New Faculty

Wiring the Mega-Thrust

Harold Tobin

When I joined the faculty at UW in September 2006, I brought with me a long-brewing project to drill deeply into a subduction zone plate boundary fault to observe plate boundary earthquake and tsunami processes in their natural habitat. I am the U.S. Chief Project Scientist for an international collaboration known as NanTroSEIZE, or the Nankai Trough Seismogenic Zone Experiment, a plan developed by some 40 scientists from eight countries over the past five years. This effort, which begins off the coast of Japan in October 2007, is actually among the largest (and certainly one of the most expensive) earth sciences research projects ever undertaken. We will deploy not one, but two, brand-new scientific deep water drilling vessels, along with 3D seismic reflection data and literally hundreds of scientists from many different countries to achieve our goals: to drill into, sample, and instrument a plate-boundary fault where megathrust earthquakes and tsunami occur.

As the December 2004 Sumatra-Andaman earthquake and Indian Ocean tsunami so tragically demonstrated, subduction "megathrust" earthquakes and the tsunami they spawn are perhaps the greatest natural hazards on the planet. They nearly always take place on faults that lie entirely offshore beneath the continental slope, hidden from view – and from the efforts of field geologists and continental geophysicists. The Nankai Trough of southwestern Japan is one such plate boundary that has produced repeated magnitude 8+ earthquakes and tsunami up to 11 meters high over the past millennium. Because of this history and other geophysical characteristics, this particular subduction zone is perhaps the best place on earth to study the seismic cycle of great subduction earthquakes.

Major unknowns in the generation of tsunami include how far earthquake fault slip can propagate up toward the sea bed and what factors control how that slip stops in accretionary wedges – the submarine mountain ranges created as sediment and

Harold Tobin on the deck of *Chikyu*.

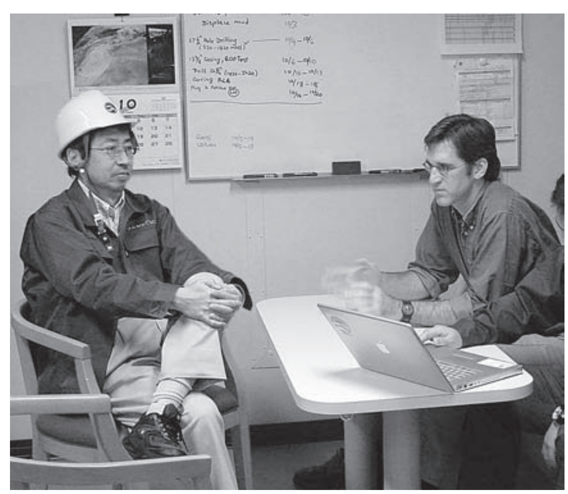
rock are scraped off the sinking plate. My research focus has long been on the faults in such wedges, which are generally thought of as aseismic, or incapable of earthquakes. By drilling into the wedge faults at Nankai Trough, we hope to learn how aseismic faults give way with depth to the seismic faulting associated with tsunami.

I have been working across both disciplinary and plate boundaries for many years, studying the structure and mechanics of plate boundary fault zones both on land and at sea. Since my graduate school days at the University of California in Santa Cruz, I have used a combination of seismic reflection studies, core sample analysis, downhole geophysical logs – and even field mapping on the sea floor from the Alvin research submarine – to shed light on the properties and internal workings of active thrust faults. This work made major use of the capabilities of the Ocean Drilling Program (ODP) and its workhorse scientific drilling vessel, the JOIDES Resolution, and has taken me to the Cascadia (Pacific Northwest), Barbados, and Costa Rica subduction zones, as well as the Nankai Trough.

The Resolution has proven capable of drilling through fault zones more than 1000 meters below the sea floor – deep enough to learn a lot about fault mechanics in sediments, but not as deep as the up-dip limit of the seismogenic zone: that portion of the plate boundary capable of contributing to the destructive slip of megathrust earthquakes. Since the late 1990s, my accretionary wedge colleagues and I have hoped to one day be able to drill into that seismogenic zone. Now that day is rapidly approaching.

