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Tectonic, sedimentary, and volcanic evolution of a back-arc basin in the East Sea (Sea of Japan)

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ABSTRACT

This paper focuses on the tectonic, sedimentary, and volcanic evolution of a unique back-arc basin (Ulleung Basin) in the southwestern part of the East Sea (Sea of Japan). The basin consists of thick extended continental (or transitional) crust and an overlying sedimentary succession (4–8 km thick), with interlayered volcanic flows and sills, defining a number of seismic units of variable reflection characteristics. The northern margin is bounded by faulted continental blocks (South Korea Plateau) with isolated basement lows and sub-basins with intruded and extruded volcanics, whereas the southern margin is underlain by deep-seated basement with a thick (>8 km thick) sedimentary succession. The western margin is bounded by a series of strike-slip and normal faults produced by NNW–SSE-directed dextral movements. These structural features suggest a south–southeastward drift of the southwestern Japanese Arc away from the South Korea Plateau during the Early to Middle Miocene, involving large-scale right-lateral strike-slip deformation along the western margin, akin to pull-apart basin formation. During the back-arc opening, the thinned continental crust was largely modified by intrusive volcanics under tensional stress regime. The volcanics also extruded across the axis of extension as well as along the boundary faults on the west. In the Middle to Late Miocene, major faults in the southern and western margins were inverted, forming partial closure of the basin especially in the southern part, although the plateau in the northern margin experienced continuous subsidence. The Ulleung Basin thus provides an example of an immature back-arc basin which experienced a rather brief episode of rifting and extension followed by closure due to tectonic inversion.

1. Introduction

A back-arc basin forms when the tectonic stress is tensional in the region adjacent to a subduction-related volcanic arc above a subducting plate. In the northwest Pacific, back-arc basins formed in relatively short time, from the Late Oligocene to the Middle Miocene, and are generally shallow in water depth (Taylor and Karner, 1983). The relatively deep (>3000 m) back-arc basins are commonly floored by oceanic crust and characterized by prominent magnetic anomalies indicative of seafloor spreading, such as the Kuril and Japan basins (Jolivet et al., 1994). On the other hand, the relatively shallow (<3000 m) back-arc basins, such as the Yamato and Ulleung basins, are underlain by an anomalously thick transitional (or extended continental) crust, characterized by an obscure magnetic anomaly pattern and the lack of basaltic seafloor (Fig. 1) (Tamaki et al., 1992; Jolivet et al., 1994; Kurashimo et al., 1996). The transitional crust is largely modified by sediments and volcanics derived from the adjacent continent and arc. For these reasons, it has been difficult to decipher the mode of back-arc rifting and extensional processes of the shallow back-arc basins.

A back-arc basin in the southwestern corner of the East Sea, the Ulleung Basin, comprises an extended continental crust without a prominent magnetic anomaly pattern, but with high heat flow (Watanabe et al., 1977; Isezaki, 1986). The Ulleung Basin is connected to the deeper Japan Basin in the north by an interplain gap, but separated from the Yamato Basin by the Oki Bank and Yamato ridges in the east and northeast, respectively (Fig. 1). The three basins are bounded by the Japanese arc on the east and south, and retain their own characteristics in basin configuration, crustal structure, and subsidence history. These variations are largely due to the changes in stress regime during the initial rifting and subsequent spreading and crustal extension. Paleomagnetic analyses of adjacent continents (Otofuji et al., 1985; Faure and Lalevee, 1987; Otofuji and Matsuda, 1987; Hayashida and Fukui, 1991; Lee et al., 1999; Otofuji et al., 2003) have generally favored fan-shaped

