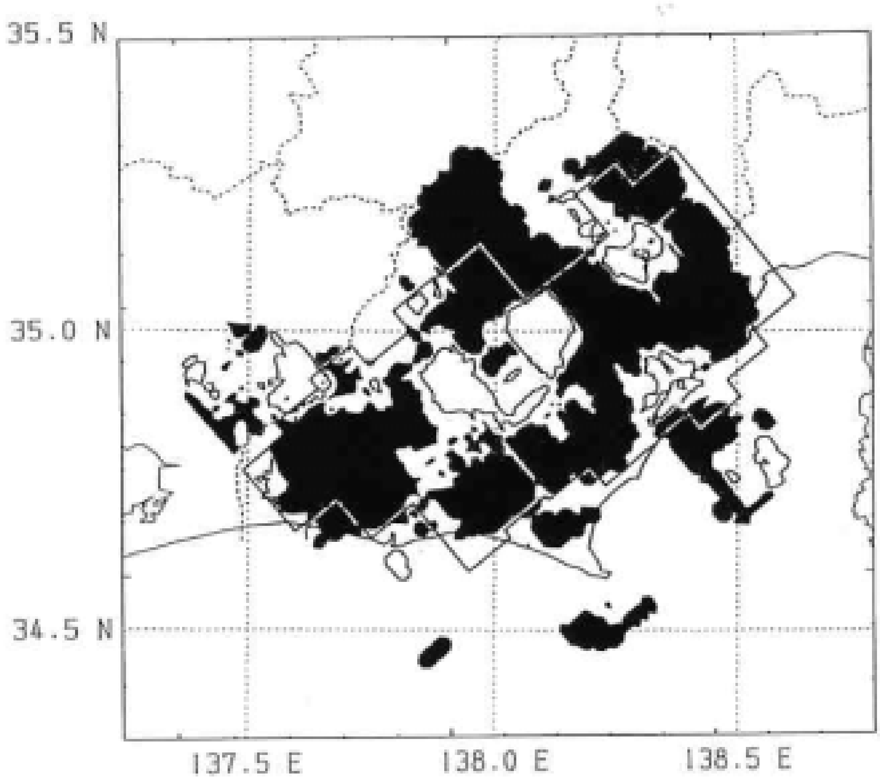

Figure 8: Spatial pattern of the seismicity rate change within the Philippine Sea slab

The locked zone on the plate boundary was once released at the occurrence of the 1854 Ansei Tokai earthquake. Just after this event, the locking state may start to hold again, and the breakage zone may be rapidly healed up. It seems natural that the strength of the locking would not be uniform over the entire locked zone. Probably even in the early stage, there should exist inhomogeneity in strength, however it would not come into the open. After a long time passes and approaches toward a critical stage, the accumulated stress should surpass the mean level of the strength. At this point of time, relatively weaker zone must be slipped, and as a result, the fraction of the stress released should be concentrated toward the stronger zone. We regard the patchwork pattern of the seismicity rate in Fig.8 as reflection of this kind of inhomogeneity in the locking state. If this is the case, the slow slipping observed around the western and northwestern fringe of the locked zone can be easily explained. It should be noted that even in such a stage, the locking is essentially remained, so the entire breakage does not yet occur, but it may be possibly in a critical stage.

5. CONCLUDING REMARKS

We know that the focus region has been accumulating the stress for about 150 years. It may have a potential enough to bring on an M8 earthquake. However, the tectonic situation around the Tokai area is not always distinct. Recently, Heki and Miyazaki(2001), and Sagiya(1999) introduced a new idea that the fraction of the Philippine Sea plate including the Izu peninsula moves independently from the main body, and works as a microplate. In this case, the velocity of the subduction is considered to be smaller than the original estimate, therefore the repetition duration should become longer than 150 years. Compared with such a long duration, the period of our observation is too short to provide an appropriate evaluation for the present state. Nevertheless, we have a great expectation for realizing a practical earthquake prediction for the next Tokai earthquake, because we could have detected finer and more delicate anomalies in continuous monitoring than we expected.

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