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Tidal rhythmites in a deep sea environment: An example from Mio-Pliocene Misaki Formation, Miura Peninsula, Japan

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ABSTRACT

The Mio-Pliocene Misaki Formation, Miura Peninsula, Japan is characterized by alternation of mafic scoriaceous pebbly sandstone, pumiceous sandstone and siltstone, and mudstone formed in a fore-arc basin in an arc–arc collisional zone. The qualitative as well as quantitative evidences of tide during the Misaki sedimentation in the Jogashima area, Miura Peninsula are presented here. The lunar synodic period of ~28 days/lunar month extracted from the Misaki tidal rhythmite agrees well with the published Miocene tidal rhythmite data. The couplet series of the Misaki tidal rhythmite, however, is often interrupted by downslope resedimentation via turbidity currents, intense penecontemporaneous deformation and bioturbation. Association of deep sea turbidites, mass flow deposits and tidal rhythmite suggest Misaki sedimentation in the Miura Peninsula took place in a submarine canyon setting.

1. Introduction

Sedimentary successions developed at destructive plate margin provide valuable record of orogenic processes and history facilitating reliable correlation between tectonic processes and consequent sedimentation (Lundberg and Dorsey, 1988; Soh et al., 1991; Busby and Ingersoll, 1995). However, the primary sedimentary structures are rarely preserved owing to the successive changes in physical properties as a consequence of strong deformation and metamorphism (Yamamoto et al., 2005). Nonetheless, the sedimentological analysis of young un-metamorphosed examples of fore-arc successions preserved on land would be a great complement to existing research (Hanamura and Ogawa, 1993; Lee and Ogawa, 1998; Yamamoto et al., 2005).

The Mio-Pliocene (Kaine et al., 1991) fore-arc succession of Miura Peninsula, south-central Japan is a unique example of an on land accretionary prism (Fig. 1; Yamamoto et al., 2005). In spite of syn-sedimentary as well as post-depositional deformation, primary sedimentary structures are well preserved (Hanamura and Ogawa, 1993; Lee and Ogawa, 1998). Detail sedimentary facies analysis of the Miura Group of rocks (the older Misaki and the younger formations, see Lee and Ogawa, 1998) has been done by earlier researchers (Lee and Ogawa, 1998; Stow et al., 1998). These authors interpreted the Misaki Formation as deep-water deposits. Lee and Ogawa (1998) have conducted detailed palaeocurrent measurement and interpreted some sedimentary structures of the Misaki Formation, Miura Peninsula are produced by deep-sea bottom current. In this paper we have re-examined the coarse scoriaceous pebbly sandstone and parallel and/or cross-laminated pumiceous fine sandstone facies in the Jogashima area (Fig. 1). Our sedimentological analyses of the fine-grained pumiceous sandstones indicate that these are tidal rhythmites. We have quantified, for the first time, tidal rhythm in a deep sea environment.

2. Sedimentary facies and inferred depositional environment

The Mio-Pliocene Misaki Formation of the Miura Peninsula, central Japan (Fig. 1A, B) represents the lower tier of the two tiered Miura Group (Soh et al., 1989; Stow et al., 1998). It is characterized by pumiceous sandstones and siltstones inter-banded with coarse grained mafic scoriaceous sandstones and tuffaceous mudstones (Fig. 2A–C) and shows lateral facies variation (Soh et al., 1989; Stow et al., 1998; Lee and Ogawa, 1998). Despite intense penecontemporaneous deformation including sediment

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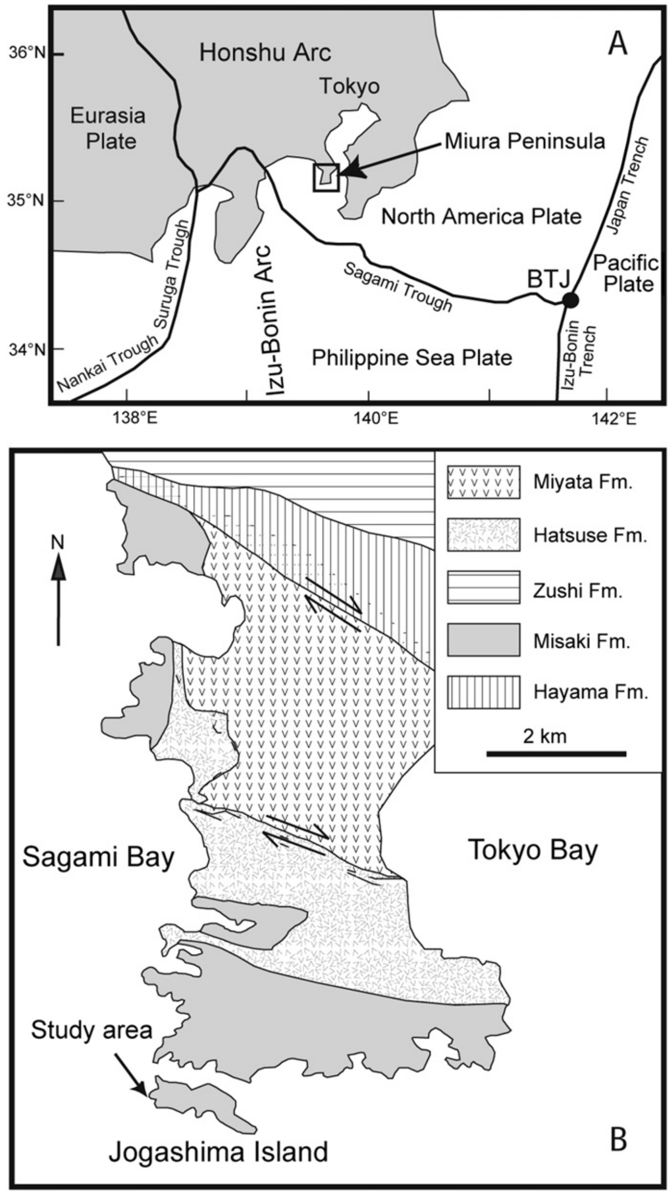

