

# Spreading process of the Shikoku Basin and the Parece Vela Basin

Shigeru KASUGA, Yasuhiko

OHARA and Kyoko OKINO

Hydrographic Department of Japan

Tsukiji, Tokyo 104, Japan

## Abstract

Seabeam and magnetic surveys of the Shikoku / Parece Vela (Okinotori-Shima) Basin revealed that a notable change in spreading direction occurred during the spreading. After the cessation of relatively uniform spreading nearly in an E-W direction, spreading axes of both basins were segmented and gradually rotated counter-clockwisely up to  $45^{\circ}$  -  $60^{\circ}$  in the later phase of the spreading process. We propose that the continuous reorientation of the spreading axes by rotation played more significant role than the discontinuous reorientation by propagation or synchronous reorientation in the spreading process of these back-arc basins.

## 1. Introduction

The Philippine Sea is composed of several large back-arc basins and it is divided into two portions by the roughly N-S trending Kyushu-Palau Ridge. To the east of the Kyushu-Palau Ridge, the Philippine Sea is postulated to be a simple eastward progression of sequentially younger basins, namely, from inactive Parece Vela Basin which merges to the north with the

Shikoku Basin, to the active Mariana Trough (Karig, 1971), but details of the evolution of these back-arc basins is not still well known.

The Hydrographic Department of Japan has been conducting the *Continental Shelf Surveys Project* since 1983 to obtain swath bathymetric data, seismic reflection profiles, magnetic and gravity anomalies in the northern part of the Philippine Sea. The surveyed area covers Izu-Ogasawara arc - trench system including Kyushu-Palau Ridge, Shikoku Basin, northern Parece Vela (Okinotori-Shima) Basin and the surrounding area (Fig.1). The majority of survey tracklines are in an E-W direction with spacing of 5 - 6 nautical miles. Bathymetric coverage in this area is roughly 30 to 40 %.

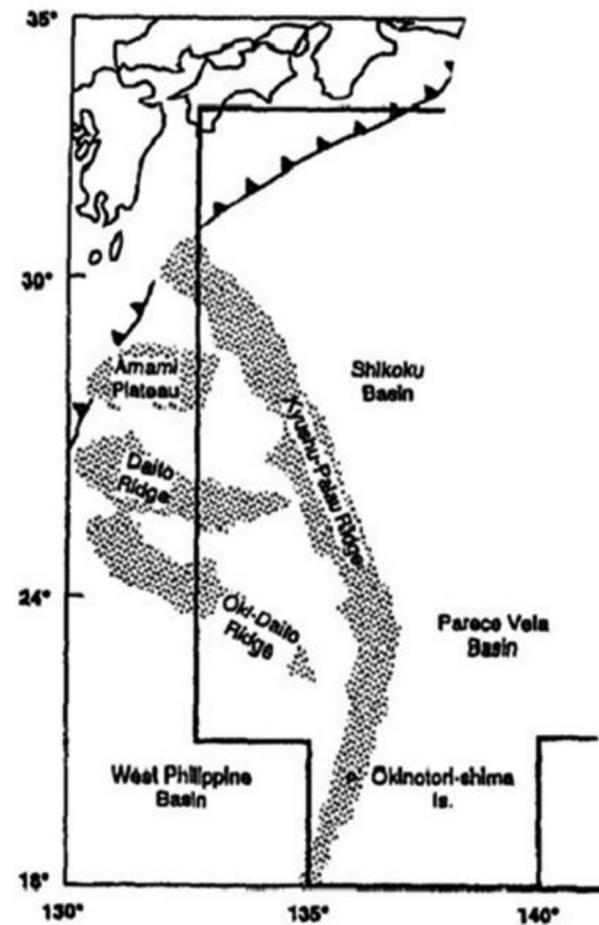


Fig.1 Major geomorphologic elements of the Philippine Sea. Thick line indicates the location of the survey tracklines.

