Answering questions on generation of earthquakes: Seismic asperities and in-situ materials and physical properties

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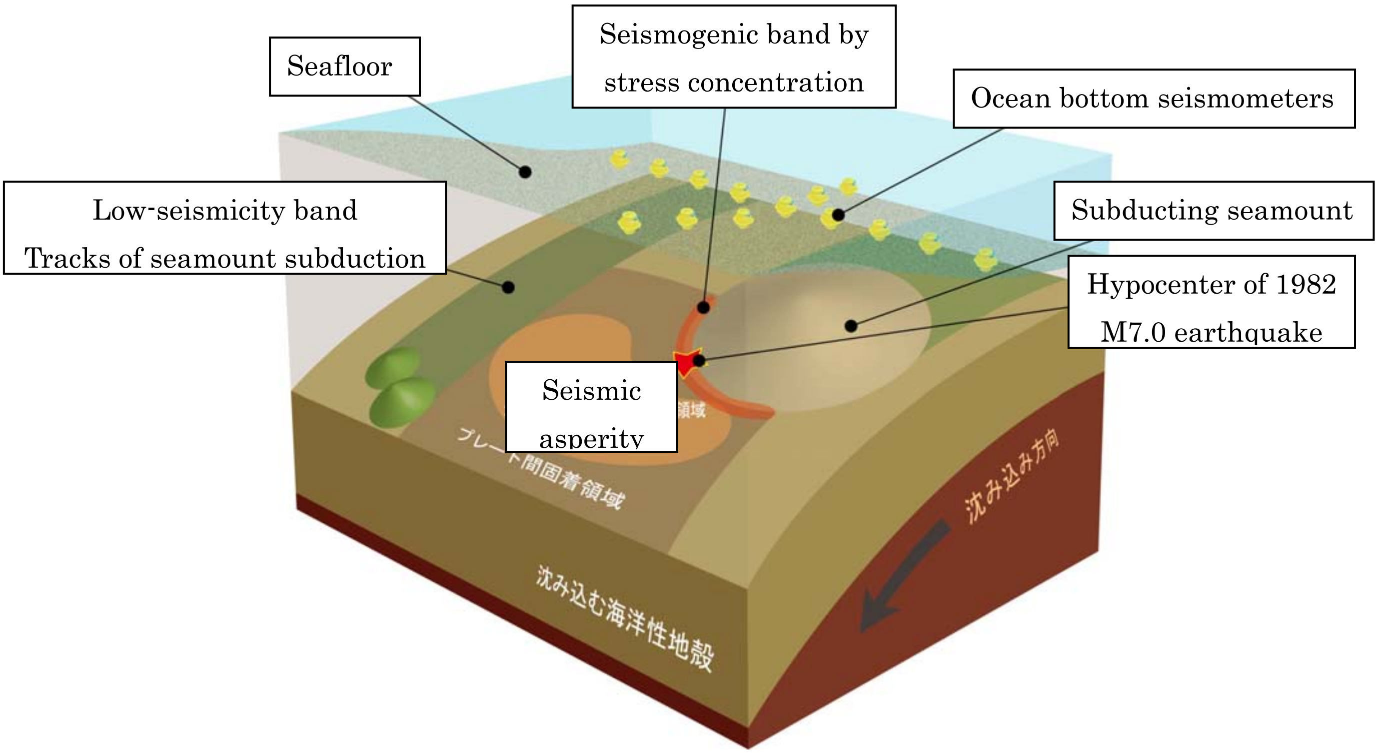
Abstract

Recent state-of-the-art marine seismic surveys and observations have revealed characteristics of earthquake activities in quite detail. We have found some aspects of earthquake activities that are inconsistent with what is expected from physical modeling. Such aspects include: 1) low seismicity over a bulge on the surface of a subducting plate where high normal stress is expected, 2) a characteristic fault boundary with regional high seismicity along the plate interface between mega-thrust earthquake faults over a single subducting plate, and 3) multiple planes of regular seismic activities in the crust and upper-most mantle of the subducting plate off the plate interface. Fluid interaction that has not yet been fully incorporated in our physical modeling of earthquake generation is considered to be the most probable explanation for the inconsistency. However, there are other possible factors that may control earthquake generation such as in-situ pressure and thermal conditions. In most cases, the above seismogenic zones are located deeper than where the current drilling technology can reach. If material sampling and in-situ measurements the physical properties at a shallower location along the direction of subduction, we may have good chances of finding the primary factors that give rise to inconsistency with physical modeling by simple down-dip extrapolation of the observations. Answering questions on mechanisms of earthquake generation within such physically specific regions should be important for constructing physical models to be applied for more general cases.