Since 2001, I have led a group of more than 40 scientists from seven countries that proposed to drill a series of boreholes down as much as six kilometers below the sea bottom into and across the plate interface fault zone at the Nankai Trough as part of IODP (the successor to ODP; the I stands for "Integrated"). NanTroSEIZE has been designated as the first major multi-expedition project to be undertaken in IODP. The IODP will operate two ships starting in October 2007, and one will be the phenomenal new drill ship Chikyu (meaning "Planet Earth" in Japanese, see cover picture), with the capability to perform scientific drilling to great depth using cutting-edge deepwater drilling technology employed in the oil and gas industry (for the cognoscenti, this is a dynamically-positioned ship equipped with a 2500 meter riser, the first one put to use for scientific drilling).

The other new vessel will be a $110 million complete overhaul and re-build of the



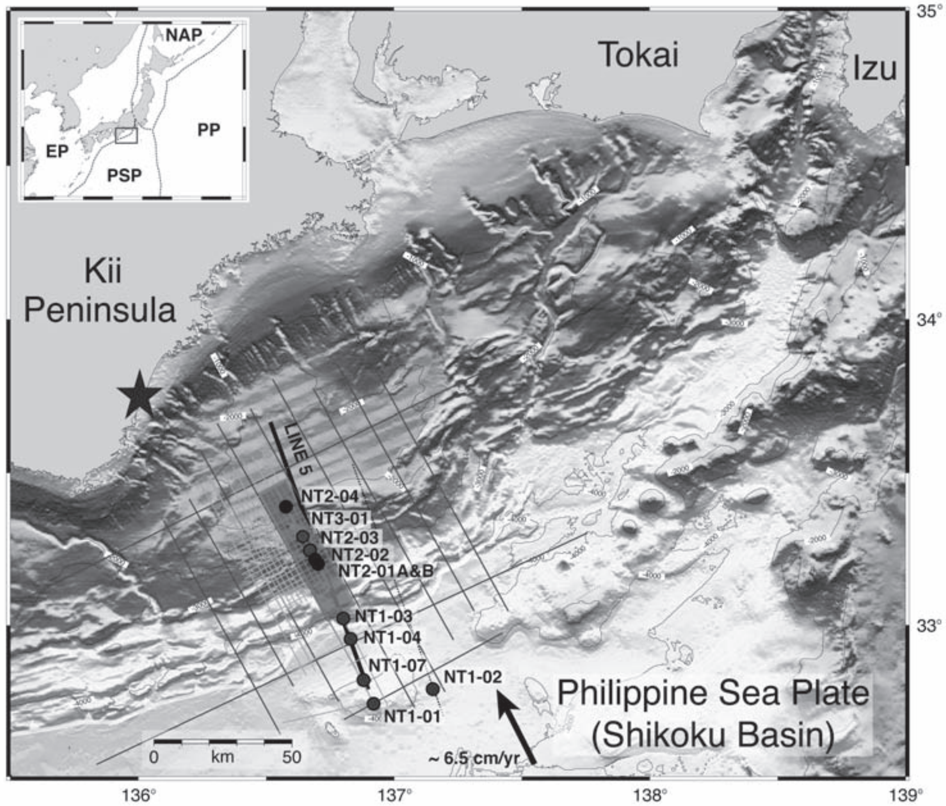
Asahiko Taira, left, chief of the drill ship operation, and Harold Tobin on board *Chikyu* in 2006.

Resolution, funded by the National Science Foundation. In late 2007 and early 2008, NanTroSEIZE is currently slated to be the very first scientific expedition of both Chikyu and the new Resolution as well.

Our goals are to drill a network of boreholes into different parts of the fault system at various depths, all in places where the water is over 2000 meters deep. We will sample fault and wall rock for geological and geochemical studies, and install seismometers, strainmeters, pore pressure sensors, and other devices to take the pulse of this seismogenic zone. By leaving data recording instruments down the boreholes over many years, the NanTroSEIZE team hopes to capture in situ signals of the seismic cycle of strain accumulation and release.