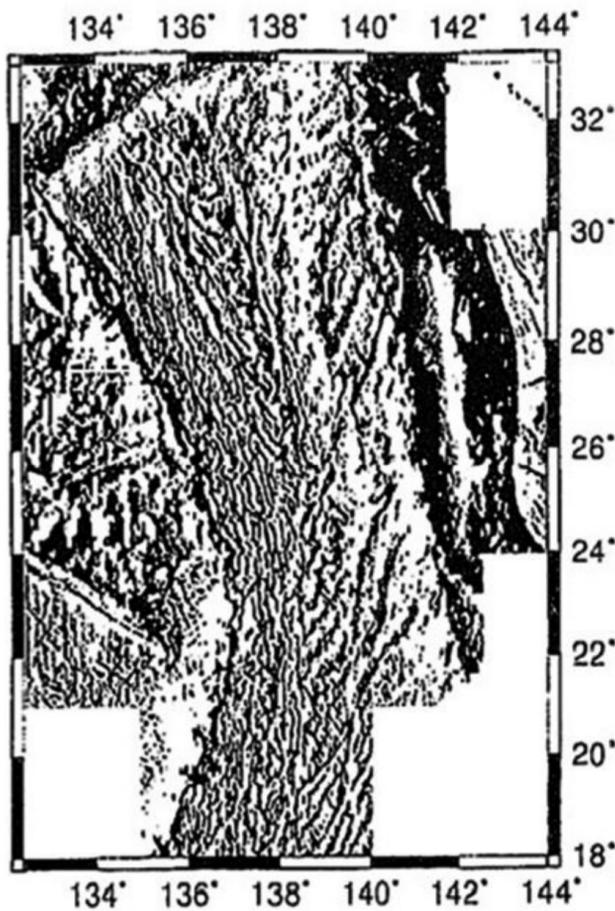


Fig.2 Shaded topographic relief map (illuminated from west) of the Shikoku Basin and Parece Vela Basin. We can identify N-S trending topographic fabric on the western part and NW-SE trending fabric which gradually change directions counter-clockwise toward the axis of the Shikoku / Parece Vela Basin.

The survey revealed the nature of the ocean floor such as topographic fabric in these area much more clearly than it used to be and give us new interpretations on the spreading process of the back-arc basins.

We propose reorientation occurred in the Shikoku Basin and the Parece Vela Basin by ridge rotation and their tectonic implications are considered with attention to the comparable model of reorientation by ridge propagation (Hey, 1977) and synchronous reorientation (Goodliffe et al., 1997).

## 2. Axial Zone of the Shikoku Basin and Parece Vela Basin

The Shikoku Basin and Parece Vela Basin

are inactive back-arc basins that formed to the west of Izu-Ogasawara / Mariana arc - trench systems, which are active at present time. Morphology of these basins are characterized by clear topographic fabric (Fig.2), which is closely related to the spreading process. It was proposed that both basins were born as back-arc spreading during roughly the same period in Miocene (Kobayashi and Nakada, 1978; Mrozowski and Hayes, 1979, Kobayashi et al, 1995).

The latest model of the evolution of the Shikoku Basin was reported in detail by Okino et al. (1994) based on an updated identification of magnetic isochrons. The central portion of the Shikoku Basin was formed with en echelon spreading axes based on the S-shaped transform faults cutting magnetic lineations as shown in Fig.3 (Okino et al, 1994).

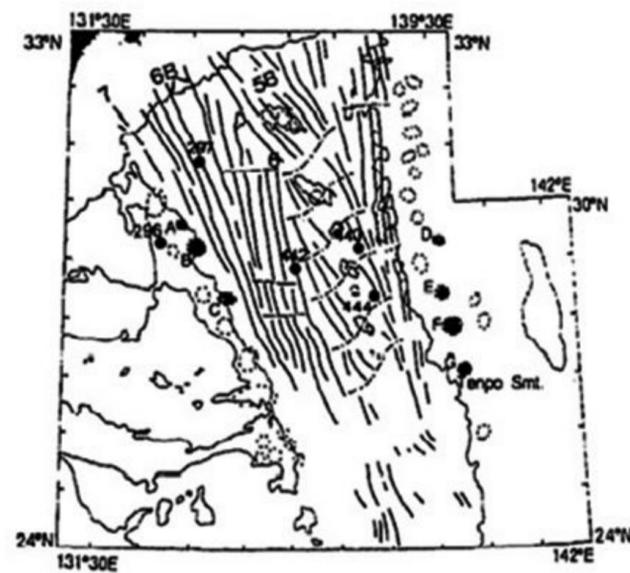


Fig.3 Magnetic isochrons and fracture zones in the Shikoku Basin identified by Okino et al. (1994).

