# The Earth's Next Move

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Oceanic plates travel long distances from oceanic ridges and are ultimately destroyed at oceanic trenches. Over a long geological time period, this process creates mountain belts on the continental side of the trench. We can experience a tiny fragment of this process through earthquakes. Large earthquakes are prone to occur at plate subduction zones, but there are, however, trenches without any significant records of large earthquakes. That is, the plate subduction may proceed with or without earthquake slips. In the real world, subduction probably proceeds with a mixture of these modes in time and space, often between the trench and the coast, where the rocks show brittle behavior. In order to understand how this is controlled, we must grasp how the earth is being strained or unstrained by the subduction process. The study of the earthquake activity alone does not provide the complete picture.

Because oceanic trenches are located more than 100 km offshore, there is no way to accurately sense this process from land. It is critically important to close in on the target, which is exactly what ODP Leg 186 accomplished offshore NE Japan in 1999 (Figure 1). Two crustal deformation observatories were successfully implanted more than 1000 m below the sea floor by the *JOIDES Resolution* in water depths of about 2000 m. The sensors can detect seismic motions, tilts, and strains in a broad observational window, that is, with high sensitivity, wide frequency range and wide dynamic range, comparable to or better than state-of-the-art sensors in use on land (Figure 2). These sensors are cemented at the bottom of the holes to assure the best possible coupling to the surrounding rocks.

The sensors are located about 10 km above the subducting plate boundary and 50 km apart. Within this small area, the seismic characteristics drastically differ in that one site is seismically active but the other site is aseismic. The question is, if the incoming plate is proceeding at about 9 cm/year over a long period of time, say 100 years, then what makes this difference? Is the incoming plate slipping with no friction in the aseismic part, or is it quietly storing strain energy to be released by a large future earthquake? Alternatively, is it releasing energy in a previously undetected manner? Is the active part always slipping due to the earthquakes? Answering yes or no from observations to any one of these questions leads to a different mechanism operating to make the incoming plate slip past the overriding plate.

Earthquakes are devastating manifestations, but only represent a portion of the total energy storage and release involved at the plate subduction zone. If we miss any significant strain event, be it stationary or episodic, and try to predict the future, it will be like playing chess without seeing the whole board yet having to make the next move. The observatories installed by ODP will help us see the whole board and better predict these natural hazards.

Figure 1. (above) Photograph of subsea station offshore Japan taken from Dolphin 3K (remotely operated underwater vehicle, "ROV"). The cylindrical superstructure sits on top of the re-entry cone and houses the power supply, recorder unit and controller unit for the borehole sensor package embedded 110 m below. ROVs periodically make electrical connections to communicate with the station, exchange the data recorder, and update the system.

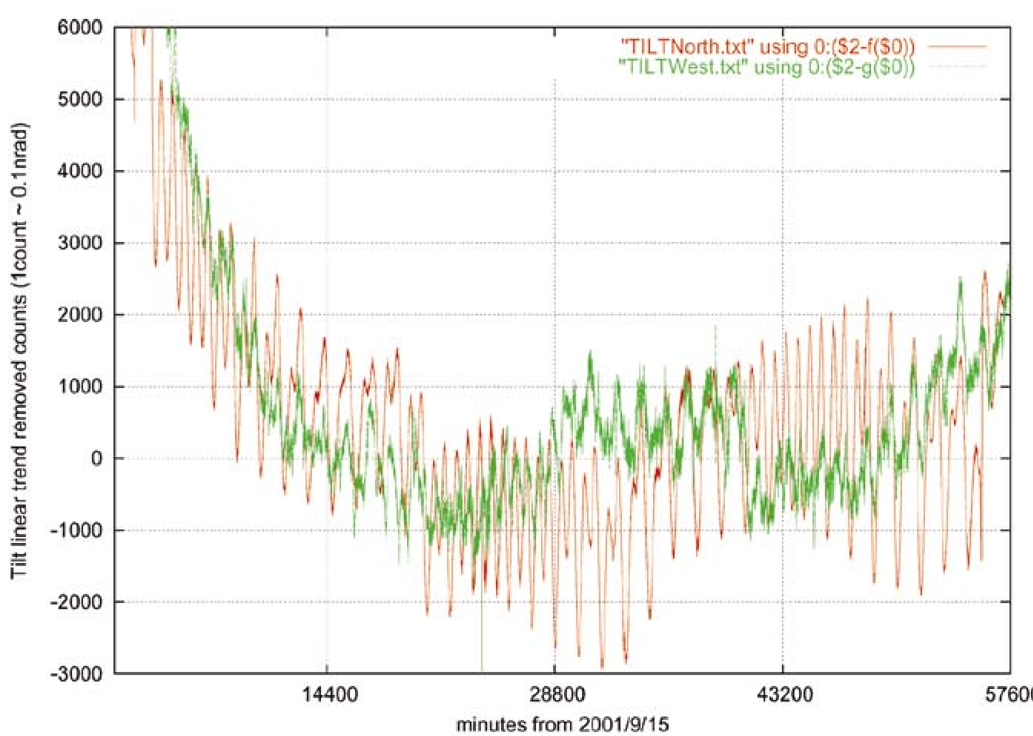


Figure 2. (right) A tiltmeter is one type of instrument used in underwater observatories that measures changes in the tilt of the Earth's surface. This tiltmeter record shows how the earth is responding to tidal forces, plate deformation and long-term tectonic forces. A state-of-the-art sensor is required to record the tidal signals.