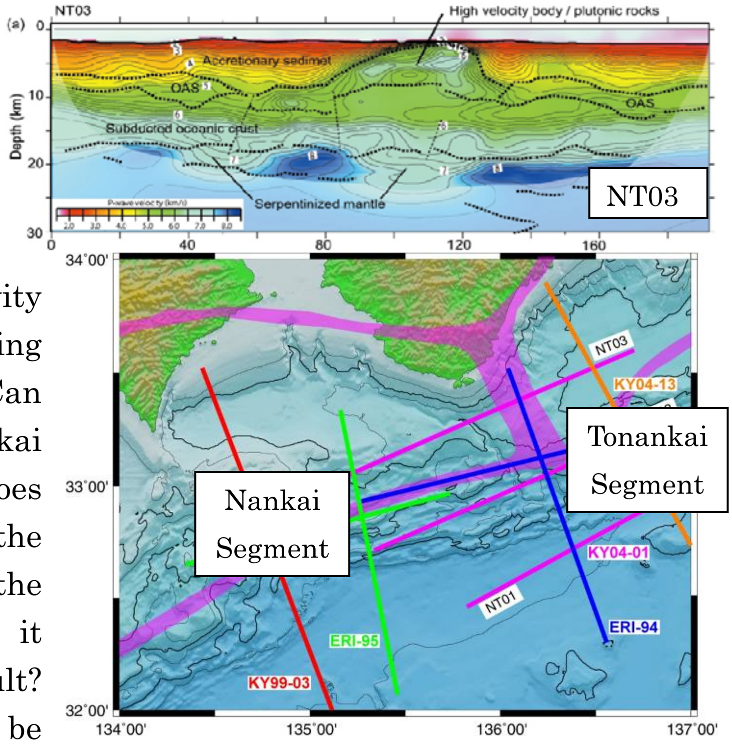
Understanding relationship between seafloor topography and seismic asperities

Seafloor topography of the subducting plate may partly govern stress distribution along the plate interface, and therefore, may be a primary factor to determine seismogenic regions. Stronger interplate friction along the interface by increase in the normal stress is expected when upward convex structure on the seafloor, such as a seamount, is subducted. Such along-interface strong friction attributed to upward-convex structure has been verified through numerical simulations. However, recent seismic surveys and observations have revealed some examples of positional mismatches between upward convex topography and asperities. A seismic asperity for repeating M7 class earthquakes off Ibaraki is located in the subduction front of the seamount base (Mochizuki et al., 2008). A proposed explanation for inconsistency with the numerical results is basal erosion resulted from hydrofracturing at the base of the hanging-wall crust caused by elevated pore pressure along the frontal area of the subducting seamount, which has not been accounted for in the numerical calculations. Drilling to the interface over a subducting seamount and in its wake would elucidate the mechanisms that prevents seismicity along seamount subduction.



Physical properties within the crust across the segment boundary mega-thrust faults

Large structural heterogeneity has been found at the fault segment boundary between the Tonankai and Nankai mega-thrust faults by seismic surveys off Cape Shionomisaki at the tip of the Kii Peninsula. Mode of micro-earthquake activity shows corresponding along-strike variation. Can both Tonankai and Nankai faults coincidentally slip? Does it take some while for the rupture to propagate across the segment boundary, once it occurs within an either fault? These questions may be answered by sampling materials from and in-situ observations of physical properties along the plate interface.



Earthquake planes within oceanic crust and mantle

Precise determination of hypocenters by marine seismic observations using ocean bottom seismometers revealed planes of seismic activity within the oceanic crust and/or upper-most mantle beneath the plate interface. Why seismicity is high off the plate interface, an already existing fault plane, should be answered by observing material samples from both crust and mantle of the subducting plate.