Synchronous Reorientation of the Woodlark Basin Spreading Center

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Abstract

A sidescan and multibeam bathymetry survey of the Woodlark Basin reveals that its 500-km-long spreading center reoriented synchronously, without propagation, about 80 ka. There is no evidence of the V-shaped pseudofault geometry typical of spreading center propagation, nor of the progressive fanning of seafloor fabric characteristic of spreading center rotation. The reorientation is recognized by a sharp contact between two seafloor fabric trends, and ruptured off-axis lithosphere formed up to 0.7 m.y. previously. The length of the reoriented spreading segments and the tendency to fault pre-reorientation seafloor fabric are controlled by the strength of the lithosphere, the angle of the reorientation, and the length of preexisting spreading and transform segments. We document the process of synchronous reorientation in the Woodlark Basin and propose that it may occur in other ocean basins.

1. Introduction

Changes in direction of seafloor spreading, as recorded by bends in fracture zones, were first well documented in the northeast Pacific [1]. From that study, it was proposed that the spreading centers had progressively rotated to remain perpendicular to each new direction of extension by conjugate asymmetric spreading (Fig. 1A). This was the accepted mechanism until it was proposed that the reorientation could take place by the propagation of a new spreading center with a different orientation into older oceanic lithosphere, progressively eliminating the old spreading center [2, 3]. Spreading center propagation produces a characteristic morphology, with a V-shaped wedge of lithosphere pointing in the direction of propagation and bounded on either side by pseudofaults that separate post- and pre-reorientation lithosphere (Fig. 1B). A fundamental way in which the spreading center propagation and rotation models differ is that the propagation model produces a sharp boundary between old and new seafloor fabric. Reinterpretations of magnetic anomaly patterns in the Pacific [4, 5, 6] showed that spreading center propagation, as opposed to spreading center rotation, was the dominant mechanism of reorientation.

In contrast, we report the results of two surveys of the Woodlark Basin and show that, about 80 ka, a 500-km-long spreading system reoriented synchronously along its length (Fig. 2), producing a sharp transition between pre- and post-reorientation fabric. We document the nature of this reorientation and propose that spreading centers elsewhere may have experienced synchronous reorientation.

2. The Woodlark Basin Spreading Center

Seafloor spreading in the Woodlark Basin began about 6 Ma, following a period of continental rifting, and has propagated westwards, separating the Woodlark Rise from the Pocklington Rise (Fig. 2) [7, 8, 9]. At the same time as it has propagated westwards, the basin has been subducted eastwards beneath the Solomon Islands [7, 8, 10].

During 1993, two marine geophysical surveys mapped the entire 500-km-long Woodlark Basin spreading system in detail. The April-May survey of the western half of the basin included HAWAII-MR1 sidescan (acoustic imagery and bathymetry) and underway geophysical data at 5-nautical-mile line spacing. The August-October survey included Hydrosweep multibeam bathymetry and magnetic data at 2.5-nautical-mile line spacing. Together, the two surveys produced total-coverage bathymetry, acoustic imagery, and interpolated magnetic field data of the spreading center and its flanks. We calculated a seafloor magnetization solution from a 3-D inversion of the bathymetry and magnetic anomaly data [11]. From this we determined the seafloor spreading history, including the extent of lithosphere formed during the Brunhes chron (Fig. 2).

One of the most striking features in the Woodlark Basin is the obliquity of the present spreading axis to older seafloor fabric and the Brunhes/Matuyama (0.78 Ma) crustal boundary (Figures 2 and 3). These features indicate that during the more recent part of the Brunhes chron, the entire length of the Woodlark Basin spreading system synchronously reoriented up to 22^{o} anti-clockwise. The spreading segments did not gradually rotate, nor did they propagate, even though there is evidence of propagation events as part of the earlier basin evolution.

The pre- and post-reorientation spreading axis, on the basis of acoustic imagery, bathymetry and magnetization, can be divided into five main segments (Figs. 2 and 3). We refer to these segments as 1 through 5 based in the pre-reorientation configuration of the positive magnetization boundary; the present day subsegments are indicated by a letter following the segment number (e.g. 3a). Although the individual subsegments are newly developed, differ in length, and vary somewhat in orientation, they generally have relative bathymetric highs near their centers and lows near their distal ends (Fig. 2) similar to the characteristic segmentation morphology on steady-state mid-ocean ridges [12].

2.1. Segment 1

Segment 1 (Fig. 3A) comprises three subsegments linked by overlapping nontransform offsets and represents the most recent development of spreading following the westward continuation of rifting into the Papuan continental margin. All three have a magnetization high [13] and a neovolcanic zone of aligned volcanic cones that form locally positive relief. The western subsegment (1a) is the youngest and least developed. It comprises two main features, an unnamed circular crater in the west approximately 3 km in diameter, and to the east, a volcanic edifice named

Cheshire seamount [14]. Subsegments 1b and 1c to the east would be hard to define on the basis of bathymetry alone, but are easily identified using the acoustic imagery [9]. The relatively straight Brunhes/Matuyama boundary from the magnetization solution indicates that prior to the reorientation a single segment was in place of the present two (Fig. 3A). We observe that the former spreading center reoriented up to 8^{o} anti-clockwise and divided into two subsegments separated by a nontransform offset.

