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Back-arc rifting in the Korea Plateau in the East Sea (Japan Sea) and the separation of the southwestern Japan Arc from the Korean margin

Han-Joon Kim [a,*], Gwang Hoon Lee [b], Dong-Lim Choi [a], Hyeong-Tae Jou [a], Zhiwei Li [c], Yong Zheng [c], Gil-Young Kim [d], Sang-Hoon Lee [a], Yi K. Kwon [e]

[a] Korea Institute of Ocean Science and Technology, Ansan, South Korea
[b] Department of Energy Resources Engineering, Pukyong National University, Busan, South Korea
[c] State Key Laboratory of Geodesy and Earth's Dynamics, Institute of Geodesy and Geophysics, Chinese Academy of Sciences, Wuhan, China
[d] Korea Institute of Geoscience and Mineral Resources, Daejeon, South Korea
[e] Department of Geo-Environment Sciences, Kongju National University, Kongju, South Korea

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ABSTRACT

The South Korea Plateau is a remnant of continental crust in the middle of the eastern Korean margin that was deformed by extension in association with back-arc rifting and separation of the southwestern Japan Arc in the Cenozoic. Multichannel seismic profiles show that the South Korea Plateau preserves structure of rift basins flanked by uplifted footwall blocks. Rift basins in the plateau are filled with distinct syn- and post-rift sequences separated by a prominent breakup unconformity resulting from uplift. The crustal and upper mantle structures computed by ambient noise tomography indicate that the South Korea Plateau defines the seaward limit of rifted continental crust; in addition, rifting occurred with vigorous asthenospheric upwelling induced along the Korean margin and depth-dependent stretching. Therefore, the South Korea Plateau underwent the entire sequence of tectonic events typical of a passive continental margin encompassing rifting with subsidence, uplift, erosion, and breakup prior to the separation of the southwestern Japan Arc. Breakup at the Korean margin may substantiate successive episodes of back-arc spreading which migrated toward the arc in response to trench retreat. We suggest that the southwestern Japan Arc moved to its present location from the southern part of the Korean margin with a significant amount of clockwise rotation during back-arc spreading.

1. Introduction

The subduction zones in the western Pacific are dynamic and tectonically diverse with abundant back-arc seas (Lebedev and Nolet, 2003). The East Sea (Japan Sea) behind the Japan Arc is one of the back-arc seas in the western Pacific subduction zones (Fig. 1). Analysis of various data from ODP legs 127 and 128 and other onshore data suggests that active opening of the East Sea commenced with fault-controlled crustal extension in the early Oligocene and subsequent back-arc spreading persisted until the middle Miocene (Jolivet et al., 1994), when changes in plate motion caused back-arc closure associated with the collision of the Bonin Arc into central Japan (Honshu) (Matsuda, 1979). The East Sea consists of three major back-arc basins (Japan, Yamato, and Ulleung (Tsushima) Basins) and intervening topographic highs (Korea Plateau, Oki Bank, and Yamato Bank). The intervening topographic highs are interpreted as rifted continental fragments left on their present positions concurrently with the opening of the East Sea (e.g., Tamaki et al., 1992). Unlike other continental fragments, the Korea Plateau is connected to the Korean Peninsula, forming a continental margin between the peninsula and the deep-sea plains of the Japan and Ulleung Basins. The separation of the southwestern Japan Arc from mainland Asia has been explained by either southward translation (e.g., Jolivet and Tamaki, 1992), or clockwise rotation (e.g., Otofuji et al., 1999), or combination of the two (Honza et al., 2004; Lee et al., 1999). In any case, tectonic evolution of the Korean margin with emphasis on the Korea Plateau was not fully and correctly addressed, despite that it is the place where the separation of the southwestern Japan Arc commenced.

The Korea Plateau is divided into the northern and southern components: the North and South Korea Plateaus, respectively (Fig. 1). Kim et al. (2007) interpreted the rift structure of the northern part of the South Korea Plateau using multichannel seismic (MCS) profiles. They suggested that (1) the Korea Plateau accommodated vigorous crustal deformation associated with the separation of the southwestern portion of the Japan Arc, (2) the southwestern Japan Arc was separated principally in the southeast direction in response to the northwestward subduction of the Pacific Plate, and (3) although the Korean margin is in a back-arc, its evolution is essentially explained by extensional processes from rifting to spreading, typical of a passive continental margin.

* Corresponding author at: Korea Institute of Ocean Science and Technology, Ansan 426-744, South Korea.
E-mail address: hanjkim@kiost.ac (H.-J. Kim).

