Marine Geology 356 (2014) 19–30

Contents lists available at ScienceDirect

Marine Geology

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

Magnetic fabric analyses as a method for determining sediment transport and deposition in deep sea sediments

B. Novak [a,*], B. Housen [a], Y. Kitamura [b,c], T. Kanamatsu [c], K. Kawamura [d]

[a] Pacific NW Paleomagnetism Laboratory, Department of Geology, Western Washington University, 516 High Street, Bellingham, WA 98225-9080, USA
[b] Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[c] Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology, 2-15 Natsushima-Cho, Yokosuka 237, Japan
[d] Graduate School of Science and Engineering, Yamaguchi University, 1677-1 Yoshida, Yamaguchi 753-8512, Japan

A R T I C L E I N F O

Article history:
Received 29 March 2013
Received in revised form 25 November 2013
Accepted 3 December 2013
Available online 10 December 2013

Keywords:
Magnetic fabric
Nankai Trough
Sediment deposition

A B S T R A C T

Anisotropy of magnetic susceptibility (AMS) analyses and the characteristic relationship between the q-value (magnetic lineation/foliation) and the imbrication angle (β) of the minimum susceptibility axes from the bedding plane (q–β diagrams) provide insight into the paleocurrent direction and depositional processes. During Integrated Ocean Drilling Program (IODP) Expedition (Exp) 333 sediments were cored from within the Nankai Trough accretionary prism at Site C0018, the depositional center for six mass transport deposits (MTDs). We analyzed specimens from the two subunits, Ia and Ib, and the six mass transport deposits identified during Exp 333. The sediments that are unaffected by MTD emplacement record episodic changes in paleocurrent direction and depositional processes including current, slope gravity, viscous suspension, and grain collision over the past 1.24 Ma at Site C0018. Magnetic fabric analyses proved useful in identifying sediment disturbance and the direction of movement at the time of emplacement, especially within MTDs 1, 2, 5, and 6. The magnetic fabric analyses were also useful in characterizing undeformed sediments within MTD 3. These undeformed sediments likely record primary depositional fabrics. We propose two additional fields, deformation/disturbance and tilting, on the q–β diagram in order to account for steep imbrication angles and relatively high q-values.

1. Introduction

Recent studies of the Nankai Trough accretionary prism have focused on the depositional dynamics and mass-movement processes of marine sediments within the accretionary wedge. Specifically, Integrated Ocean Drilling Program (IODP) Expedition (Exp) 333 collected sediments from within the Nankai Trough accretionary prism as part of the NanTroSLIDE project. Coring was focused on a location with stacked mass transport deposits (MTDs) identified through the use of the NanTroSEIZE 3-D multi-channel seismic data volume and Line 95 from the Institute for Research on Earth Evolution (IFREE) mini 3-D seismic survey (Park et al., 2008; Moore et al., 2009). The MTDs were cored in an effort to characterize the mass movement history within the accretionary wedge (Henry et al., 2012).

MTDs are gravity controlled cohesive deposits that are deposited by processes such as creep, slump, slide, debris flow, and mudflow. Because MTDs encompass many types of deposits, a thorough study of each MTD is necessary in order fully understand mass movement within the accretionary wedge and the possible hazards associated with MTDs. A characterization of the magnetic fabric within these deposits is useful in clarifying the deposition and remobilization behavior of submarine mass movements.

Previous studies have identified depositional processes through magnetic fabric analyses. Joseph et al. (1998) successfully discriminated between hemipelagic processes, turbidity deposits, and drift deposits in deep-sea sediments through a combination of grain size and magnetic fabric analyses. Current direction determination was not within the scope of their work. Pares et al. (2007) found that paleocurrent direction determination was possible with the reorientation of specimens, but depositional processes were not characterized during their study. But as this study demonstrated characterizing the direction of paleocurrent flow as well as the intensity and mode of deposition is important to fully understanding sediment deposition.

In this study, we attempt to determine the depositional processes for the six MTDs and surrounding sediments at IODP Exp 333 Site C0018 using anisotropy of magnetic susceptibility (AMS) measurements. These determinations are based on the shape of the AMS ellipsoid, the orientation of the magnetic susceptibility axes, and the relationship between the imbrication angle of the sediment grains and the degree of magnetic lineation and foliation development within the magnetic fabric.

2. Geologic setting

Site C0018 is located in the Pleistocene–Holocene accretionary wedge in the Nankai Trough off the coast of the Kii Peninsula in Japan

* Corresponding author at: Western Washington University, 516 High Street, Bellingham, WA 98225-9080, USA.