The eastern end of segment 1 and the western end of abandoned segment 2 form opposing V-shaped overlapping tips evident in the magnetization and bathymetry. An intervening continental sliver was isolated and rotated anti-clockwise by complementary spreading on the overlaping system.

2.2. Segment 2

Segment 2, separated by a nontransform offset from segment 1 (Fig. 3A), forms the longest ridge segment, with a 3-4 km wide axial valley, coincident high acoustic reflectivity and an axial magnetization high. A left stepping deval is present halfway along its length. The present ridge sharply crosscuts older seafloor fabric and the abandoned spreading segment. In the approximately 12^{o} anti-clockwise reorientation, the spreading center remained in one piece and maintained the deval. That the deval survived suggests the possibility that it could have served as a nucleation point for the reorientation. To the west and east of the deval, the abandoned spreading center can be seen north and south of the present axis respectively (Fig. 4A).

2.3. Segment 3

Moresby transform, with depths in excess of 4500 m and a width of approximately 10 km, links segments 2 and 3. East of Moresby transform we locate the spreading center by its negative relief, high acoustic reflectivity, and correlation with magnetization highs. The Hydrosweep acoustic reflectivity data to the east of 154°45'E are of lower resolution than the HAWAII-MR1 acoustic imagery to the west.

Segment 3 (Fig. 3B) was a single segment prior to its approximately 17° anti-clockwise reorientation, with a small, westward propagating, nontransform offset. Two subsegments separated by a nontransform offset formed following the reorientation, the longer one to the west (3a). At the western end of subsegment 3a, the old spreading axis can still be discerned as a bathymetric deep with high acoustic backscatter, just to the north of the present axis [9]. Subsegment 3a crosscuts the older seafloor fabric in a similar way to segment 2. Subsegment 3b to the east, however, does not crosscut pre-reorientation fabric in the same way, instead forming a wider region of reoriented seafloor fabric. This could be interpreted as indicating that the reorientation took place earlier there than directly to the west. Our preferred interpretation, based on consideration of data from segments 3 and 4 (see below) is that much of the reoriented fabric is made up of faulted and subsided pre-reorientation seafloor.

2.4. Segment 4

Segment 4 (Fig. 3B) is separated from segment 3 by a transform with longitudinally offset fracture zones to the north and south. The formerly single segment divided into at least four subsegments, similar in appearance to the adjacent subsegment 3b, and reoriented by 12°-22° anti-clockwise . The pre-reorientation seafloor fabric is truncated to both the north and south of the reoriented fabric, but the two sides do not fit back together. Segment 4 and its surroundings can be subdivided into three regions (Fig. 4B). The first region comprises undisturbed, E-W trending, pre-reorientation seafloor fabric. Region 2 is made up of faulted and subsided seafloor with a fabric subparallel to the third region, which is composed of oceanic crust formed on the new spreading center. The boundary between regions 2 and 3 is often ambiguous, so using segment 4 alone, it would be difficult to estimate when the reorientation took place. However, where best defined, the width of region 3 is similar to that of post-reorientation oceanic crust for segments 1 through 3a. Our interpretation of segment 4 is that the initial change in spreading direction caused (1) faulting of the lithosphere in an area close to the then spreading center and (2) creation of a set of new spreading segments within the faulted area. It is unclear if these two processes happened successively or at the same time.

2.5. Segment 5

Unlike the boundaries between segments 2, 3 and 4, the boundary between segments 4 and 5 (Fig. 3B) was a propagating spreading center, as shown by the pseudofaults to the north and south converging to the east. In the reorganization, the instantaneous transform part of the propagator evolved into a transform fault, with a small intra-transform spreading segment high. Subsegment 5b, in which the spreading center again occupies negative relief, reoriented by up to 20^{o} anti-clockwise, but did not subdivide into subsegments, perhaps because it was initially short. The region of reoriented seafloor fabric is narrow, like segment 3a.

There are two distinct trends to the transform fault and fracture zones at the eastern end of segment 5. A NNW-SSE transform fault continues north to the New Britain trench (Fig. 2). Formerly, the transform fault trended N-S (like the fracture zone at 156^{o}30'E to the south) and connected to the next spreading segment to the east, now subducted [7, 8, 10]. In addition there is a SSE-trending fracture zone ridge, but it extends only about 50 km to the south. The seafloor to the east of segment 5 may have rotated as it entered the New Britain trench.