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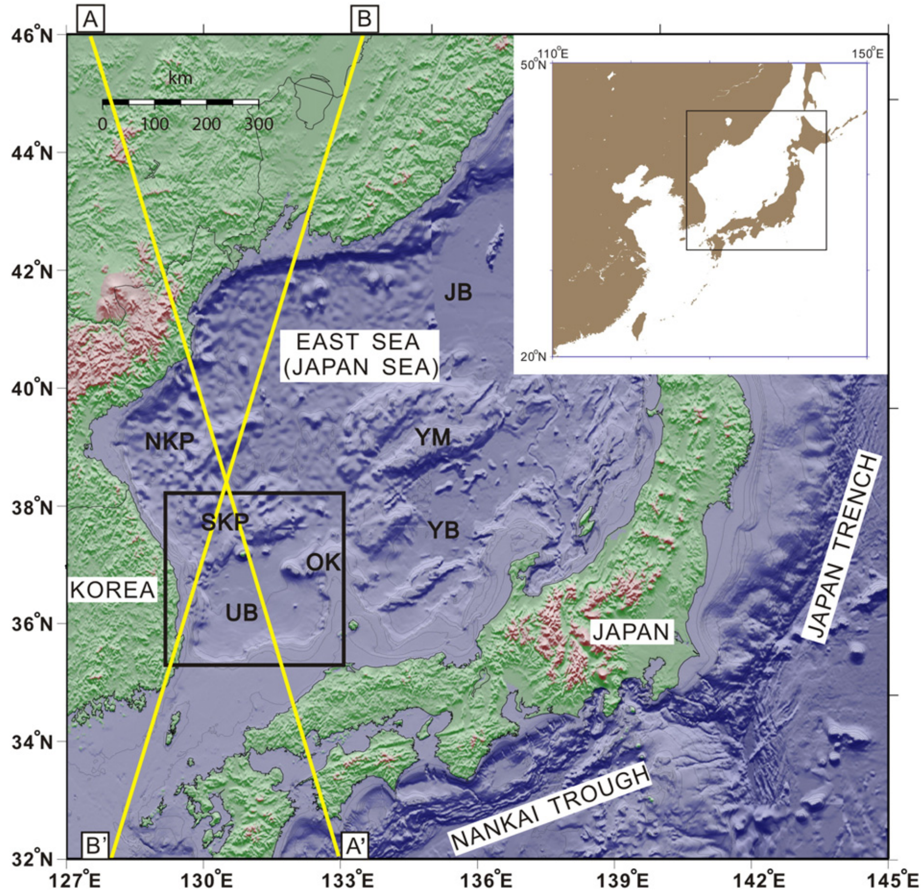

Fig. 1. Physiography of the East Sea (Japan Sea). JB, YB, and UB (= Japan, Yamato, and Ulleung Basins, respectively) are back-arc basins. NKP, SKP, OK, and YM (= North Korea Plateau, South Korea Plateau, Oki Bank, and Yamato Bank, respectively) are fragmented continental crust. The rectangle indicates the area with detailed bathymetry shown in Fig. 2. A–A′ and B–B′ are two transects along which s-wave velocity structure down to 80 km depth was computed (see Fig. 6). The area is indicated by a rectangle in the inset.

Passive or Atlantic-type continental margins document a breakup event which indicates that stretching of the continental lithosphere through rifting gave way to the emplacement of the new oceanic lithosphere. On seismic profiles, the end of rifting can be characterized by a breakup unconformity that truncates syn-rift sediments in the rift basins, separating them from the overlying post-rift sediments (Falvey and Mutter, 1981; Franke, 2013). In this study, we interpret complete structure of continental rifting to breakup in the South Korea Plateau by combining new seismic profiles acquired in the southern part of the plateau with the profiles in Kim et al. (2007). The seismic profiles reveal the presence of a breakup unconformity in the South Korea Plateau that signifies the change from rifting to spreading. Therefore, addressing tectonic evolution of the Korean margin needs accurate understanding of how the crustal nature and structure vary across it. It is also important to understand how the upper mantle flow was involved in rifting and spreading because a back-arc region above the subducting slab is affected by vigorous mantle convection (e.g., Currie and Hyndman, 2006) which plays an important role in the opening of a back-arc sea. For this purpose, we infer crustal and upper mantle structures in and around the East Sea from shear-wave (s-wave) velocities down to 80 km depth using ambient noise tomography. We then discuss in detail the processes of the separation of the southwestern Japan Arc from the Korean margin.

2. Geologic setting of the Korean margin

The eastern Korean margin, extending from 35°N to 40°N in latitude, shows contrasting topography between its northern and southern parts (Fig. 1). The northern part approximately from 37°N to 40°N is dominated by prominent bathymetric highs of the North and South Korea Plateaus. In contrast, the continental margin south of the South Korea Plateau demonstrates relatively simple topography seawards, consisting of a narrow continental shelf and a steep slope descending into the Ulleung Basin.

The basement rocks of the South Korea Plateau comprise Mesozoic granites, Precambrian amphibolites, gneiss, and Paleozoic granite and sedimentary rocks, indicating that the plateau is a continuation of the middle of the Korean Peninsula in rock composition (Ryu and Han, 1996). The South Korea Plateau is further segmented into the eastern (the eastern South Korea Plateau, ESKP) and the western (the western South Korea Plateau, WSKP) blocks, separated by an about 100 km-long trough. The WSKP, connected to the Korean Peninsula, is composed of rifts and surrounding topographic highs (Fig. 2). The outer, eastern part of the WSKP contains the Bandal and Okgye Basins, while the inner landward part includes the Onnuri Basin. The Bandal Basin is a conspicuous rift in the WSKP with its width widening southeastward up to 30 km (Fig. 2). The Bandal Basin is surrounded by an uplifted flank on the southeastern side that is convex outward. It thus shows fundamental units of rift architecture (e.g., Rosendahl, 1987). The Onnuri and Okgye Basins immediately south of the Bandal Basin, as wide as 25 km, are also flanked by uplifted shoulders on either the exterior seaward or the interior landward side (Fig. 2).

The ESKP is fragmented in a trapezoidal shape that widens toward the south–southeast, measuring about 120 km lengthwise and 70 to 110 km widthwise. The ESKP is rugged with narrowly-spaced ridges aligned northeast–southwest (Fig. 2). Individual ridges neither divide nor trend away from each other. These ridges are generally spaced 10 to 20 km apart with linear troughs in between, constituting a system of horsts and grabens.