Shallow structure and late Quaternary slip rate on the Osaka Bay Fault: Aspects of climate-tectonic interaction

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>100 km inboard from the subduction interface in western Japan, the crustal seismogenic zone exists at ~5–20 km depth, as inferred from cut-off depths of seismicity and heat flow gradient. Active faulting is manifested under the contemporary compressional regime formed by the oblique subduction of the Philippine Sea Plate under the Japan arc at a current velocity of ~4–6 cm/yr. At the latitude of 34°N from the Ise bay to the Osaka bay, patterns of geodetic strain accumulation infer that NW-SE shortening of ~1–2 cm/yr is nearly perpendicular to existing faults, posing a major seismic hazard potential to the densely-populated areas of the Kansai region. Previous seismic reflection surveys have revealed a fold-and-thrust belt consisting of ~40° west- and east dipping reverse faults beneath the Osaka basin, Ise basin, and the Suzuka mountains. Whereas, to the west, ~70–80° east dipping, high-angle reverse faults characterize the structures around the Awaji island and contribute to the subsidence in the Osaka bay, including the Nojima fault that ruptured in the devastating 1995 Mw6.9 Southern Hyogo Prefecture Earthquake, and the offshore Osaka bay fault, which did not rupture in the 1995 earthquake.

To study the recent deformation history on the Osaka bay fault, high-resolution seismic profile data were collected along 14 survey lines in the Osaka bay, using a Mini GI air gun (Sercel; 15/15 in^3) and Boomer (100–200 J) as active sources, together with multi-beam bathymetry data on the T/S Fukaemaru and R/V Onokoro. In this study, we characterize the shallow structures of the Osaka bay fault, and assess the fault slip rates, in comparison with deep structures imaged by previous seismic surveys that targeted greater depth. The Osaka bay is filled by ~3 km-thick sediments of the Plio-Pleistocene Osaka Group, which consists of fluvial, lacustrine, and marine sequences, as revealed by multiple boreholes around the bay. Within the sedimentary section, distinct marine clay layers that correlate with global eustatic sea-level highstands are present, marking key beds useful for tying the regional stratigraphy. In this study, we assign the ages in our seismic profiles based on the age-correlated reflectors by Inoue et al. (2003), at the intersection points between our survey lines and previously acquired lines.

Our seismic profiles show that the Osaka bay fault is blind and not surface emergent, and that the deformation along the thrust reaches near surface by fault-propagation folding, characterized by a >5 km-wide asymmetric anticline of which its forelimb becomes steeper with depth. In the footwall, a >2 km-wide syncline and associated thickening of sediments develop packages of growth strata. These strata are further buried by younger sediments, where distinct on-laps of sediments onto folded strata form a regional sequence boundary. We interpret these shallow sediments to represent the Holocene alluvial sequence, overlying the late Pleistocene Upper Osaka Group strata. From the seismic profiles, we observe along-strike variation of sediment thickness of the Holocene sediments (0–20 m thick) in the hanging wall and footwall, revealing horizons where the erosional surface of the fold is exposed at the seafloor, and horizons where the fold is buried by recent sediments.

To document the strain accommodated by the thrust, we use three approaches by measuring: 1) the sediment thickness variations between the hanging wall and footwall, 2) the offsets across the forelimb, and 3) the areas of uplift defined by the geometry of the hanging wall anticline and footwall syncline. The observed variations in shallow sediments on the thrust system indicate multiple changes in deposition, additionally affected by paleoclimate and tidal currents in the bay. We combine our observations with borehole data and regional sea-level records, and report on our assessments of fault slip rates and sediment responses through time, and their north-south variations on the Osaka bay fault.

Keywords: Osaka bay fault, Fold-and-thrust belt, Seismic reflection survey