3. Discussion

The sharp contact between abyssal hill fabrics at an angle of 8°-22° along the 500-km-long-axis of the Woodlark Basin is clear evidence for spreading center reorientation. We infer that the reorientation occurred synchronously because the width of newly accreted seafloor does not change appreciably along the length of the spreading center. The reorientation does not show the V-shaped pseudofault geometry typical of spreading center propagation and does not show the progressive asymmetric fanning of seafloor fabric predicted by spreading center rotation. The major transforms faults in the basin are still active, whereas a propagation event crossing the basin would be expected to pass through and render them inactive. It is also notable that the reorientation took place with no discernible time lag east and west of the ~50 km offset Moresby transform.

3.1. Model

Figure 5 shows our interpretation of the synchronous reorientation of the Woodlark Basin spreading system. In this case, what was once a single spreading segment has split into one long segment and one short segment (as in the case of segment 3) and reoriented by 20° anti-clockwise. The older seafloor is crosscut by the new spreading axis, forming a sharp contact between the two abyssal hill orientations. In the overlap between the two new segments pre-reorientation fabric has been faulted and sheared, imposing upon it the new spreading center orientation. This gives the appearance of a wider region of newly formed lithosphere, and if interpreted just on this basis, could lead to the reorientation being dated as older than it really is.

3.2. Timing

What is the timing of the reorientation? By measuring the amount of post-reorientation seafloor, spreading segments 1-3a and 5 give consistent estimates of 80 ka as the time of the reorientation (using 0.78 Ma as the date of the start of the Brunhes chron and assuming constant spreading rates). Examination of the contact between post- and pre-reorientation seafloor fabric shows that the reorientation took at the most 25 k.y.

3.3. How is the lithosphere fractured?

How is oceanic lithosphere fractured during the reorientation? The propagating rift model [3] fractures lithosphere by stress concentration at the propagator tip. Initiation of the propagator can occur in a number of places where the lithosphere is weakest, or where tectonic stresses are concentrated, such as along transform faults. The spreading center rotation model [1] exploits the weak spreading axis, gradually rotating the axis within the neovolcanic zone. Synchronous reorientation does not require weak zones, but on the contrary may crosscut existing seafloor without regard for pre-existing lines of weakness. Although older oceanic lithosphere becomes increasingly more difficult to fracture by conventional plate tectonic forces [15, 16], the affected lithosphere in the Woodlark Basin is younger than 0.78 Ma. It has been shown, in an attempt to explain apparently instantaneous ridge jumps in the Southern Ocean [17], that oceanic lithosphere remains relatively weak until it reaches an age of 4 m.y. At this age, a maximum deviatoric stress required for brittle failure of 40 MPa may still enable ridge jumps to take place. Thus, in the Woodlark Basin, there should be no difficulty fracturing 0.7 Ma lithosphere. What appear to be instantaneous ridge jumps into <3 Ma lithosphere with no evidence for propagation have also been observed in the Manus Basin [18].

3.4. Variations along strike

The character of the reorientation in the Woodlark Basin varies along strike. Faulting and subsidence of pre-reorientation seafloor is more important on segments 3b and 4, and reoriented axes extend further into older lithosphere on segments 2 and

3a. Three factors may be responsible for this variation; (1) contrasting lithospheric strength within the basin across Moresby transform, (2) segment length and transform offset, and (3) the angular magnitude of the reorientation; as this angle increases, a new spreading segment will encounter stronger lithosphere sooner, resulting in shorter segments. Additionally, rifting on the margins becomes important to the west, taking up some of the extension across the basin and buffering the change in direction of opening. This factor is most relevant to segment 1 and may result in a smaller degree of reorientation than would otherwise be the case.

West of Moresby transform, the seafloor is generally shallower, the abyssal hill fabric less continuous and of lower relief than to the east. Bouguer anomalies are characteristically 10-20 mGal lower to the west of Moresby transform than to the east [19]. This requires either lower density or thicker crust, and/or higher mantle temperatures (possibly resulting from induced mantle convection due to the proximity of the cooler lithospheric roots of the margins to the intervening rising hot asthenosphere [20]). Such lithosphere would be weaker, with the result that a spreading center could reorient further off-axis in the west than in the east, resulting in longer post-reorientation spreading centers (compare segments 2 and 4). In the case of segment 1, the pre-reorientation segments are largely bounded by rifted continental crust which may have inhibited the new axes from crossing these boundaries, and instead favored smaller subsegments to develop within young oceanic lithosphere. In the case of segment 3, the reorientation has served to shorten Moresby transform (relative to its pre-reorientation length), thus minimizing the amount of energy that is expended in movement along it. To achieve this, subsegment 3a is longer than those further east.

Figures 4A and 4B show how segments 2 and 4 (as end-members) differ in the way they reorient. Segment 2 comprises one long new spreading segment, which has grown from a simple fracture in the oceanic lithosphere. Faulting and subsidence of the adjacent seafloor have been minimal. Segment 4, however, split into a number of short segments that nucleated simultaneously. Faulting and shearing of pre-reorientation fabric are evident in the overlap zones. Additionally, faulting and subsidence of adjacent seafloor are important, and makes up a significant percentage of the reoriented fabric.