Our recent survey revealed that the central zone of the Parece Vela Basin is characterized by the N-S trending chain of the depressions

forming right-step en-echelon alignment (Fig.2). Morphology of these depressions are diamond-shaped and bordered by steep escarpments with 1000 to 1500 m relative height. These escarpments extend NE-SW from the depressions into the surrounding basin floor and they gradually fade out. It is noted that these escarpments have S-shaped trend, and their geometry seems to be symmetric about the depressions. Minor ridges and troughs trending orthogonal to these escarpments are recognized. Although magnetic anomalies of the basin are very weak, magnetic lineations trending parallel to the topographic trend are recognizable in the central and western parts of the basin. We concluded that these depressions and escarpments are a topographic expression of extinct spreading axes and S-shaped transform fault, respectively (Kasuga and Ohara, in press).

### 3. Rotation of the spreading axes in the Shikoku / Parece Vela Basin

Kasuga and Ohara (in press) proposed a model of spreading process of the Parece Vela Basin in two stages based on the trend of geomorphological fabrics and magnetic lineations (Fig.4). The first stage is an E-W spreading with spreading axes trending N-S. The second one is a rotation of spreading direction characterized by rotating spreading axes counter-clockwisely and by changing spreading directions from E-W to NE-SW. The S-shaped scarps of transform fault origin were

formed by the rotation of spreading axes which also caused the segmentation of it. Since the configuration and geometry of the S-shaped transform faults seems to be symmetric about the axial depressions, we consider central part of the basin were formed by symmetric spreading and these depressions are extinct spreading axes.