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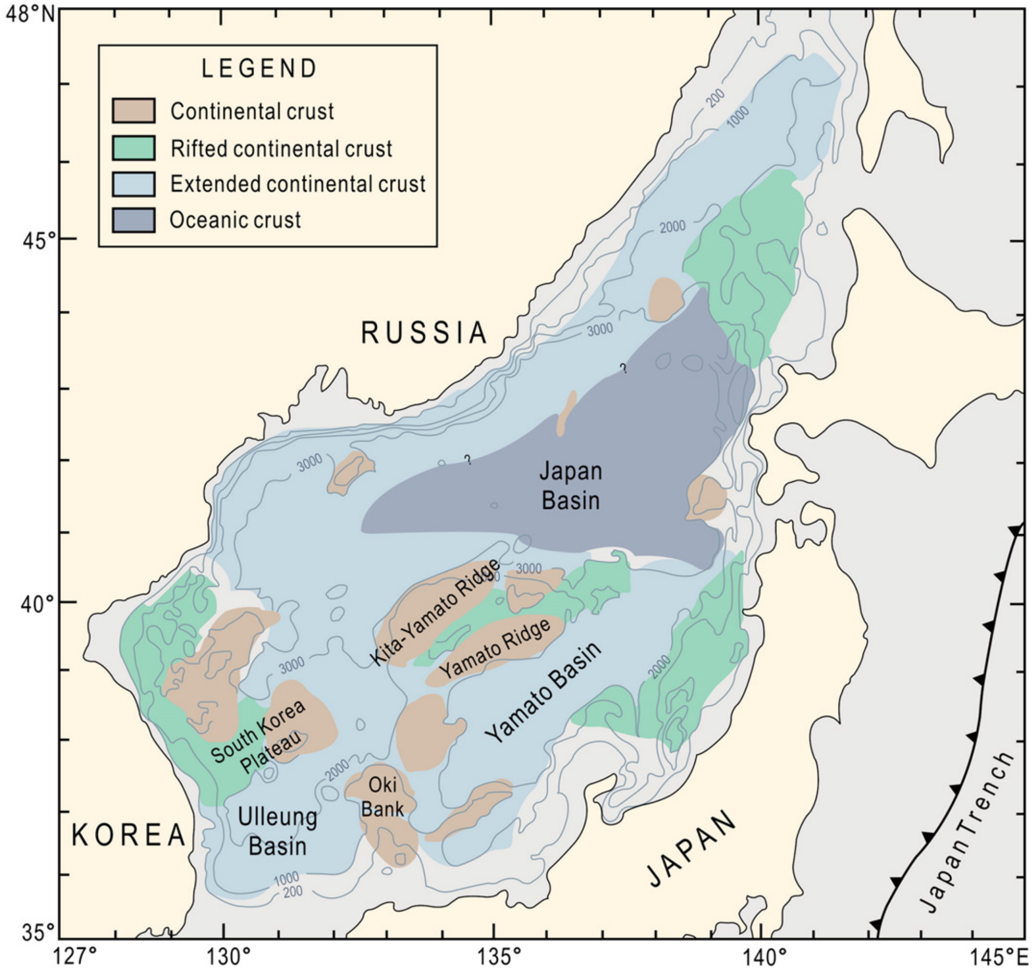

Fig. 1. Location map of the East Sea, showing distribution of crust type suggested by Tamaki (1988). The discrimination of the crust type is based on seismic reflection/refraction data, bottom sampling data, geomagnetic data, basement depth, and topography. Bathymetric contours are in meters.

opening. On the other hand, analyses of fault patterns and kinematics are suggestive of pull-apart opening, influenced by the far-fetched collision of the Indian Plate with Eurasian Plate (Lallemand and Jolivet, 1985/86). These hypotheses assume a pivotal role of the Ulleung Basin for the opening of the basins in mode of rifting and plate geometry (Yoon and Chough, 1995).

In the past 20 years, various studies have been employed to decipher geologic and tectonic evolution of the anomalously thick crust in the back-arc basins, using multichannel reflection profiles, refraction and ocean bottom seismometer surveys and exploration and long drill wells (Chough and Barg, 1987; Hirata et al., 1989; Tamaki et al., 1990; Ingle, 1992; Kurashimo et al., 1996; Kim et al., 1998a; Lee et al., 2001; Sato et al., 2006; Kwon et al., 2009). In particular, an unprecedented array of closely spaced multichannel seismic profiles was obtained in the Ulleung Basin, submarine plateaus and banks, and the adjacent interplain gaps (Chough and Lee, 1992; Kwon et al., 2009; Kim et al., 2011a) (Fig. 2). These studies made it possible to map the basement structures and the occurrence of sedimentary and volcanic deposits, which formed during the initial rifting and subsequent crustal extension. In addition, recent studies of volcanic deposits in the ridges, seamounts, islands, and the adjacent continents (Kim et al., 2011a; Kwon et al., 2011; Sohn et al., 2013) provide constrains on the interior of Earth beneath the back-arc basin. This review provides a synthesis of tectonic and sedimentary evolution of a back-arc basin in a tectono-volcanic framework.

2. Regional setting

2.1. Physiography

The Ulleung Basin occupies the southwestern corner of the East Sea (Fig. 1). The basin is rhomboidal in geometry, bounded by continental slopes of the Korean peninsula and the southwestern Japanese islands on the west and south, respectively, and by submarine topographic highs of the South Korea Plateau and the Oki Bank on the north and east, respectively (Fig. 3). The northern and western margins are relatively steep with a gradient of up to 10°, whereas the eastern and southern margins are characterized by rather gentle slope gradients (<3°). The basin floor lies at water depths of 2000 to 2500 m and gradually deepens to the north and northeast. It is fairly smooth and flat except for a few volcanic islands and seamounts in the northeastern part. The basin extends to the Japan Basin through a long and narrow Ulleung Interplain Gap (UIG), between the Ulleung and Dok islands (Chough, 1983).

On the western margin (eastern Korean continental margin), the continental shelf is dominantly flat and narrow (<20 km wide) and abruptly drops off into a steep continental slope at water depths of 130 to 150 m (Fig. 3). The upper continental slope comprises a submarine ridge (Hupo Bank) and a trough (Hupo Trough), which are aligned parallel to the shoreline (Fig. 3). The Hupo Bank is about 100 km long and has a relatively flat top between 10 and 200 m below sea level. To

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