ARTICLE IN PRESS
TECTO-126624; No of Pages 11
Tectonophysics xxx (2015) xxx–xxx

Contents lists available at ScienceDirect
Tectonophysics
journal homepage: www.elsevier.com/locate/tecto

Distribution of stress state in the Nankai subduction zone, southwest Japan and a comparison with Japan Trench

Weiren Lin [a,*], Timothy B. Byrne [b], Masataka Kinoshita [a], Lisa C. McNeill [c], Chandong Chang [d], Jonathan C. Lewis [e], Yuzuru Yamamoto [f], Demian M. Saffer [g], J. Casey Moore [h], Hung-Yu Wu [i], Takeshi Tsuji [j], Yasuhiro Yamada [i], Marianne Conin [k], Saneatsu Saito [i], Takatoshi Ito [l], Harold J. Tobin [m], Gaku Kimura [n], Kyuichi Kanagawa [o], Juichiro Ashi [p], Michael B. Underwood [q], Toshiya Kanamatsu [r]

[a] *Kochi Institute for Core Sample research, Japan Agency for Marine-Earth Science and Technology, Nankoku, Japan*
[b] *Center for Integrative Geosciences, University of Connecticut, Storrs, CT, USA*
[c] *Southampton Oceanography Centre, University of Southampton, Southampton, UK*
[d] *Department of Geology, Chungnam National University, Daejeon, Republic of Korea*
[e] *Department of Geoscience, Indiana University of Pennsylvania, Indiana, PA, USA*
[f] *Department of Mathematical Science and Advanced Technology, Japan Agency for Marine and Earth Science and Technology, Yokohama, Japan*
[g] *Department of Geosciences and Center for Geofluids, Geomechanics, and Geohazards, The Pennsylvania State University, University Park, PA, USA*
[h] *Earth and Planetary Sciences Department, University of California, Santa Cruz, CA, USA*
[i] *Research and Development Center for Ocean Drilling Science, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan*
[j] *International Institute for Carbon-Neutral Energy Research, Kyushu University, Fukuoka, Japan*
[k] *University of Lorraine, ENSMN, Nancy, France*
[l] *Institute of Fluid Science, Tohoku University, Sendai, Japan*
[m] *Department of Geoscience, Univ. WI-Madison, Madison, WI, USA*
[n] *Department of Earth and Planetary Science, The University of Tokyo, Tokyo, Japan*
[o] *Department of Earth Sciences, Chiba University, Chiba, Japan*
[p] *Atmosphere and Ocean Research Institute, The University of Tokyo, Tokyo, Japan*
[q] *Department of Geological Science, University of MO, Columbia, MO, USA*
[r] *Research and Development Center for Earthquake and Tsunami, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan*

ARTICLE INFO

Article history:
Received 10 September 2014
Received in revised form 2 April 2015
Accepted 20 May 2015
Available online xxxx

Keywords:
Stress state
Nankai subduction zone
Japan Trench
Ocean drilling

ABSTRACT

To better understand the distribution of three dimensional stress states in the Nankai subduction zone, southwest Japan, we review various stress-related investigations carried out in the first and second stage expeditions of the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) by the Integrated Ocean Drilling Program (IODP) and compile the stress data. Overall, the maximum principal stress σ_1 in the shallower levels (<~1 km) is vertical from near the center of forearc basin to near the trench and; the maximum horizontal stress S_{Hmax} (interpreted to be the intermediate principal stress σ_2) is generally parallel to the plate convergence vector. The exception to this generalization occurs along the shelf edge of the Nankai margin where S_{Hmax} is along strike rather than parallel to the plate convergence vector. Reorientation of the principal stresses at deeper levels (e.g., >~1 km below seafloor or in underlying accretionary prism) with σ_1 becoming horizontal is also suggested at all deeper drilling sites. We also make a comparison of the stress state in the hanging wall of the frontal plate-interface between Site C0006 in the Nankai and Site C0019 in the Japan Trench subduction zone drilled after the 2011 Mw 9.0 Tohoku-Oki earthquake. In the Japan Trench, a comparison between stress state before and after the 2011 mega-earthquake shows that the stress changed from compression before the earthquake to extension after the earthquake. As a result of the comparison between the Nankai Trough and Japan Trench, a similar current stress state with trench parallel extension was recognized at both C0006 and C0019 sites. Hypothetically, this may indicate that in Nankai Trough it is still in an early stage of the interseismic cycle of a great earthquake which occurs on the décollement and propagates to the toe (around site C0006).

