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Evolution of the eastern margin of Korea: Constraints on the opening of the East Sea (Japan Sea)

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Abstract

We interpreted marine seismic profiles in conjunction with swath bathymetric and magnetic data to investigate rifting to breakup processes at the eastern Korean margin that led to the separation of the southwestern Japan Arc. The eastern Korean margin is rimmed by fundamental elements of rift architecture comprising a seaward succession of a rift basin and an uplifted rift flank passing into the slope, typical of a passive continental margin. In the northern part, rifting occurred in the Korea Plateau that is a continental fragment extended and partially segmented from the Korean Peninsula. Two distinguished rift basins (Onnuri and Bandal Basins) in the Korea Plateau are bounded by major synthetic and smaller antithetic faults, creating wide and considerably symmetric profiles. The large-offset border fault zones of these basins have convex dip slopes and demonstrate a zig-zag arrangement along strike. In contrast, the southern margin is engraved along its length with a single narrow rift basin (Hupo Basin) that is an elongated asymmetric half-graben. Analysis of rift fault patterns suggests that rifting at the Korean margin was primarily controlled by normal faulting resulting from extension rather than strike-slip deformation. Two extension directions for rifting are recognized: the Onnuri and Hupo Basins were rifted in the east-west direction; the Bandal Basin in the east–west and northwest–southeast directions, suggesting two rift stages. We interpret that the east–west direction represents initial rifting at the inner margin; while the Japan Basin widened, rifting propagated southeastward repeatedly from the Japan Basin toward the Korean margin but could not penetrate the strong continental lithosphere of the Korean Shield and changed the direction to the south, resulting in east–west extension to create the rift basins at the Korean margin. The northwest–southeast direction probably represents the direction of rifting orthogonal to the inferred line of breakup along the base of the slope of the Korea Plateau; after breakup the southwestern Japan Arc separated in the southeast direction, indicating a response to tensional tectonics associated with the subduction of the Pacific Plate in the northwest direction. No significant volcanism was involved in initial rifting. In contrast, the inception of sea floor spreading documents a pronounced volcanic phase which appears to reflect asthenospheric upwelling as well as rift-induced convection particularly in the narrow southern margin. We suggest that structural and igneous evolution of the Korean margin, although it is in a back-arc setting, can be explained by the processes occurring at the passive continental margin with magmatism influenced by asthenospheric upwelling.

Keywords: Multichannel seismic profiles; Korean margin; Back-arc rifting; Pronounced volcanic phase; Passive continental margin

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1. Introduction

The East Sea (Japan Sea) is a back-arc sea behind the Japan Arc, lying on the eastern margin of the Eurasian Plate (Fig. 1). This sea is principally comprised of three deep basins (the Japan, Ulleung, and Yamato Basins) separated by rifted continental fragments (the Korea Plateau, the Oki and Yamato Banks). It is generally accepted that this sea was formed by the process of back-arc spreading (Tatsumi and Kimura, 1991). Analysis of various data from ODP (Ocean Drilling Program) Legs 127 and 128 and other onshore data suggests that active opening commenced with fault-controlled crustal extension in the early Oligocene and subsequent back-arc spreading persisted until the middle Miocene, when the strain field inverted from extensional to contractile (Jolivet et al., 1994) resulting from the collision of the Bonin Arc into central Japan (Honshu) (Matsuda, 1979).

The mode of separation of the Japan Arc from the Korean Peninsula has been the subject of debate on the opening of the East Sea, for which a variety of models have been put forward. For example, 'bending or fan-shaped opening' (Otofuji, 1996) and 'pull-apart' (Lallemand and Jolivet, 1985; Jolivet et al., 1994) models are at present most frequently cited. The bending model, based on land paleomagnetic data, suggests that NE (northeastern) Japan and SW (southwestern) Japan underwent counterclockwise and clockwise rotation away from Asia, respectively. On the other hand, the pull-apart model proposes that the East Sea opened as a mega-pull-apart basin associated with the southward translation of the Japan Arc.

In spite of prolific studies on the opening mode of the East Sea, little is known about the nature and spatial configuration of rifting at its continental margins where the early history of rifting to breakup was registered. The eastern Korean margin, consisting of continental shelf and slope between the Korean Peninsula and the Ulleung Basin, is conjugate to the SW Japan Arc. The eastern Korean margin is complicated in morphology; it is embossed with basement highs of the Korea Plateau and the Hupo Bank, at the same time engraved with rift basins such as the Bandal, Onnuri, and Hupo Basins (Fig. 2a). Apparently, these structural units at the Korean margin were formed and deformed by tectonic evolution that led to the separation of the SW Japan Arc. Recent studies employing ocean bottom

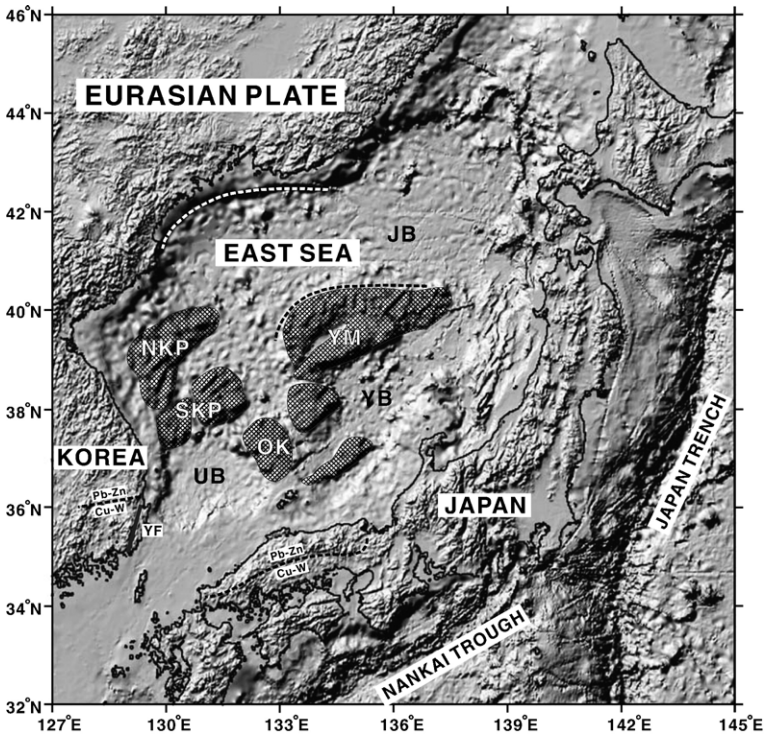

Fig. 1. Physiography of the East Sea (Japan Sea). JB, YB, and UB—Japan, Yamato, and Ulleung Basin, respectively, YF—Yangsan fault. The hatched areas represent continental fragments (YB—Yamato Bank, OK—Oki Bank, NKP and SKP—North and South Korea Plateaus). The dotted line (Pb–Zn/Cu–W) in SE Korea and SW Japan is a metallogenic belt formed prior to 46 Ma.