Figure 1. A: Regional plate tectonic setting of the Miura Peninsula, Japan. B: Simplified geological map of the Miura Peninsula, Japan showing the disposition of the Misaki Formation.

injection, complex folding and thrusting (cf. Ogawa, 1982; Ogawa et al., 1985; Yamamoto et al., 2000, 2005), primary sedimentary structures are well preserved within the Misaki Formation. These sediments were deposited in a fore-arc basin on the eastern side of a proto Izu-Bonin arc prior to and during accretion of the Miura block onto the Honsu arc (Fig. 1A; Soh et al., 1991; Stow et al., 1998).

Stow et al. (1998) have done a detailed sedimentary facies analysis of the entire Miura Group in the Miura and Boso Peninsula. We have examined the sedimentary successions well exposed in and around Jogashima (Fig. 1). We agree with the facies classification of Stow et al. (1998) and mentioned here only the salient facies characteristics briefly that are relevant to our study and also for the sake of brevity. Interested reader must consult Stow et al. (1998) for a detailed facies description and interpretation.

The Misaki Formation in and around Jogashima is made up of (I) coarse-grained scoriaceous sandstone facies (II) pumiceous sandstone facies (III) tuffaceous mudstone facies.

(I) *Coarse-grained scoriaceous sandstone facies*:

These are dark greenish, brownish or black-colored coarse-grained sandstone/pebbly sandstone beds dominantly composed of basic to intermediate lava fragments (scoria) that sharply overlies the pumiceous siltstone/sandstone facies (Fig. 2A). The scoriaceous pebbly sandstone facies shows normal grading (Figs. 2A and 3A). At places, these are conglomeratic and bear traces of planar stratification.

(II) *Fine-grained pumiceous sandstone/siltstone facies*:

The pumiceous sandstone and siltstone facies represent the most dominant facies of the Misaki Formation, Miura Peninsula. These are up to 60 cm thick and comprise a mixture of pumice, clay minerals and biogenic materials such as diatoms, radiolarians and foraminifera (Lee and Ogawa, 1998 and references therein). The sandstones exhibit parallel lamination or cross lamination/cross-bedding (set thickness ranges 3–20 cm) and often show bioturbation (Fig. 3B). Cross laminations indicating flow reversals are found at places (see top part of the Fig. 3C). Double mud drape (cf. Visser, 1980; Shanmugam, 2003; Mazumder and Arima, 2005; Fig. 3D) However, the ripple lee faces are often over steepened due to deformational rotation.

(III) *Tuffaceous mudstone facies*:

This facies is characterized by thin-bedded, white colored, felsic tuffs and are interbedded with the scoriaceous sandstones and pumiceous sandstones and siltstones. These are generally normally graded but otherwise structureless (Fig. 2B, bottom left). This facies forms a minor (<5%) but persistent and distinctive facies class. At places, two or more tuff beds are stacked to form a thicker and composite tuff unit.

Presence of normal grading (Figs. 2A and 3A), laterally persistent, alternate coarse pebbly sandstone and tuffaceous mudstone with profuse penecontemporaneous deformation structures (Figs. 2B and 3A) and 2000–3000 m (mid-abyssal to abyssal) palaeo-depth determined from the occurrences of benthic foraminifers (Akimoto et al., 1991; see Lee and Ogawa, 1998 and references therein) corroborate that the scoriaceous coarse pebbly sandstone facies represents deep sea turbidite (cf. Stow et al., 1998). Confinement of various syn- and meta-depositional structures (cf. Nagtegaal, 1963; Owen, 1995; Mazumder et al., 2009) and their confinement along selected stratigraphic levels sandwiched between undeformed beds in a deep sea setting (cf. Stow et al., 1998, 2002; Lee and Ogawa, 1998) indicate that the majority of the penecontemporaneous deformation structures preserved within the Misaki Formation are seismites (cf. Seilacher, 1984; Van Loon, 2009; Fig. 3A).

In significant contrast to the scoriaceous coarse pebbly sandstone and tuffaceous mudstones, the pumiceous fine-grained sandstone facies bears oppositely oriented current ripples and double mud drapes (Fig. 3C, D). This clearly indicates tidal influence in a deep sea setting (see Shanmugam, 2003 and references therein) and therefore we interpret this pumiceous fine-grained sandstone facies as deep sea tidal rhythmites (cf. Mazumder and Arima, 2005).

3. Misaki tidal rhythmite

The focus of this paper is the tidal rhythmite exposed along the rocky coast of the Tokyo bay in and around Jogashima (Fig. 1A, B). These are well sorted, fine-grained sandstones with characteristic thick-thin laminae alternations (Fig. 3C) and double mud drapes