3.5. Synchronous reorientation vs. propagation

Why did the most recent reorientation take place by a synchronous reorientation rather than by spreading center propagation, when both have been active in the Woodlark Basin? What controls how the spreading center reorients? A large rapid change in direction of plate motion could be an important factor. In general the rate of change is a poorly constrained parameter [6], with the Woodlark Basin being one of the few places where we can directly estimate the time needed for the entire length of a spreading center to complete a large magnitude reorientation. We propose 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. There are many potential causes for large local plate motion changes, with the New Guinea- Solomon area being composed of a number of small plates buffering the oblique convergence of the Pacific and Australian plates. In this buffer zone, plate movements are complex, and plate motion changes could be rapid and remain local.

3.6. Global Implications

Recognition of synchronous spreading center reorientations in other parts of the world could help us to constrain the question of why in some instances reorganization occurs by spreading center propagation or rotation, and in others by synchronous reorientation. The Woodlark Basin is the first place that this type of reorientation has been documented along an entire spreading system. Other studies [17, 18] have shown what appear to be instantaneous spreading center jumps, or at least show no evidence of propagation and/or rotation. Is this process more common than previously recognized? This study has shown that recognition of this type of reorientation requires high-resolution bathymetry and, preferably, acoustic imagery from a dense coverage of ship tracks; high resolution magnetic data alone are not sufficient. It is also true that most of the seafloor lacks the high-resolution geophysical data needed to resolve this process. One example where a synchronous spreading center reorientation may have been misinterpreted is the Eocene reorientation of the Pacific-Farallon spreading center north of the Mendicino fracture zone [6]. In this area, it has been difficult to date the progression of what was assumed to be a propagating spreading center, because ages of the seafloor formed by the propagator were not found to be consistently younger in any direction. It was considered in the study [6], that although the data indicated that the new spreading center had appeared almost synchronously along its entire length, this was extremely unlikely, and a best guess propagation direction was used. We have shown from our study of the Woodlark Basin that a newly oriented spreading center can in fact form synchronously along its entire 500-km length without resolvable propagation. Another assumption made in these studies [5, 6] was that spreading center propagation [2, 3] could be proven on the basis that a sharp contact between pre- and post-reorientation fabric exists. From our study in the Woodlark Basin, we know that a sharp contact can also be created by a synchronous reorientation of the spreading center, and only a very detailed survey can distinguish this from conventional propagation. In the Woodlark Basin several conditions allow us to recognize the synchronous reorientation: (1) a complete geophysical data set including closely spaced magnetic isochron identifications which bound the axis along its length; (2) the reorientation took place recently, which minimizes extrapolation errors; (3) there is little sediment cover, allowing fabric and high-backscatter areas to be easily imaged; and (4) both sides of the spreading center are visible, allowing comparison of the conjugate sides. In other areas these conditions are often not met [5, 6, 17, 18].

4. Conclusions

1. The 500-km-long spreading center in the Woodlark Basin reoriented synchronously, without evidence of propagation or rotation, about 80 ka.
2. A sharp contact between pre- and post-reorientation seafloor fabric is produced by synchronous reorientation, as is also the case with spreading center propagation. The presence of such a sharp contact is thus insufficient evidence to distinguish between the two processes.
3. In areas where there is overlap between reoriented spreading centers, pre-reorientation seafloor fabric is faulted and sheared resulting in lineations parallel to the new orientation and a wider zone of reoriented fabric than would be produced by spreading alone.
4. In the eastern Woodlark Basin, faulting and subsidence of adjacent pre- 80 ka seafloor produces a large proportion of the reoriented seafloor fabric.
5. The length of the reoriented spreading segments and the tendency of pre-reorientation seafloor fabric to fault is controlled by the strength of the lithosphere, the angle of the reorientation, and the length of preexisting spreading and transform segments.
6. Instantaneous reorientation may have been misinterpreted as spreading center propagation in other ocean basins, with the Eocene reorientation of the Pacific-

Farallon spreading center north of the Mendicino fracture zone being a potential candidate.

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References

[1] H. W. Menard and T. Atwater, Changes in direction of sea floor spreading, Nature 219, 463-467, 1968.

[2] J. Shih and P. Molnar, Analysis and implications of the sequence of ridge jumps that eliminated the Surveyor transform fault, J. Geophys. Res. 80, 4815-4822, 1975.

[3] R. N. Hey, A new class of "pseudofaults" and their bearing on plate tectonics: A propagating rift model, Earth planet. Sci. Lett. 37, 321-325, 1977.

[4] D. S. Wilson, R. N. Hey and C. Nishimura, Propagation as a mechanism of reorientation of the Juan de Fuca Ridge, J. Geophys. Res. 89, 9215-9225, 1984.

[5] R. N. Hey, H. W. Menard, T. M. Atwater and D. W. Caress, Changes in direction of seafloor spreading revisited, J. Geophys. Res. 93, 2803-2811, 1988.