1. Introduction

Stress and earthquakes are known to be interrelated: stress triggers earthquakes and earthquakes alter the shear and normal stresses on surrounding faults (Hardebeck, 2004; Lin et al., 2007; Ma et al., 2005;

* Corresponding author at: Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology, 200 Monobe-otsu, Nankoku 783-8502, Japan. Fax: +81 88 78 2192.
E-mail address: lin@jamstec.go.jp (W. Lin).

http://dx.doi.org/10.1016/j.tecto.2015.05.008
0040-1951/© 2015 Elsevier B.V. All rights reserved.

Please cite this article as: Lin, W., et al., Distribution of stress state in the Nankai subduction zone, southwest Japan and a comparison with Japan Trench, Tectonophysics (2015), http://dx.doi.org/10.1016/j.tecto.2015.05.008

Seeber and Armbruster, 2000; Stein, 1999). On the other hand, the stresses both on the fault and in the formation gradually build up in the interseismic period (Kanamori and Brodsky, 2001). The Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE), a comprehensive scientific drilling project conducted by the Integrated Ocean Drilling Program (IODP) in the Nankai subduction zone, southwest Japan, is designed to investigate the mechanics of the subduction megathrust through drilling and a wide range of allied studies (Tobin and Kinoshita, 2006; Tobin et al., 2009a). In this area, Mw 8.0 class great earthquakes repeat at intervals of 100–200 years as a result of the convergence of the Philippine Sea and Eurasian plates (Ando, 1975; Fig. 1). The last two great earthquakes in the Nankai subduction zone occurred in 1944 (Tonankai, M 8.0–8.3) and 1946 (Nankai, M 8.1–8.4), generating tsunamis and causing significant damage in southwest Japan (Kanamori 1972). The NanTroSEIZE project sampled and continues to monitor the characteristics of the seismogenic zone during the interseismic interval. In contrast, IODP expedition 343 to the Japan Trench (also referred to as the Japan Trench Fast Drilling Project or JFAST), was conducted just after a great earthquake, about 13 months after the 2011 Mw 9.0 Tohoku-Oki, Japan earthquake (Mori et al., 2012; Chester et al., 2012; Fig. 1).

Establishing the in situ stress state along active subduction zones is critical for understanding the accumulation and release of most of Earth's seismic energy (Lallemand and Funiciello, 2009). Determination of in situ stress is one of the most important scientific objectives of both NanTroSEIZE and JFAST, and also one of the major goals of the IODP as the seismogenic parts of plate margins are often only accessible through drilling. First, we review various stress-related investigations carried out in association with NanTroSEIZE stages 1 and 2. We then compare the present-day stress states in the frontal part of the plate-interface at the Nankai and Japan Trench subduction zones and propose hypotheses on the temporal and spatial evolution of stresses in the frontal plate-interface in Nankai, SW Japan.

2. Stress estimates and direct measurements from stages 1 and 2 of the NanTroSEIZE drilling project

The multi-stage scientific drilling project NanTroSEIZE, conducted by the drilling vessel D/V *Chikyu*, began in 2007 with IODP expedition 314 and is continuing with planned deep riser drilling in the coming years (Hirose et al., 2013; Kinoshita et al., 2008). To date more than 10 drilling sites have been drilled along the NanTroSEIZE transect with at least one vertical borehole(s) at each site. This transect is approximately orthogonal to the Nankai Trough axis (plate boundary) (Figs. 2, 3 and 4a and Table 1).