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http://dx.doi.org/10.1016/j.margeo.2013.12.001

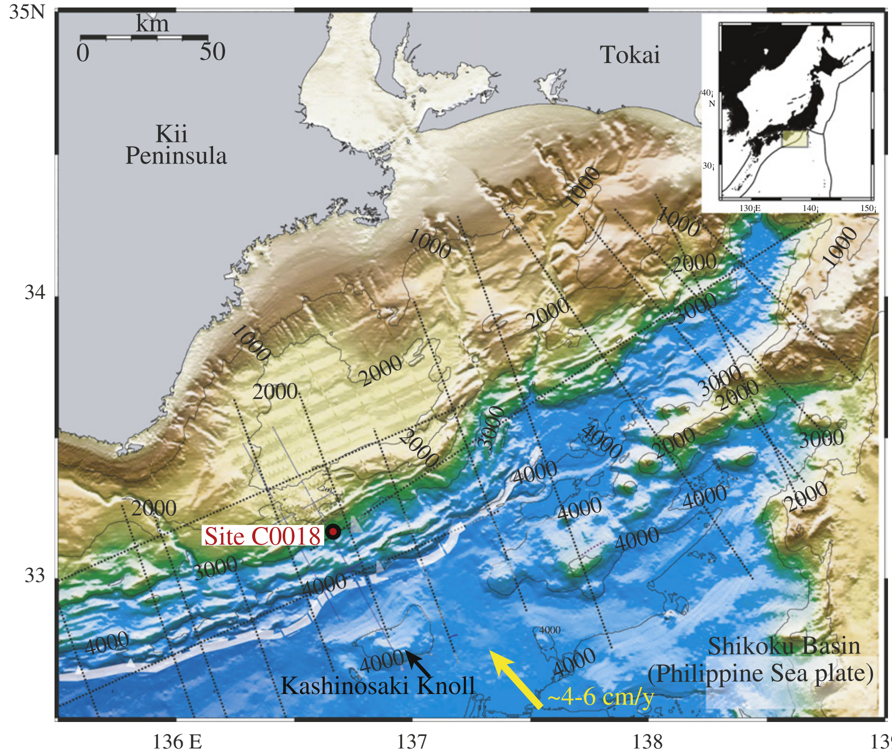

Fig. 1. Bathymetric map of the Shikoku Basin off the coast of the Kii Peninsula in Japan adapted from Henry et al. (2012). Contours are depth in meters below sea level. The location of Site C0018 is marked (red circle). The yellow arrow depicts the estimated convergence between the Philippine Sea plate and Japan (Seno et al., 1993; Heki and Miyazaki, 2001; Henry et al., 2012).

(Figs. 1 and 2; Henry et al., 2012). The site is within a slope basin depositional center where the presence of stacked MTDs was determined through seismic imagery interpretation. Sample collection was aimed at characterizing the slide dynamics and establishing the stratigraphy of Quaternary mass-movement deposits along the Nankai Trough accretionary prism (Henry et al., 2012).

Coring at Site C0018 extended from 0 to 314.15 m below the seafloor (mbsf) with approximately 86% recovery (Fig. 3; Henry et al., 2012). Magnetostratigraphy, biostratigraphy, and tephrochronology were used to date the sediments. The Site C0018 sediments range in age from approximately 1.6 Ma at 314.14 mbsf to present at 0 mbsf (Henry et al., 2012). Depositional units were distinguished based on variations in grain size, mineralogy, composition, and the presence of sand and ash layers (Henry et al., 2012). Site C0018 sediments were divided into two subunits, Subunit Ia and Subunit Ib, based on lithology (Henry et al., 2012).

Subunit Ia (0–190 mbsf) is composed of greenish gray to grayish silty clay with thin (<5 cm) interbedded volcanic ash (Henry et al., 2012). Based on internal variations Subunit Ia was further subdivided into three facies: Iai, Iaii, and Iaiii (Henry et al., 2012). The deposition of Subunit Ia on the continental slope is likely dominated by hemipelagic settling, submarine landslides, and small contributions of volcanic ash with the onset of the hemipelagic environment at approximately 190 mbsf (Henry et al., 2012).

Facies Iai, which comprises the shallowest sediments at Site C0018, is predominately greenish gray silty clay with minor contributions of ash (Fig. 3). The ash layers are <2 cm thick, are fine grained, and are partly laminated. The lower boundaries of the ash layers are sharp while the upper contacts are diffuse (Henry et al., 2012).

Below Facies Iai lie the sediments of Facies Iaii. The dominant lithology of Facies Iaii is greenish to dark gray silty clay, silt, and sparse fine-grained sand (Fig. 3). The silty and sandy layers are dominantly

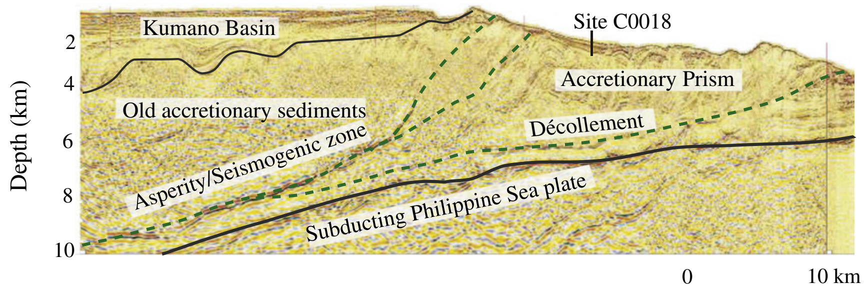

Fig. 2. Spliced composite cross-section from NanTroSEIZE 3-D multi-channel seismic data volume (Moore et al., 2009) and Line 95 from IFREE mini 3-D seismic survey (Park et al., 2008). The location of Site C0018 is marked. The lowest dashed line is interpreted as the major decollement surface and the upper dashed lines are interpreted to be part of the megasplay fault. The lowest solid line separates the overlying ocean sediments from the subducting oceanic crust below whereas the uppermost solid line separates the Kumano Basin sediments from the old accretionary sediments.