[6] D. W. Caress, H. W. Menard and R. N. Hey, Eocene reorganization of the Pacific-Farallon spreading center north of the Mendicino fracture zone, J. Geophys. Res. 93, 2813-2838, 1988

[7] J. K. Weissel, B. Taylor and G. D. Karner, The opening of the Woodlark spreading system, and the evolution of northern Melanesia since mid-Pliocene time, Tectonophysics 87, 253-277, 1982.

[8] B. Taylor and N. F. Exon, An investigation of ridge subduction in the Woodlark-Solomons region: introduction and overview, in: Marine geology, geophysics, and geochemistry of the Woodlark basin-Solomon Islands, B. Taylor and N. F. Exon, eds., pp. 1-24, Circum Pacific Council for Energy and Mineral Resources, Houston, T.X., 1987.

[9] B. Taylor, A. M. Goodliffe, F. Martinez and R. N. Hey, Continental rifting and initial sea-floor spreading in the Woodlark basin, Nature 374, 534-537, 1995.

[10] K. A. W. Crook and B. Taylor, Structure and Quaternary tectonic history of the Woodlark triple junction region, Solomon Islands, Mar. Geophys. Res. 16, 65-89, 1994.

[11] R. L. Parker and S. P. Huestis, The inversion of magnetic anomalies in the presence of topography, J. Geophys. Res. 79, 1587-1593, 1974.

[12] K. C. Macdonald, P.J. Fox, L. J. Perram, M. F. Eisen, R. M. Haymon, S. P. Miller, S. M. Carbotte, M. -H. Cormier and A. N. Shor, A new view of the mid-ocean ridge from the behavior of ridge-axis discontinuities, Nature 335, 217-225, 1988.

[13] K. D. Klitgord, Sea-floor spreading: The central anomaly magnetization high, Earth Planet. Sci. Lett., 29, 201-209, 1976.

[14] R. A. Binns and D. J. Whitford, Volcanic rocks from the western Woodlark basin, Papua New Guinea, Proc. Pacif. Rim Congr. 87, 525-529, 1987.

[15] C. Goetze and B. Evans, Stress and temperature in the bending lithosphere as constrained by experimental rock mechanics, Geophys. J. R. Astr. Soc. 78, 5961-5971, 1979.

[16] D. L. Turcotte and G. S. Schubert, Geodynamics applications of continuum physics to geological problems, 450 pp., John Wiley & Sons, New York, N.Y., 1982.

[17] C. Small, Observations of ridge-hot spot interactions in the Southern Ocean, J. Geophys. Res. 100, 17931-17946, 1995.

[18] F. Martinez and B. Taylor, Backarc spreading, rifting and microplate rotation between transform faults in the Manus basin, Mar. Geophys. Res. in press, 1996.

[19] A. M. Goodliffe, B. Taylor, F. Martinez and R. N. Hey, The western Woodlark basin, Evolution of a new ocean basin, Trans. Am. Geophys. Union 75, 604, 1994.

[20] W. R. Buck, Small-scale convection induced by passive rifting: the cause for uplift of rift shoulders, Earth Planet. Sci. Lett., 77, 362-372, 1986.

Figure Captions

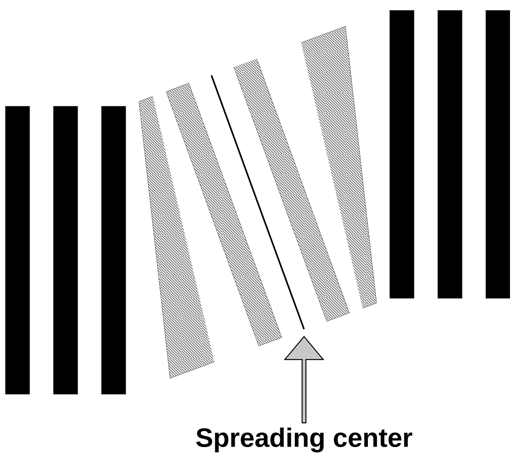
Fig. 1. Models of spreading center reorientation by (A) gradual rotation [1] and (B) propagation [3]. Modified from [5].

Fig. 2. Regional setting and tectonics of the Papua New Guinea-Solomon Islands region. Spreading rates for the Brunhes chron are labeled in mm yr^{-1}. MT and ST are the Moresby and Simbo transforms respectively; DE is the D'Entrecasteaux islands. Top inset shows the geographical location of the study area, bottom inset shows the axial depth profile of the Woodlark Basin spreading center, with the five spreading segments numbered. Modified from [9].

