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Borehole image analysis of the Nankai Accretionary Wedge, ODP Leg 196: Structural and stress studies

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Abstract

Electrical images recorded with Resistivity-At-Bit (RAB) from two sites drilled during Ocean Drilling Program (ODP) Leg 196 were analyzed to study the effects of subduction at the Nankai margin. For the first time in the history of scientific deep-sea drilling in ODP, in situ complete borehole images of the décollement zone were obtained. Analyses of all drilling-induced fracture data indicated that the maximum horizontal compressive stress (S_{Hmax}) axes have an azimuth of 303°, and analyses of breakout data from RAB images indicated an azimuth of 310°. These azimuths approximate the convergence direction of the Philippine Sea plate towards the Eurasian plate. The frontal thrust at Site 808 was encountered at about 389 mbsf. Density, porosity, resistivity, and gamma ray data change across the frontal thrust. The décollement zone at the deformation front was identified between 937 and 965 mbsf. The base of the décollement is sharply defined as the maximum extent of conductive fracturing and is marked by abrupt changes in physical properties [Mikada, H., Becker, K., Moore, J.C., Klaus, A., Austin, G.L., Bangs, N.L., Bourlange, S., Broilliard, J., Brückmann, W., Corn, E.R., Davis, E.E., Flemings, P.B., Goldberg, D.B., Gulick, S.S., Hansen, M.B., Hayward, N., Hills, D.J., Hunze, S., Ienaga, M., Ishiguro, H., Kinoshita, M., Macdonald, R.D., McNeill, L., Obana, S., Hong, O.S., Peacock, S., Pettigrew, T.L., Saito, S., Sawa, T., Thaiprasert, N., Tobin, H.J., Tsurumi, H., 2002. Proc. ODP, Initial Rep., 196, College Station, TX, (Ocean Drilling Program)]. The upper boundary of the décollement is marked by several sets of conductive fractures and by high variability in physical properties. The décollement zone is characterized by intense brittle fracturing. These fractures are considered to be the consequence of cyclic stresses and high fluid pressures in this zone. We analyzed fracture dips and their orientations at both sites and found that they are all consistent with a unique stress field model surrounding the two sites.

Keywords: Décollement; Borehole breakout; Nankai Trough; LWD; RAB; ODP

1. Introduction

The active margin offshore Japan (Fig. 1a) has periodically generated large subduction earthquakes of

