Marine and Petroleum Geology 66 (2015) 404–417

Contents lists available at ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Research paper

Paleocurrent analysis of Pleistocene turbidite sediments in the forearc basin inferred from anisotropy of magnetic susceptibility and paleomagnetic data at the gas hydrate production test site in the eastern Nankai Trough

Machiko Tamaki [a, *], Kiyofumi Suzuki [b], Tetsuya Fujii [b]

[a] Japan Oil Engineering Co. Ltd., Tokyo 104-0054, Japan
[b] Japan Oil, Gas and Metals National Corporation, Chiba 261-0025, Japan

ARTICLE INFO

Article history:
Received 30 September 2014
Received in revised form
12 February 2015
Accepted 16 February 2015
Available online 4 March 2015

Keywords:
AMS
Magnetic fabric
Turbidite
Forearc basin
Paleocurrent
Depositional process
Eastern Nankai Trough

ABSTRACT

To understand the paleocurrent directions and depositional processes in the forearc basin along the active convergent margin of the eastern Nankai Trough, analysis of the anisotropy of magnetic susceptibility (AMS) has been applied to Pleistocene turbidite sediments in a borehole core obtained in the vicinity of the gas hydrate production test site. Sixty-one core specimens mainly sampled from silty and sandy sediments were measured, and the AMS results show generally oblate magnetic fabrics characterized by girdle-distributed weakly-clustered maximum and intermediate susceptibility axes. Diagnostic magnetic fabric parameters show that the sediments generally preserve primary sedimentary structures without significant sediment disturbance due to events such as coring and bioturbation. The characteristic remanent magnetization was also measured to determine the reorientation of each core. Paleocurrent directions estimated from the offset of the minimum susceptibility axes in the stratigraphic coordinates show two predominant directions: one toward the southwest (SW) and the other toward the northwest (NW). On the basis of the interpretations of 3D seismic data, the principal SW direction is generally parallel to the trough-shaped basin axis; this suggests that the sediments were carried by axial turbidity currents within the channel. The subordinate NW direction corresponds to the downslope direction of the Daini–Atsumi Knoll; this may be due to a sediment supply from the southeast associated with a submarine slope failure and landslide evolution or it may be due to flow reflections from the slope toward the basin center. The results of the paleocurrent analysis suggest that the Pleistocene depositional system around the Daini–Atsumi Knoll is affected by the basin configuration. These results are in good agreement with previous studies of the coeval depositional system for the adjacent forearc minibasin around the eastern Nankai Trough.

1. Introduction

Gas hydrates constitute an unconventional energy resource that may become an important alternative source of energy. On the basis of an extensive study of bottom simulating reflectors (BSRs) appearing in seismic reflection profiles, several potential gas hydrate deposits are believed to exist in offshore areas surrounding Japan (e.g., Hayashi et al., 2010). Among them, BSRs are widely distributed in the forearc basins and accretionary prism along the Nankai Trough (Figs. 1 and 2) (e.g., Baba and Yamada, 2004). Gas hydrates around the eastern Nankai Trough have been extensively investigated from 2D/3D seismic data and from well log and core data by the Research Consortium for Methane Hydrate Resource in Japan (MH21). These studies found that gas hydrates are well developed in pore spaces of unconsolidated sandy sediments in the turbidite facies of the forearc basins (e.g., Tsuji et al., 2004, 2009; Uchida et al., 2004; Fujii et al., 2009; Takano et al., 2009), as are conventional hydrocarbon-bearing reservoirs. Recently, gas hydrates and free gas have also been investigated based on the results of International Ocean Discovery Program's Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) (e.g., Doan et al., 2011; Miyakawa et al., 2014) (Fig. 1).

* Corresponding author. Tel./fax: +81 3 5548 1663.
E-mail address: tamaki_m@joe.co.jp (M. Tamaki).