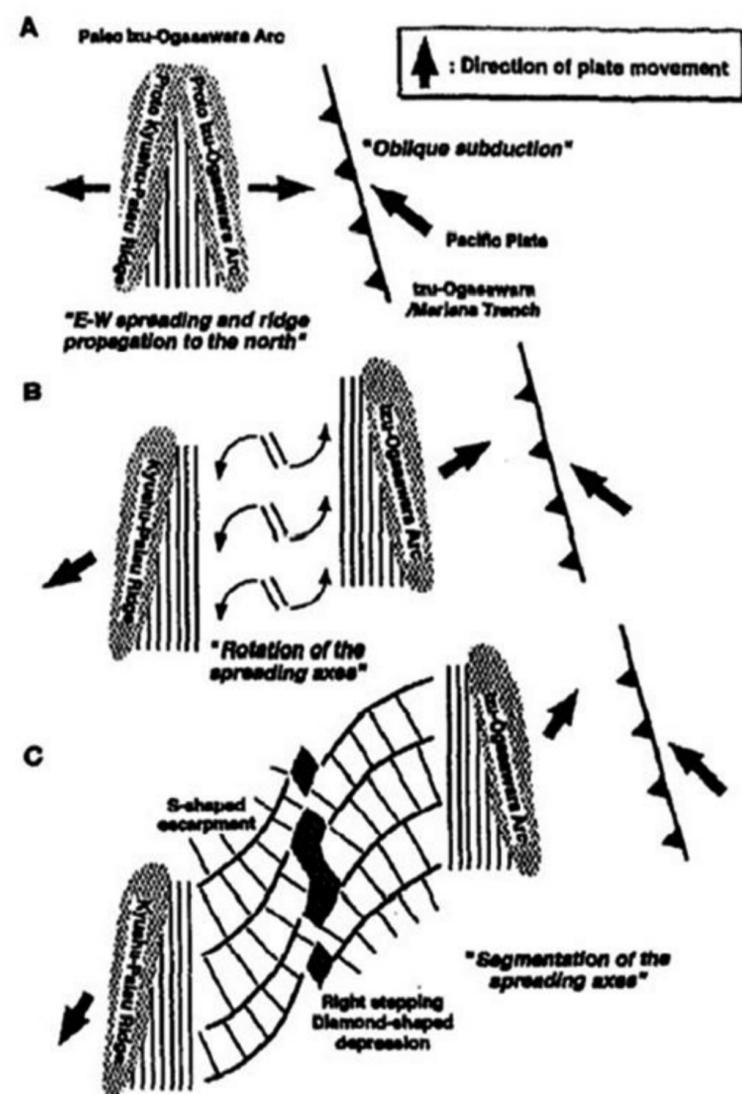


Fig.4 Proposed model showing the break-up of the Paleo Izu-Ogasawara Arc and spreading process of the Parece Vela Basin from Kasuga and Ohara (in press).

This spreading model of the Parece Vela Basin is quite similar to that of the Shikoku Basin proposed by Okino et al. (1994). Topographic fabric and magnetic lineation of both basins show the progressive asymmetric fanning, which is characteristic feature of the

rotation of spreading axes. Spreading axes of both basins were segmented and gradually rotated after the spreading rate decreased in a later phase of the basin evolution

Kasuga and Ohara (in press) argued that the cause of the significant change in the spreading direction of the Shikoku and Parece Vela Basins in a later stage of their evolution might be attributed to the oblique subduction of the Pacific Plate beneath the Philippine Sea Plate. It is inferred that the oblique subduction causes an extensional strike-slip movement of the forearc sliver relative to the backarc plate. In the case of the Paleo Kyushu-Palau Ridge, forearc sliver had been subject to northward extensional tectonics due the oblique subduction of the Pacific Plate. At the early stage of the opening when spreading and emplacement of the oceanic crust is confined within a limited zone of the extended arc lithosphere, northward migration of the forearc sliver (Izu-Ogasawara / Mariana arc) was constrained by the adjoining backarc plate (Kyushu-Palau Ridge), and then spreading direction was E-W (Fig.4 (A)). At the later stage of the opening after spreading axis extended throughout the arc, the forearc sliver was almost completely separated or decoupled from the backarc plate by an overall emplacement of the young oceanic crust between them. Then, the forearc sliver gradually migrated northward (Fig.4 (B), (C)). The northward migration of the forearc plate induced reorientation of the spreading axis and counter-clockwise rotation of the spreading direction.

#### 4. Discussion

Change in direction of seafloor spreading is one of the common features recognized in many back-arc basins (Tamaki and Honza, 1991).