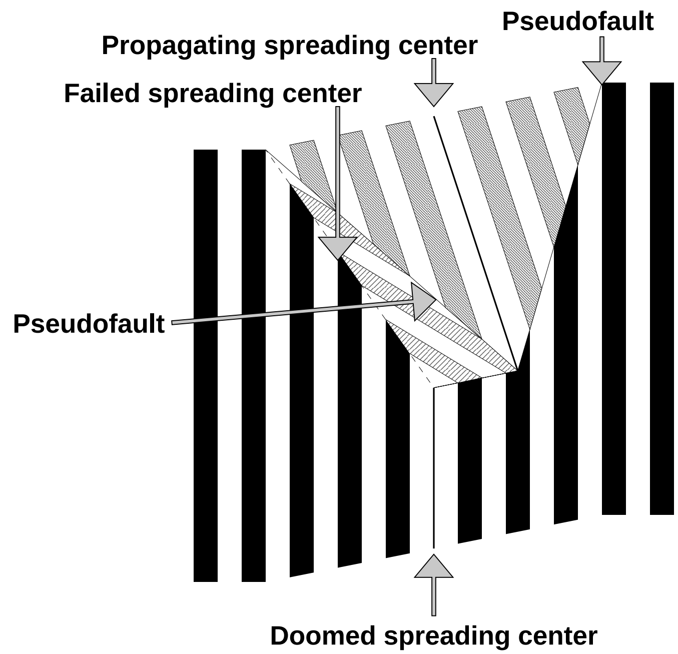
Fig. 3. Gray scale bathymetry illuminated from the north in the region of segments 1 and 2 (A) and 3, 4 and 5 (B). The wide dashed black line represents the extent of positively magnetized crust generated within the Brunhes chron, which generally corresponds to the Brunhes/Matuyama boundary except for propagation tips and parts of segment 1 which may be more recently developed. The solid line black represents the present spreading axis and the narrow dashed line represents abandoned axis segments. Subsegments are labeled along the bottom of both A and B.

Fig. 4. Line drawing of sea-floor fabric in the vicinity of the spreading center for segment 2 (A) and segment 4 (B).

Fig. 5. Schematic model of spreading center reorientation by synchronous jumping.



(A) Reorientation by rotation



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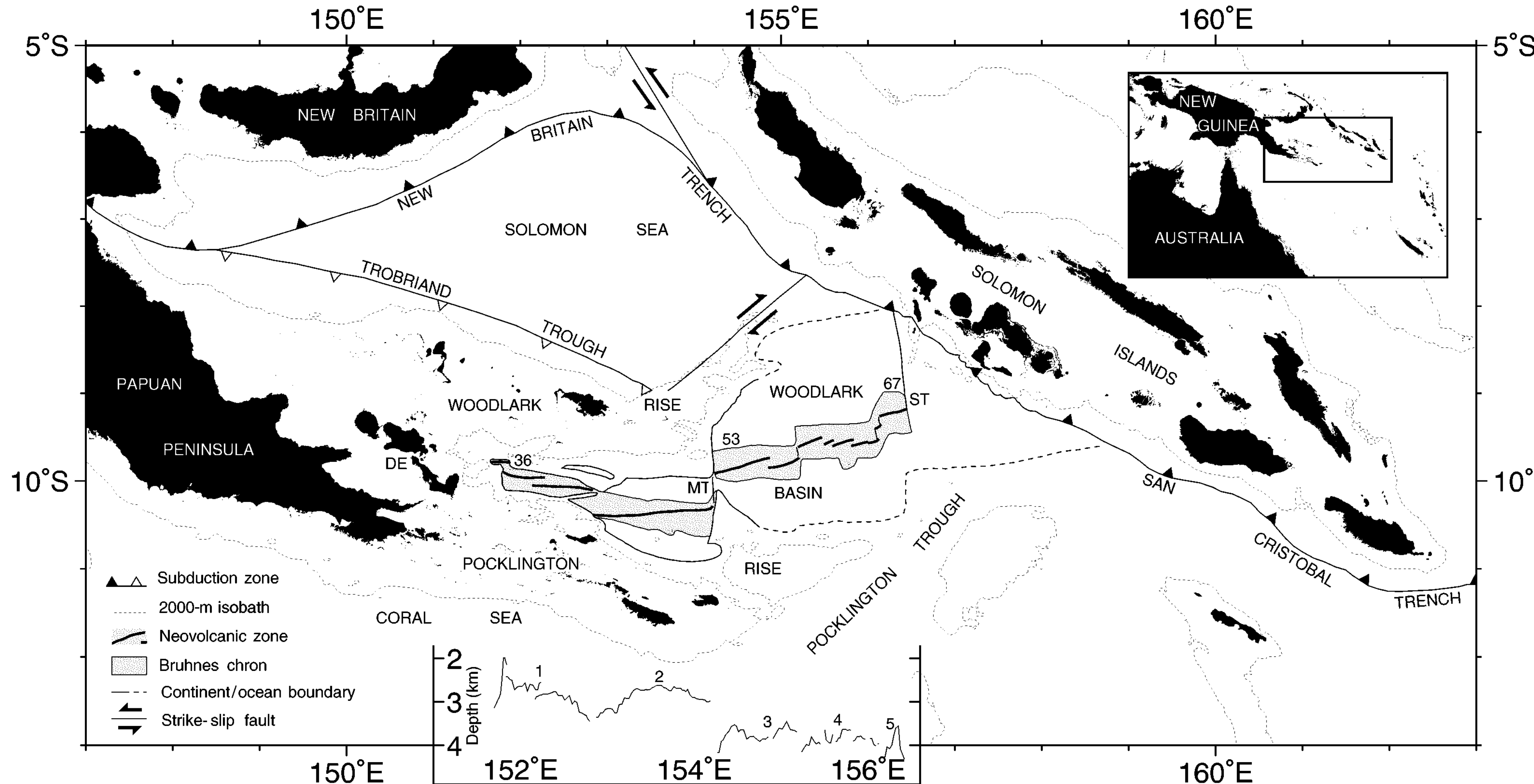