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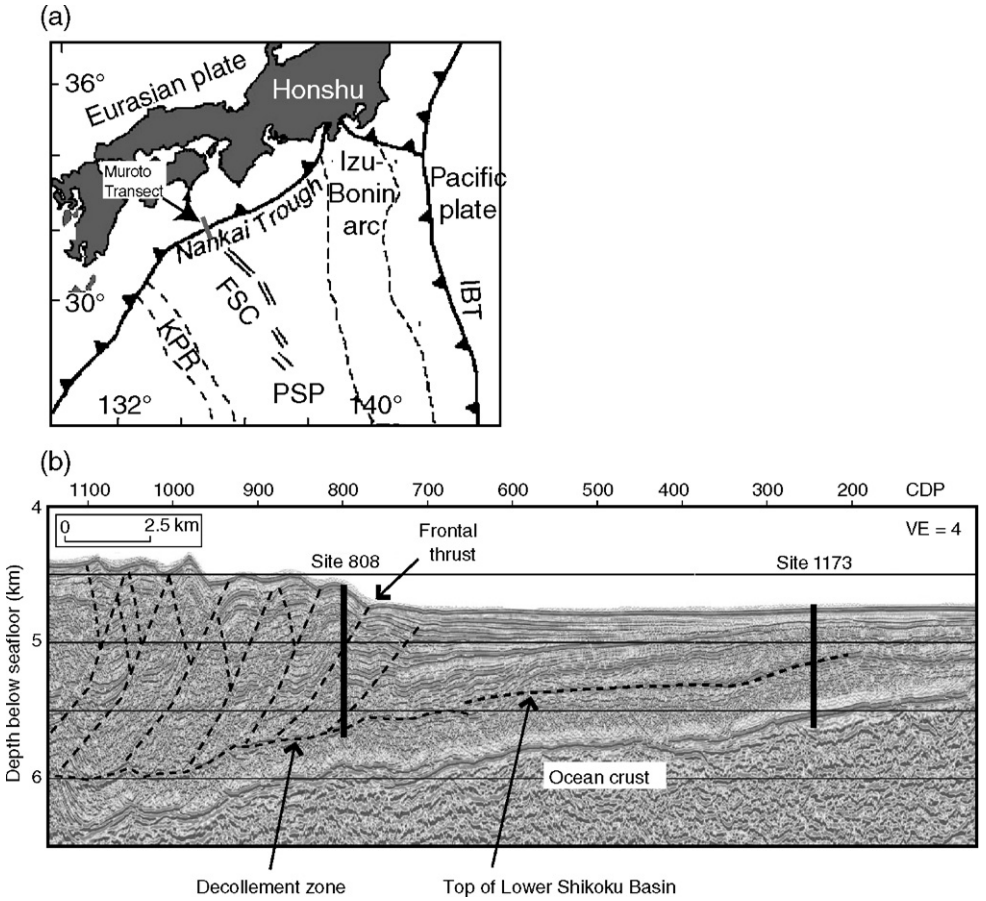

Fig. 1. (a) Location map shows tectonic setting of the Nankai Accretionary Prism. PSP=Philippine Sea Plate; KPR=Kyushu Palau Ridge; Fsc=Fossil Spreading Center; IBT=Izu Bonin Trench. (b) Seismic reflection profile across the Muroto transect (Moore et al., 1990). Recognizable thrust faults, Décollement zone, and top of Lower Shikoku Basin sediments are shown in broken lines. Thrusts and their conjugate faults form a complex structure on the left side of figure. A strong seismic reflector perceived as Décollement zone (left half of figure) jumps to the top of the Lower Shikoku Basin sediments where a number of normal fault type discontinuities are observed below the reflector.

the order of magnitude 8 (e.g., in 1605, 1707, 1854, 1946; Ando, 1975). The Nankai Trough is one of the best-studied convergent plate boundaries. Subduction complexes provide an opportunity to examine the initiation of décollement zones, i.e., detachment planes that separate accreted from subducted sediments and ruptures during subduction earthquakes. Recent studies on subduction zones have established that fluids play a major role in their physical and chemical evolution and seismogenic activities (Hyndman et al., 1995). The overall structure of the prism and the general nature of the deformation processes are now reasonably well known. However, many questions remain and the distribution, nature, shape, and origin of the décollement zone at the base of the prism are still poorly understood.

The objective of Ocean Drilling Program (ODP) Leg 196 was to clarify the nature of deformation and fluid flow in the Nankai accretionary prism. Leg 196 was the 5th deep-sea drilling investigation at the Nankai Trough, following DSDP (Deep-Sea Drilling Project) Legs 31 and 87 and ODP 131 and 190. Logging-while-drilling (LWD) was carried out during Leg 196 to measure the physical properties of the décollement zone and overlying prism. A logging tool string was located just above the drill bit to measure resistivity, density, porosity, and sonic velocity. In Leg 196, two sites were drilled to obtain physical properties: one is the Site 808 in the proto-thrust zone of the prism and the other Site 1173 about 9 km seaward from the Nankai Trough. The décollement and the seaward stratigraphic equivalent of the décollement (referred to as “pre-décollement” here) zones were penetrated. Sites 808 and 1173 were selected for investigation of the early stages of décollement evolution. The décollement zone was characterized seismically as a high-amplitude reversed-polarity reflection (Fig. 1b), which might suggest