http://dx.doi.org/10.1016/j.marpetgeo.2015.02.030

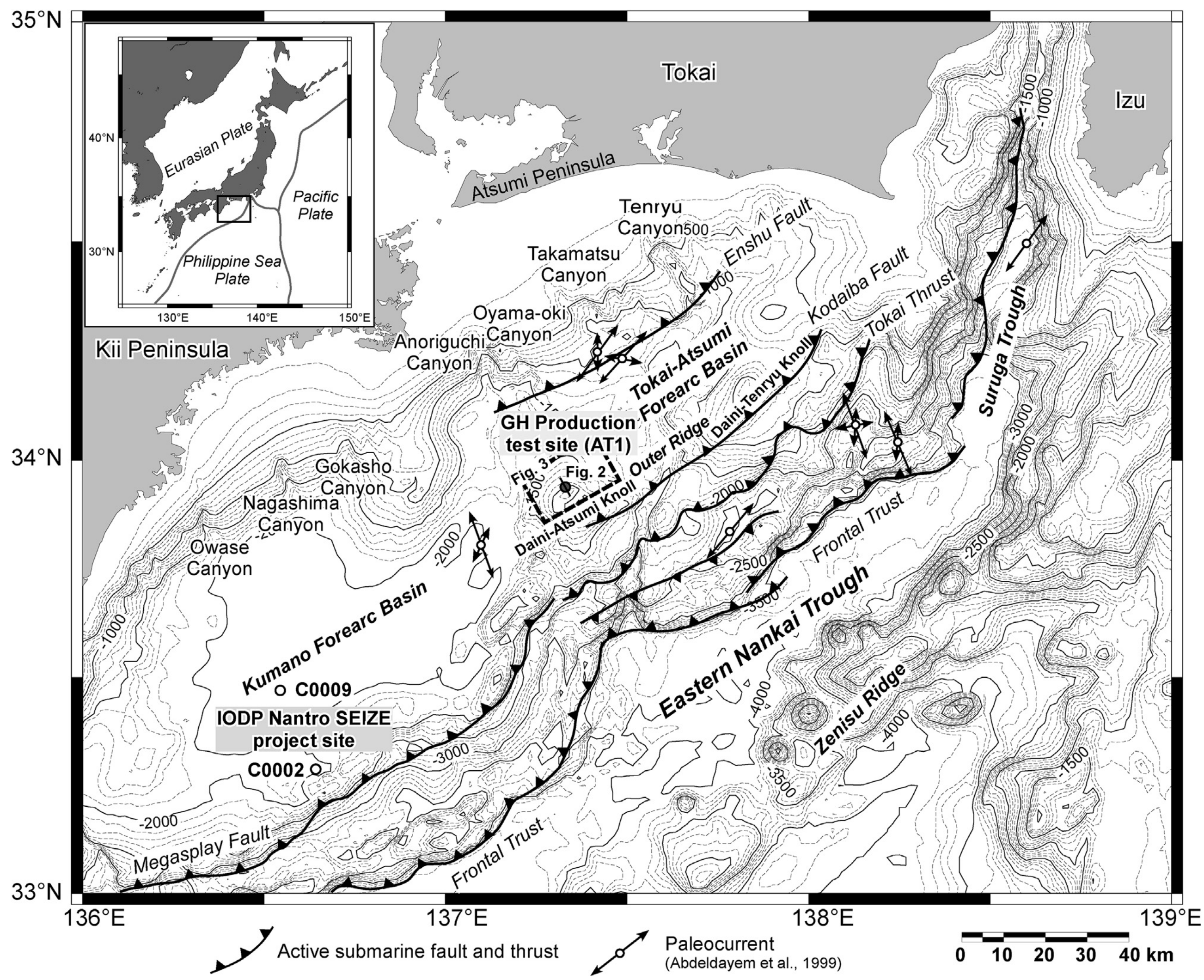

Figure 1. Index maps of the Tokai–Atsumi–Kumano forearc basin in the eastern Nankai Trough and the location of the study area at the first offshore gas hydrate (GH) production test site (AT1 site). Arrows show paleocurrent directions obtained from AMS analyses using modern sediments (Abdeldayem et al., 1999). Bathymetric data were derived from the ETOPO1 dataset (Amante and Eakins, 2009).

At the AT1 site in the eastern Nankai Trough (Fig. 1), MH21 conducted the first offshore gas hydrate production test (Yamamoto et al., 2014). To accurately capture the behavior of gas hydrate dissociation and gas production during the test, a detailed gas hydrate reservoir characterization of turbidite facies has been conducted (e.g., Fujii et al., 2015). In such a process, the evaluation of turbidite facies distributions is important because petrophysical properties (i.e., gas hydrate saturation, porosity, and permeability), which are required to simulate gas production performance, are commonly controlled by facies-related properties (i.e., grain size and mineralogy) (e.g., Fujii et al., 2015; Ito et al., 2015; Konno et al., 2015). Therefore, it is essential to understand the depositional environment and sedimentary processes of gas hydrate-bearing sediments, which provide insight into a first-order evaluation of turbidite facies distributions.

Previous studies suggested that the depositional environment of gas hydrate-bearing sediments around the test site comprised a submarine-fan turbidite system in which sediments were deposited in a trough-shaped forearc basin whose axis is parallel to the eastern Nankai Trough (e.g., Takano et al., 2009, 2013; Noguchi et al., 2011). It has also been suggested that forearc depositional styles during the Pleistocene around the test site were strongly controlled by tectonic events; thereby, a multidisciplinary approach is needed to evaluate the evolution of the turbidite system in the forearc basin of the eastern Nankai Trough.

The reconstruction of paleocurrents is an important contribution to basin reconstruction. On the basis of seismic geomorphology, Takano et al. (2009, 2013) found that the Pleistocene depositional patterns show some spatial differences between regions around the eastern Nankai Trough, possibly caused by segmentation of the forearc basin and variations in sediment supply. During the deposition of sediments, the sediment supply to the basin is mainly derived from several submarine canyons (Noguchi et al., 2011) (Fig. 3). At the AT1 site, NE to SW and NNE to SSW paleocurrent directions were deduced from seismic attributes and the internal architectures of the channel complex (Noguchi et al., 2011). However, such seismic attributes as amplitude, velocity, and attenuation are enhanced by gas hydrates and associated free gas above and below BSRs (e.g., Baba and Yamada et al., 2004; Saeki et al., 2008; Dvorkin and Uden, 2004); consequently, these seismic anomalies cause difficulties in stratigraphical and geomorphological interpretations. For a better understanding, it is necessary to