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WOODLARK RISE
WOODLARK BASIN
DE
36
53
67
ST
MT
SOLOMON ISLANDS
SAN CRISTOBAL TRENCH
POCKLINGTON TROUGH
POCKLINGTON RISE
CORAL SEA
NEW GUINEA
AUSTRALIA
Subduction zone
2000-m isobath
Neovolcanic zone
Bruhnes chron
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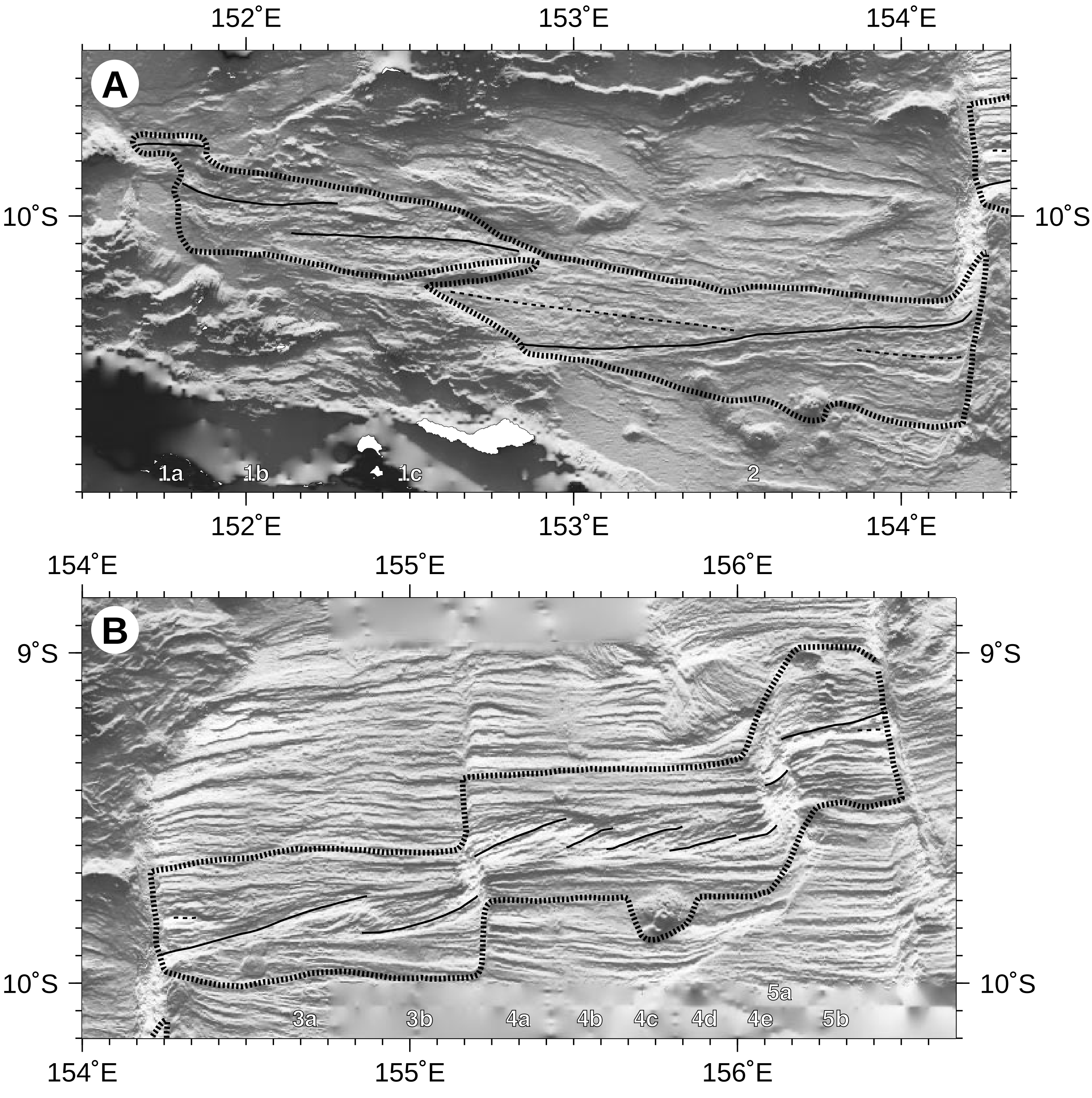
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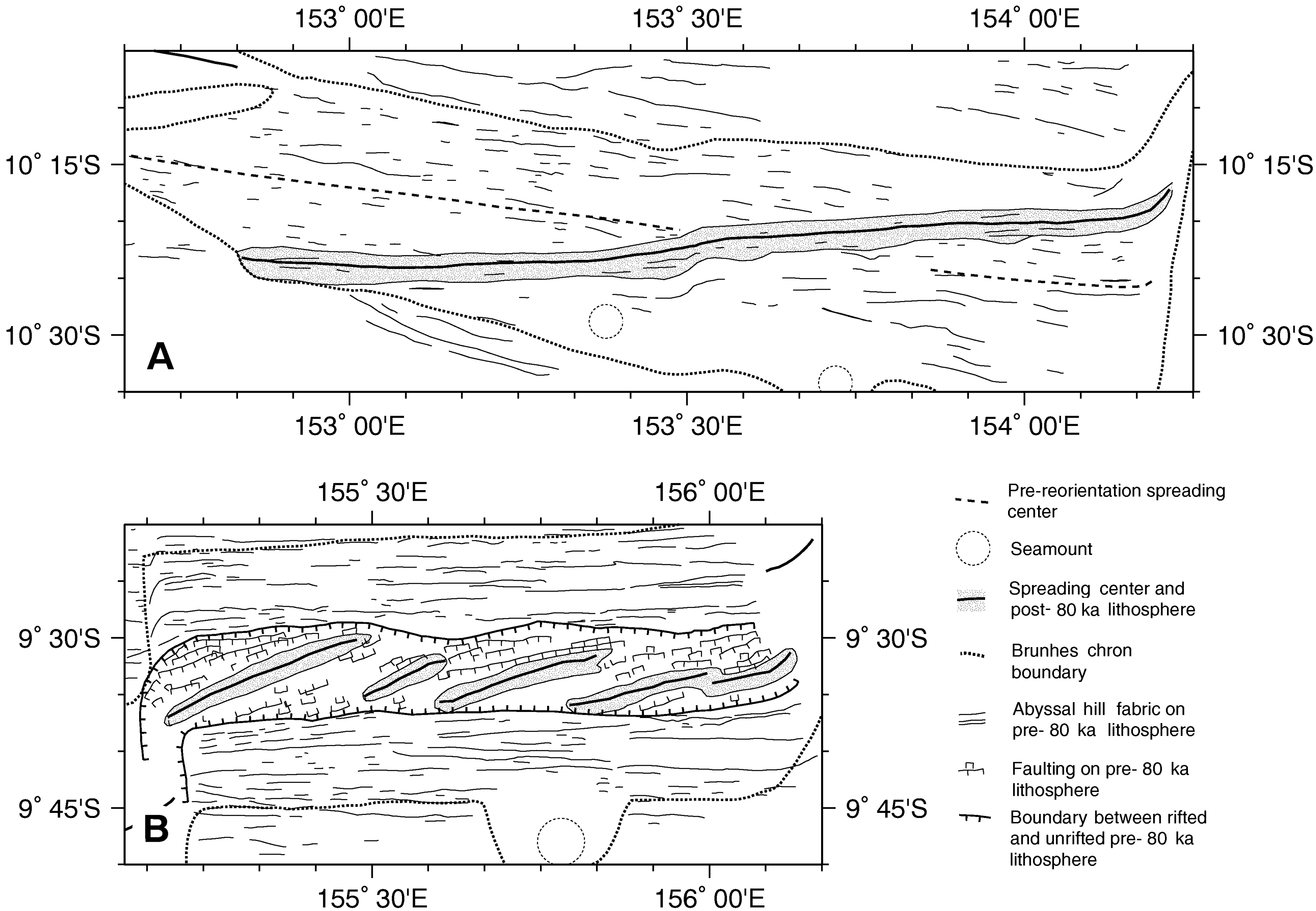
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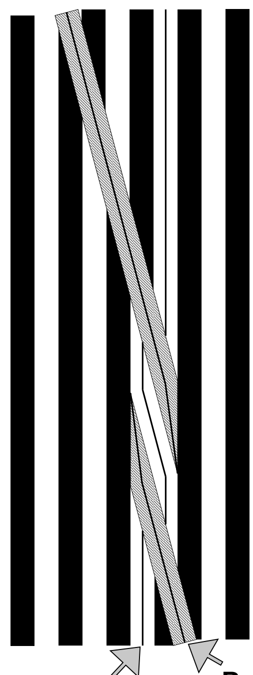
Pre-reorientation spreading center
Seamount
Spreading center and post- 80 ka lithosphere
Brunhes chron boundary
Abyssal hill fabric on pre- 80 ka lithosphere
Faulting on pre- 80 ka lithosphere
Boundary between rifted and unrifted pre- 80 ka lithosphere



Synchronous reorientation