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Cycle of multi-segment earthquake along the Nankai Trough, revealed by coastal paleoseismology

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Along the Nankai Trough subduction zone which is a boundary between the Phillipine Sea Plate and the Eurasian Plate, interplate large earthquakes have repeatedly occurred at every 100-150 years, but rupture pattern was varied at each event because seismic source can be mainly divided into three segments of Tokai, Tonaikai and Nankai. The latest event was ruptured from initially the Tonankai segment at 1944 (M 7.9) and sequentially to the Nankai segment at 1946 (M 8.0). During the penultimate event, 1854 Ansei earthquake series (M 8.4s), the Tokai and Tonankai segments were simultaneously ruptured, but the Nankai segment behaved singly 30 hours later. The 1707 Hoei earthquake (M 8.6), the largest earthquake in written history of Japan, was multi-segment earthquake ruptured on all segments.

Evaluation of rupture simultaneity of seismic segments in past events is very important for prediction of magnitude of future earthquake. However rupture extent of past events before the 1707 Hoei earthquake is not known well. To clarify the timing and recurrence of past multi-segment large earthquake, we Subduction Zone Paleoearthquake Recurrence Research Team in Geological Survey of Japan are investigating geological evidence of past earthquake and tsunami by using method of coastal paleoseismology. In this paper, we introduce the current survey results of three sites (Ukishimagahara, Shima Peninsula and Kii Peninsula) along the Nankai Trough.

[Ukisimagahara]

Coastal marsh sequence in the Ukishimagahara, eastern edge of the Nankai Trough, reveals that great plate boundary earthquakes have caused the coastal area to subside. We analyzed eight drilling cores obtained from a coastal marsh neighboring the plate boundary, Fujikawa-kako Fault zone, central Japan. The marsh stratigraphy consists of alternation of dark-colored peat and light-colored mud layers, each ranges several tens of cm to 100 cm in thickness. Six couplets of peat and mud layers were recognized from the stratigraphic record formed in the last 1500 years. Micro-biological and sedimentological analyses indicate that rapid water-level rise caused the facies change from peat layers to mud layers. Wide lateral extent of the facies boundary and the suddenness of facies change imply the regional coastal subsidence due to large earthquake. If all facies changes indicate the rupture of plate boundary of the Tokai segment, mean recurrence interval of earthquake is thus estimated to be about 300 years, but a few events might have been caused from the Fujikawa-kako Fault zone. On the basis of radiocarbon ages and tephrochronology, the latest event can be correlated to the 1707 Hoei earthquake.

[Shima Peninsula]

Drilling survey on coastal lowland revealed candidates of historic and prehistoric tsunami sands in Shima Peninsula. The studied marsh is in a region inundated repeatedly by historical tsunamis associated with

earthquakes occurred along the Nankai Trough. The sands are in a succession of peat and organic-rich silt, and contain marine fossils. Radiocarbon ages of seeds, leaves and woods indicate that these shell-rich sand layers deposited in the last 4000 years and that younger two sand layers were deposited just after AD 780-990 and AD 1390-1450 respectively. The sand layer dated just after AD 1390-1450 observed at sites more than 550 m inland implying its wide distribution. Though additional dating is needed, part of these candidate paleo-tsunami layers would be correlated with historical tsunamis such as the 1096 and the 1498 earthquake tsunamis. If only unusual large tsunami events have left sand layers on the marsh, recurrence interval of such event detected from nine tsunami sand layers during 4500-500 years ago is estimated to be about 400-500 years.

[Kii Peninsula]

To evaluate the rupture history just around the segment boundary between the Tonankai and Nankai, we investigated the height distribution, structure and ages of emerged sessile assemblages along the southern coast of the Kii Peninsula. Assemblages are mainly divided into four levels below 4m in altitude. Some well-developed assemblages are characterized by layered structure composed of several vertical layers. Based on radio-carbon dating result, it can be interpreted that each of the layers has been formed by a seismo-tectonic cycle with interval of 100-150 years. A whole of assemblage which was developed during 400-600 years was eventually emerged by unusual uplift associated with multi-segment earthquake such as the 1707 Hoei earthquake. Timing of such events are inferred to be 5200 cal yBP, 4500 cal yBP, 3000 cal yBP, 2200 cal yBP, 1700 cal yBP, AD1361. The height distributions of emerged sessile assemblages indicate that net vertical crustal movement since middle Holocene cannot be explained by accumulation of coseismic vertical displacement associated with repeated earthquakes along the Nankai Trough.

Although the large earthquakes generated from the plate boundary along the Nankai Trough have occurred at every 100-150 years, geological records obtained from three sites show longer recurrence as 300-600 years. This suggests that only unusual large tsunami and crustal movement caused by multi-segment earthquake can record to coastal deposit and emerged shoreline. Since one of three or four cycles of earthquake seems to be multi-segment rupture with recurrence interval of 300-600 years, next event might be large as like the Hoei earthquake.