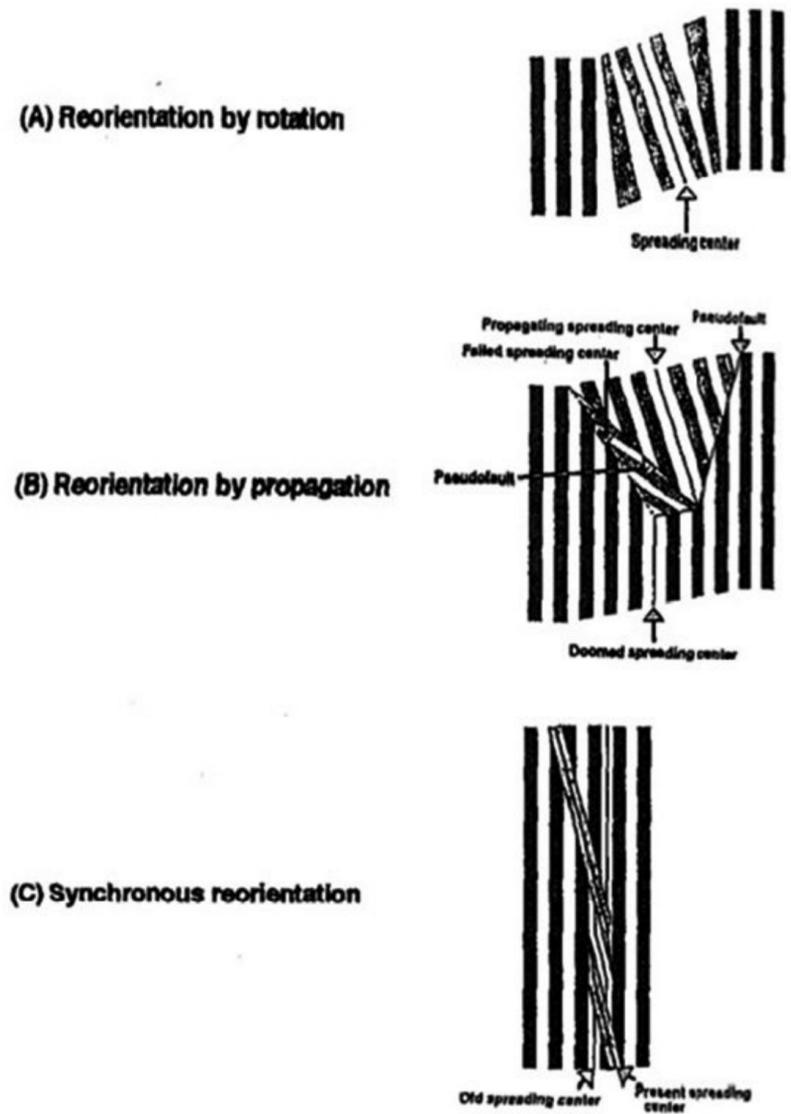


Fig.5 Comparison of the models of spreading center reorientation.

- (A) Rotation (Menard and Atwater, 1968)
- (B) Ridge propagation (Hey, 1977)
- (C) Synchronous reorientation (Goodliffe et al, 1997)

Several models of spreading center reorientation have been reported. A ridge reorientation takes place with smooth and continuous rotations due to the change of spreading axes in seafloor at mid-oceanic ridge, which was first proposed as ridge rotation model (Fig.5 (A)) by Menard and Atwater (1968). An alternative model is the propagating ridge model (Fig.5 (B)), that is,

changes in spreading axes by the creation of new spreading ridge with a new trend and its subsequent propagation which gradually replaces the old ridge, was proposed by Hey (1977). Based on a detailed survey at the Juan de Fuca Ridge and the northeast Pacific, he concluded that the abrupt change in the direction of topographic fabric and magnetic lineations indicate a ridge propagation. In addition to these two models, Goodliffe et al. (1997) has proposed another model of ridge reorientation, that is, synchronous reorientation of the Woodlark Basin spreading center based on a recent sidescan survey and multibeam bathymetry of the basin (Fig.5 (C)). What controls the mode of the ridge reorientation? The rate of the change in direction of the spreading could be one of the critical factor determining how ridge reorientation occurs. Goodliffe et al. (1977) proposed that a synchronous reorientation may occur as a result of a large and rapid change in direction of plate motion, with propagation or rotation occurring when the change in direction of plate motion is slower or has a smaller difference in direction. In the case of the Shikoku Basin, an average rate of rotation is about 10/Ma, assuming that rotation occurred during 19 - 15 Ma (Okino et al., 1994). A similar or a little larger rate could be expected in the Parece Vela Basin, assuming that the rotation occurred at the same period as the Shikoku Basin. In the case of the Woodlark basin where the synchronous reorientation occurred, far more rapid change in direction of

the spreading can be expected because up to 22° anti-clockwise reorientation occurred in a very short time within 25 k.y. (Goodliffe et al., 1997). Since the ridge propagation produces a sharp boundary between old and new fabrics, change in the spreading direction might be quite rapid and discontinuous. Further study is necessary to elucidate the critical factors determining how oceanic lithosphere fractured in the process of reorientation and what is predominant mode of reorientation among continuous ridge rotation and discontinuous ridge reorientation by propagation and synchronous reorientation.

## 5. Conclusion

Spreading process of the Shikoku Basin and the Parece Vela Basin behind the Izu-Ogasawara arc - trench system can be divided into two main stages.

- (1) At the earlier stage, the direction of spreading was roughly E-W.
- (2) At the later stage, the spreading axes were segmented associated with a counter-clockwise rotation up to 45° - 60°. The rotation continued smoothly and caused the S-shaped transform fault. The final direction of the spreading was NE-SW.

Continuous reorientation by rotation rather than discontinuous reorientation by propagation or synchronous reorientation could play significant role in the evolution of the back-arc basins when change in the spreading direction is slow and gradual.

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