Summary

This comprehensive report presents the results of a special research project "Improvement in prediction accuracy for the Tokai earthquake and research of the preparation process of the Tonankai and the Nankai earthquakes", which was conducted by the Seismological and Volcanological Research Department, MRI, from FY 2004 to FY 2008 (five years). The report consists of five chapters: "Investigation of the crust and plate structure beneath the Tonankai and the Nankai areas", "Analysis of underground physical properties using the signal from the Accurately Controlled Routinely Operated Signal System (ACROSS)", "Estimating vertical displacement by tide gauges", "Development of the long baseline laser extensometer", and "Prediction of the earthquake generating process by three-dimensional numerical simulation".

Chapter 1 reports the investigation of the crust and plate structure from seismic observation. Section 1.1 describes seismic observations with pop-up ocean bottom seismometers. Ten terms of observations were conducted in areas along the Nankai trough. Observed seismicity and technical issues are described in this section. Section 1.2 discusses seismicity in the southern area off the Kii Peninsula. Seismic activity beneath the trough axis was found from four-term observations. Section 1.3 analyzes aftershocks of an earthquake that occurred on September 5, 2004 (M_J7.4) southeast off the Kii Peninsula. Aftershocks were divided into two clusters, shallow ones and deep ones. The shallow cluster was considered to be related to splay faults over the subducting Philippine Sea plate. Section 1.4 describes the three-dimensional seismic velocity structure in and around the Philippine Sea plate subducting beneath southwestern Japan. The structure was obtained by using the double-difference tomography method. A low S-wave velocity (Vs) and high Vp/Vs layer several kilometers thick has been clearly imaged at locations immediately above the top of intraslab seismicity in a wide area from Tokai to Kyushu. Based on the obtained location of the low Vs and high Vp/Vs layer and hypocenter distribution of relocated intraslab earthquakes, we estimated the configuration of the upper surface of the Philippine Sea slab in all of southwestern Japan.

Chapter 2 reports on analysis of underground physical properties using signals from the Accurately Controlled Routinely Operated Signal System (ACROSS), which has been developed for detecting temporal variation of the structure between the transmitter and the observed station. The Meteorological Research Institute deployed a seismic ACROSS transmitter at Mori-machi in March 2006, just above the source region of the anticipated Tokai earthquake, and has been studying the possibility of monitoring the status at the boundary between the Philippine Sea plate and its overriding plate. Section 2.1 explains the principle of ACROSS and the method of calculating the tensor transfer function. Section 2.2 presents an overview of the seismic ACROSS transmitter deployed at Mori-machi. The main feature of the Mori-machi transmitter is its higher seismic energy release at low frequency by introducing a mechanism that allows an optional addition of a large eccentric moment as low as 3.5Hz. Section 2.3 discusses the results obtained by the analysis of the seismic ACROSS transmitter. Section 2.3.1 describes the preliminary analysis using the Tono ACROSS transmitter, and section 2.3.2 presents the results obtained by analysis of the Mori-machi ACROSS transmitter. The characteristics of the record section of the transfer function depend on propagation direction. Stations in the E-direction have a rather simple waveform, and stations in the NW-direction have a long coda. In the next step, the temporal variation of the transfer function is derived. We can detect the sub-millisecond-order variation of travel time by this analysis. Annual variation can be observed in most of the stations and is correlated with such meteorological parameters as temperature and rainfall. Section 2.4 discusses seismic array observation deployed to monitor the ACROSS signal at 20km from the Mori-machi ACROSS transmitter. We deployed a small seismic array, and found that a coherent P-coda of relatively high apparent velocity was reflected from deep part in the crust, and the signal-to-noise ratio of coherent waves was increased with

array signal processing.

Chapter 3 reports the vertical displacement estimated by tide gauges. Section 3.1 discusses slow slip events (SSEs) detected with a tide gauge. The Maisaka tide gauge station is located near the center of the Tokai long-term slow slip area, which began slipping in the autumn of 2000. The tide level change indicates an uplift of the ground by the slow slip there. Similar changes are also recognized from 1980 to 1982 and from 1988 to 1990. Long-term slow slips also may have occurred during these periods. Section 3.2 examines the sea area divisions defined by Tsumura (1963) to deduce vertical crustal movement using monthly sea level data from 1961 to 2000. The divisions defined by Tsumura were confirmed to be appropriate at most of the stations, although several stations were found to be better grouped into different sea areas.

Chapter 4 reports the development of a long baseline laser extensometer. Section 4.1 describes the necessity of stable and high-resolution observation of crustal deformation. A long-term SSE had been observed in the Tokai district by the GPS network of Geographical Survey Institute since 2001. Strainmeters in the Tokai district established by Japan Meteorological Agency, however, did not detect abnormal changes related to the long-term SSE. We quantitatively evaluate detection levels of these observation instruments and compare evaluated detection levels with amounts of crustal deformation induced by short-term and long-term SSEs. Section 4.2 reports on technical issues of the laser extensometer. Optical parts suitable for the long baseline, an iodine stabilized laser, and a laser path of high vacuum were adopted to achieve stable and high-resolution observation. The laser extensometer was installed in a tunnel in Hamamatsu City, Shizuoka Prefecture. Obtained strain data is described in section 4.3. We experimentally observed crustal strain on the 200m-long baseline for one year, beginning in December 2007. The amplitude of the observed tidal strain was half that of the theoretically predicted one. The effect of atomospheric pressure change was the same as that of the multi-component strainmeter. The precipitation effect was small and limited to the summer. The power spectrum of noise strain of Tenryu-Funagira is similar to that of other laser extensometers, and the evaluated detection level achieves a preliminary estimate. The laser extensometer observed crustal strain caused by the short-term SSE from August to September 2008. We started regular observation of the 400m-long baseline in March 2009.

Chapter 5 describes the numerical simulation of the earthquake-generation process using three-dimensional models. We intend to simulate the great earthquakes along the Nankai trough and the recurrent long-term SSE before the occurrence of cyclic great earthquakes, using a three-dimensional earthquake cycle model based on the rate- and state-dependent friction law. Section 5.1.1 describes our investigation of the mechanism of occurrence order of two adjacent great interplate earthquakes, the Tonankai and the Nankai earthquakes, along the Nankai trough by varying the size of the asperities or values of frictional parameters. Our result suggests that the Tonankai earthquake is followed by the Nankai earthquake when the size of asperity or the absolute value of negative frictional parameter a-b for the Tonankai earthquake is smaller than that for the Nankai earthquake for a given homogeneous plate convergence rate and the same characteristic distance L. Sections 5.1.2 and 5.1.3 describe our simulation of the initiation point of great earthquakes along the Nankai trough by using a realistic three-dimensional plate boundary configuration and our estimation of the value and depth distribution of frictional parameter a-b by comparing the simulation results of crustal movement and observed GPS data. Section 5.2 discusses our simulation of recurring SSEs with a period of 30 to 40 years beneath Lake Hamana, by applying small negative values to frictional parameter (a-b) and small values to characteristic distance L for the western region of the Tokai district, and large values to L for regions off the Tokai district, where seismic structure surveys indicate the existence of a subducting ridge. In sections 5.3.1 and 5.3.2, we estimate the effects of nearby large earthquakes, such as the Shizuoka earthquakes (1935, 1965), on the timing of the Tokai earthquake. The results indicate that the nearby large earthquakes advance or delay the occurrence of the Tokai earthquake from a few days to a few years, depending on their locations and times.