In the first stage of NanTroSEIZE (2007–2008), borehole wall images obtained by logging while drilling (LWD) technology yielded regional patterns of stress orientations and magnitudes through observations of drilling-induced compressive failures (borehole breakouts) and tensile fractures (DITFs) (e.g., Chang et al, 2010; Lee et al., 2013; Lin et al., 2010a; Moore et al., 2011; Tobin et al., 2009b). This stage involved five drilling sites in three structural settings in which LWD was performed: the frontal thrust at the toe of the accretionary prism, Site C0006; the megasplay hanging wall and footwall, Sites C0010, C0004 and C0001, and the seaward edge of the Kumano forearc basin, Site C0002 (Figs. 2, 3 and 4a). These regional studies were followed by more detailed core-based analyses and geophysical studies, including interpretation of high-resolution seismic reflection data and S-wave splitting that provided a three-dimensional understanding of the stress field and the evolution of stresses through time (Byrne et al., 2009; Conin et al., 2014; Kimura et al., 2011; Lewis et al., 2013; Moore et al., 2013; Sacks et al., 2013; Tsuji et al., 2011a). Taken together, these results show that

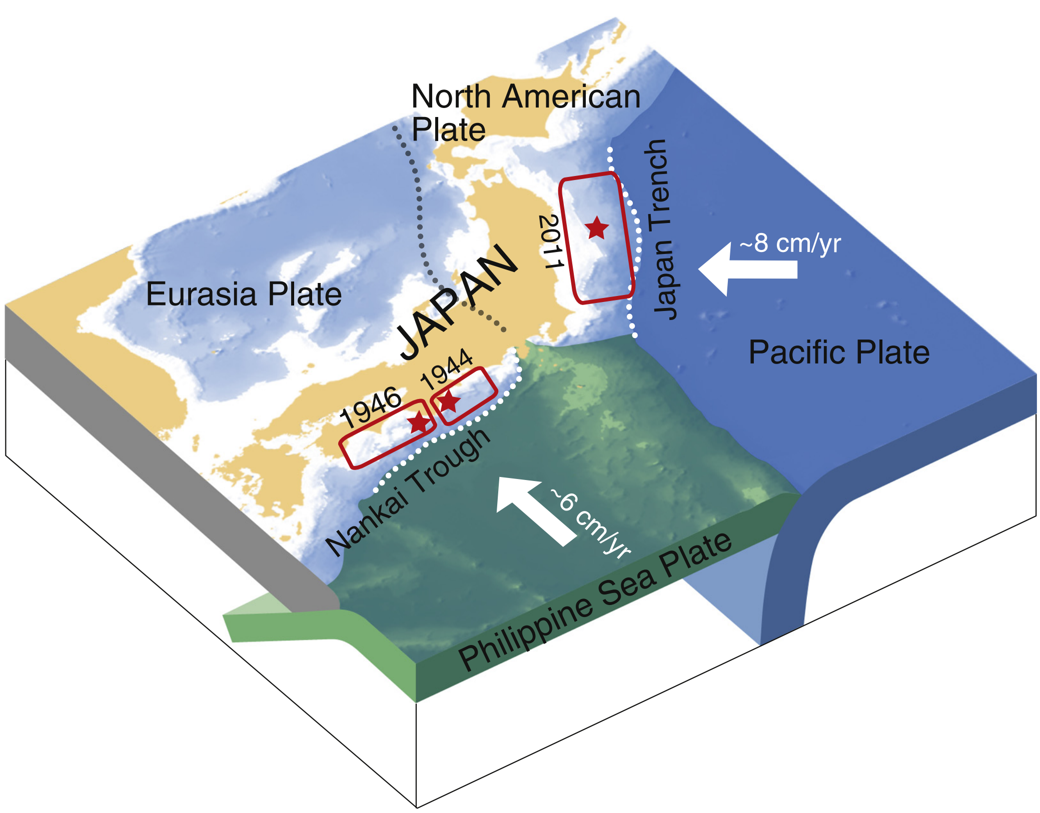

Fig. 1. Nankai and Japan Trench subduction zones and plates around Japan islands. Red stars and numbers show the epicenters of the earthquakes and its occurrence year; the red frames are the area of rupture zones during the earthquakes. White arrows and numbers show directions and rates of plate motion, respectively (Apel et al., 2006; Loveless and Meade, 2010; Ozawa et al., 2011; Sella et al., 2002). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Please cite this article as: Lin, W., et al., Distribution of stress state in the Nankai subduction zone, southwest Japan and a comparison with Japan Trench, Tectonophysics (2015), http://dx.doi.org/10.1016/j.tecto.2015.05.008