A Proposed Method and Its Field Application of Deep Stress Measurements

*Takatoshi Ito[1]

1.Institute of Fluid Science, Tohoku University

We have proposed a new concept in which the in-situ stress state is determined by integrating (i) the Hydraulic Fracturing (HF) method and (ii) the Diametrical Core Deformation Analysis (DCDA). The DCDA is a kind of core based method, which has been proposed recently by the authors (Funato at al., 2012, Funato & Ito, 2015), which allows us to estimate the state of in-situ stress from cross-sectional shape of boring cores. The integration leads to improve practicality and compensate disadvantages compared with the case using each data solely for the stress determination. This new concept is illustrated in Figure 1, where we assume for simplicity that the borehole is vertical and a core sample is retrieved from the same depth of the HF test interval. This new concept provides several data set available to estimate the magnitude of the maximum horizontal stress SHmax and its orientation in multiple ways, while the magnitude of the minimum horizontal stress Shmin must be estimated only from the shut-in pressure Ps observed in the HF test. The extra data sets lead to improve practicality so much that the validity of results can be confirmed from their consistency, and they provide flexibility to determine the stress state completely, even if the data set will be missed partially.

The pressures Pr and Ps are related theoretically to SHmax and Shmin as follows (Ito et al., 1999),

Pr = (3 Shmin –SHmax)/2 (1)

Ps = Shmin (2)

If the compliance C of the fracturing system is not appropriately small, the reopening pressure Pr corresponding to Eq. (1) cannot be detected by the HF test (Ito et al., 1999; 2005; 2006). It means that the magnitude of SHmax cannot be determined by using Eqs. (1) & (2) and the data set “a” in Figure 1. This problem can be solved by using Eqs. (2) & (3) and the data set “b” combining the core data instead of Pr. If the tensile strength T of rock can be determined using the core sample, it may be possible to roughly estimate SHmax from the breakdown pressure Pb which is another distinctive pressure observed in the HF test. However, it should be noted that the relationship between Pb and in-situ stresses is complicated to be changed depending on the effect of pore pressure, and it is not easy to correctly measure T at the in-situ condition. On the other hand, even if the impression packer is not available for detecting the induced fracture orientation, the orientation of SHmax can be estimated as that of the maximum diameter of the core sample, i.e. the data ”e”. The orientation of SHmax can be estimated also from the other stress indicators, i.e. the data “f”, such as the borehole breakout (BO) and the drilling induced tensile fracture (DITF) which can be detected by the borehole wall image logging. This method was successfully applied for (i) the stress measurement in a central region of the Kumano forearc baisn at a water depth of 2054 m using a 1.6 km riser hole drilled in the Integrated Ocean Drilling Program (IODP) Expedition 319 (Ito et al., 2013) and (ii) the stress measurement at a depth of about 1 km of a deviated oil well in Japan.

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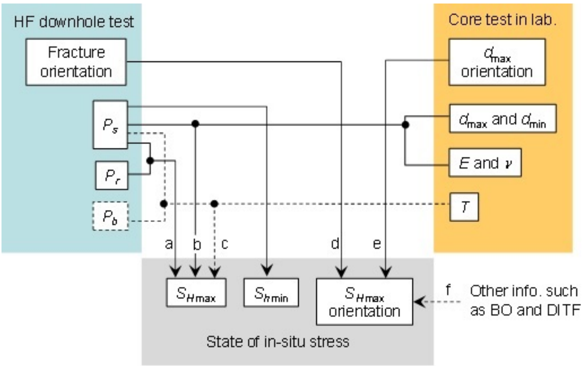

Figure 1. Procedure of stress determination in the proposed method.

