Continental Margin Geology of Korea: Review and constraints on the opening of the East Sea (Japan Sea)

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The East Sea / Japan Sea
a back-arc sea in the WP formed in a region of complex plate boundaries

Marginal basins: a common feature of the subduction zone in the western Pacific

JB, YB, and UB = Japan, Yamato, and Ulleung Basins
KP = Korea Plateau; YM = Yamato Bank
Models for the opening of the East Sea

various models for its formation close in on

(1) Fan-shaped opening
   (Otofuji et al., 1983, 1985; Otofuji, 1996)

(2) Pull-apart opening
   (Lallemand & Jolivet, 1985; Tamaki et al., 1992; Jolivet et al., 1994)
The mode of opening (fan-shaped opening)

Clockwise deflection in declination was found in pre-middle Miocene rocks in SW Japan.

Counter-clockwise deflection in declination was found in early Miocene rocks in NE Japan.

SW Japan rotated clockwise away from Asia by 45°.
NE Japan rotated counter-clockwise by 40°.

The differential rotation occurred concurrently at about 15 Ma mostly during the period of 2 Ma.

A very fast spreading rate of 21 cm/yr.

(Otofuji et al., 1983, 1985; Otofuji, 1996)
The mode of opening (pull-apart opening)

Lallemand and Jolivet (1985), Tamaki et al. (1992), Jolivet et al. (1994), Fournier et al. (1994)

The pull–apart opening model relates the opening of the East Sea to the India–Asia collision.

Indentation tectonics (Tapponier and Molnar, 1976; Fournier, 1994)

- Dextral shear zones are produced parallel to the eastern free boundary.
- An additional component of extension induces the formation of basins controlled by those dextral shear zones.
• The Japan Arc translated southward along strike-slip faults on the eastern and western sides in the early Miocene.

• The strike-slip faults were produced by indentation tectonics

(Lallemand & Jolivet, 1985; Tamaki et al., 1992; Jolivet et al., 1994)
Why is the Korean margin important?

- Transition from continental to back-arc crust
- Rift architecture (rift basin, uplifted rift flank, slope)
- Pronounced volcanic phase associated with margin tectonics
- Constraints on the opening of the East Sea/Japan Sea

BB = Bandal Basin; OB = Onnuri Basin; HB = Hupo Basin

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Geophysical study of the Korean margin

- **Material**
  - > 1500 km MCS data, swath bath and magnetic data (1994–1999)

- **Objectives**
  - Investigation of crustal structure
  - Explanation of (1) basement structure & igneous stratigraphy,
    (2) processes of continental rifting to spreading
    (3) separation of SW Japan from Korea
Deep Seismic Sounding using OBSs at the Korean Margin

1991

1998
MCS data collection (96 and 56 channels)
Magmatic underplating (?) and extrusive volcanism at the Korean margin
(Kim et al., 2003)
* Well-imaged velocities typical of 2B, 2C, and 3
* Presence of 2C
* Acoustic basement at 6 km depth

Kim et al. (1994)
Thicker than normal oceanic crust created above the hotter than normal mantle (Kim et al., 1998)
Mantle structure of NE Asia from global tomography

(Kim et al., 2003)
MCS profiles from the rifts in the Korea Plateau
MCS profiles from the shelf to the center of UB

(a) [Graphical representation showing MCS profiles with two-way travel time in seconds and distances marked in kilometers.]

(b) [Graphical representation showing additional MCS profiles with similar parameters as in (a).]
Structural interpretation of MCS data
Conclusions

- **The Korean margin**
  Structural elements consist of a seaward succession of rift basin, uplifted rift flank, steep slope, and deep sea basin called the Ulleung Basin.

- **Crustal structure**
  - Thicker than normal oceanic crust in the Ulleung Basin
  - Emplacement of oceanic crust above the hotter than normal mantle
  - Magmatic underplating & extrusive volcanism at the Korean margin

- **Continental rifting before breakup**
  Rifts show a fundamental unit of rift architecture
  - **border fault zone**: convex dip slope, zig-zag arrangement along strike
Fault Pattern

- Rifting was controlled by normal faulting resulting from extension: no strike-slip deformation (no pull-apart opening)

Two-stage rifting, breakup, and spreading

- Rifting orthogonal to the line of breakup along the slope base: some amount of rotation of SW Japan during back-arc spreading (partly compatible with fan-shaped opening)
- Separation of the SW Japan Arc: SEward in response to the NW subduction of the Pacific Plate

Volcanism

- Pronounced volcanic phase at breakup and onset of sea floor spreading
- Asthenospheric upwelling and rift-induced convection

Structure and igneous evolution of the Korean margin

- Explained by the processes occurring at the passive continental margin
Thanks!
Lee et al. (2003)
Why is magnetization low in the Ulleung Basin?

Enclosed back–arc basin with thick sediments

* Sediments seal extrusive basalts and enhance hydrothermal circulation: Fe from Fe–Ti oxides is removed and precipitated as nonmagnetic FeS

* Slow Cooling or elevated temperatures

* Long–lived post–spreading volcanism
Why was volcanism so vigorous at the Korean margin?

Secondary convection in the upper mantle
* The Korean margin is vary narrow.

Mantle plume
* No evidence of a deep–rooted plume
* But East Asia is floored by a large compositional and thermal anomaly in the upper mantle.

Asthenospheric upwelling
* induced in a back–arc region by the subducted slab