Estimation of Minimum Principal Stress from an Extended Leak-off Test Onboard the *Chikyu* Drilling Vessel and Suggestions for Future Test Procedures

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Introduction

To understand the physics of faulting and rupture propagation for the great M8-class Nankai earthquakes that recur approximately every 100 years, a comprehensive drilling project is underway: the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE; Tobin and Kinoshita, 2007), which is part of the Integrated Ocean Drilling Program (IODP). Stress levels along seismogenic faults must be known in order to understand processes controlling the timing, energetics, and extent of earthquake ruptures. For scientific drilling projects such as NanTroSEIZE, it is very important to determine the *in situ* stress state at the decollement and the mega splay fault in the Nankai Trough.

Preliminary experiments to determine the orientations and magnitudes of principal stresses in the Nankai Trough were undertaken during the NanTroSEIZE Stage 1 expeditions using borehole image analysis (stress-induced breakouts and tensile fractures; Kinoshita et al., 2008) and indirect, core-based methods such as anelastic strain recovery (ASR; Lin et al. 2006). These experiments will provide necessary and important information about *in situ* stress. However, to improve reliability and reduce experimental uncertainties in these stress determinations, it is necessary to have direct *in situ* measurements of stress magnitudes—in particular, the minimum principal stress—at depth. These direct measurements are best obtained using methods involving the initiation and propagation of hydraulic fractures at depth, such as the traditional hydraulic fracturing test, a leak-off test (LOT), or an extended leak-off test (XLOT, sometimes ELOT) (Zoback et al., 2003). In the present paper, we aim to show that with the advent of the riser drilling vessel *Chikyu*, the XLOT is applicable and effective in deep scientific ocean drilling projects.

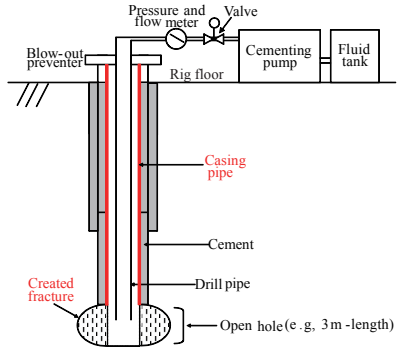

Figure 1. Schematic borehole configuration during a leak-off test (LOT) or extended leak-off test (XLOT; after Yamamoto, 2003)

During previous ODP expeditions and non-riser IODP expeditions, LOT or XLOT (which are sometimes used to determine drilling parameters such as optimal mud density) have not been conducted because the borehole was open to the seafloor. Thus, it has been impossible to pressurize a short interval of open hole below the casing as needed to conduct a LOT or XLOT (see below) without utilizing time-consuming and frequently unreliable drill-pipe-deployed packers. In contrast, the new drilling vessel *Chikyu* provides a riser-drilling capability that allows pressuring the entire casing string with drilling mud immediately after the casing is cemented in place. Therefore, NanTroSEIZE Stage 2 will present the first opportunity for a scientific ocean drilling program to use LOT or XLOT procedures without using a packer, providing direct information on the *in situ* magnitude of the minimum principal stress at minimal cost and risk.

In this study we will demonstrate the feasibility of using LOT and XLOT data acquired during the new riser-drilling program to determine stress magnitude. We will first describe LOT and XLOT procedures, and then use an XLOT data set that was acquired during the 2006 Shimokita shakedown cruise of the *Chikyu* drilling vessel to estimate the magnitude of minimum principal stress. We then recommend what we believe to be the optimum procedures for implementation of LOT–XLOT for determination of stress magnitude during future *Chikyu* riser-drilling programs.

Description of the Tests

A LOT is a pumping pressure test carried out immediately below newly set casing in a borehole (Fig. 1). It is similar to other pumping pressure tests known as the pressure integrity test, formation integrity test, or casing-shoe integrity test. Each of these tests has a different target pumping pressure. The LOT technique was originally developed in the oil industry to assess the "fracture gradient" of the formation (i.e., the maximum borehole pressure that can be applied without mud loss) and to determine optimal drilling parameters such as mud density (Kunze and Steiger, 1991). The LOT procedures are relatively simple. An XLOT is a more complex test with extended pressurizing procedures, as described in detail below. In future riser-drilling by *Chikyu*, it may be possible to regularly implement LOT or XLOT at each casing shoe immediately after casing has been run and cemented.