NanTroSEIZE is the most ambitious undertaking in scientific ocean drilling since the famous Project MoHole of the 1960s, which some old-timers will no doubt remember (the main objective of which – drilling across the oceanic Moho into the mantle – still has not been achieved). Drilling and instrumenting the holes will involve many separate expeditions to the area, literally scores of scientists and engineers, and many hundreds of days of ship time. In the end, my hope is that this wired fault zone will give us an unprecedented, real-time look at how faults work.

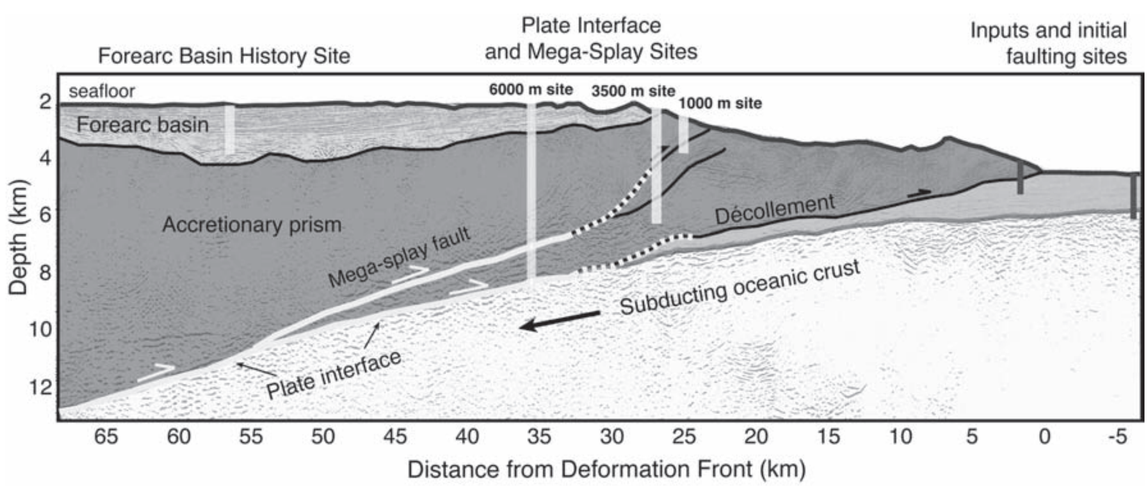
Investing all this time and effort requires well-defined drilling targets. In April and May 2006, the NanTroSEIZE team marked another milestone: we collected the first true, modern, oil-industry style marine 3D seismic reflection survey ever performed for purely scientific goals. With funds from NSF and the Japanese oceanographic institution JAMSTEC, an 11 x 55 km survey was shot by the PGS vessel Nordic Explorer over our drill sites.



The Nankai Trough off Central Japan has a long history of great subduction earthquakes and tsunami. It has been the subject of intensive geophysical study including the seismic surveys shown here, along with the planned drilling transect. Star shows epicenter of the 1944 M8.1 earthquake, which broke up into the drilling area.

We just got the first processed version of our 3D volume in December, and my graduate students Matt Knuth and Pete Garaffo and I are diving right in, using our new Landmark-based computer facility.

My students and I, along with collaborators from Japan, the University of Texas, and Penn State, will spend a lot of time processing and interpreting the seismic reflection data, trying to extract key information about the physical properties, pore fluid pressure, and stress state in the faults and sediments of subduction zone accretionary wedges. Imaging of the fault system to this level of detail will help us map out the distribution of stresses and strains in the plate boundary, and to extrapolate away from the boreholes. Laboratory rock physics work at UW on the core samples will add further insight into the fault zones and provide a link between seismic data and the plate boundary rocks. ●



Deep seismic reflection profile from the Nankai Trough, with planned drilling sites. Drilling begins in 2007.
(Images courtesy of Harold Tobin)