Tectonic and magmatic development of Bismarck Sea, Papua New Guinea

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Abstract : The Bismarck Sea represent a unique region in the equatorial western Pacific where one can explore the relationship between tectonic and magmatic processes associated with back-arc opening. The sea, located north of Papua New Guinea and just south of the equator, formed during the final stages of a long, complex geological development of the Melanesian Borderland. The development resulted from the Cenozoic convergence between the Australian and Pacific-Caroline Plates and the opening of back-arc basins. At present, the Bismarck Sea straddles two oppositely facing trenches, the inactive Manus trench and the active New Britain trench, and covers two basins, the New Guinea Basin (NGB) to the west and the Manus Basin (MB) to the east. The two basins are separated by the shallow Willaumez-Manus Rise (WMR), which trends roughly from WNW to ESE. The origin of these major structural units and their relationship with the present-day zone of major seismicity along the Bismarck Sea Seismic Lineation (BSSL) remains unclear and is the main focus of our study.

A detailed examination of geophysical and geochemical data, combined with geologic and geodetic information from surrounding regions, attests that the Bismarck Sea went through some rather unusual events of back-arc development beginning in the middle Pliocene. In this study, we reconstruct the opening of the Bismarck Sea. Around 3.5 Ma, the northern tip of New Guinea came into contact with the Finisterre-Huron Range. The event triggered a back-arc opening that eventually divided the Bismarck seafloor into North and South Bismarck Plates. We speculate that the rapid opening also caused an upwelling of anomalously hot upper mantle beneath the Bismarck Sea. A large volcanic outflow during this period may have contributed to the formation of the rise west of Manus Island. Both the North and South Bismarck Plates interacted with surrounding plates and small and large changes may have occurred throughout their history. A sudden shift in plate motion may have caused the mantle upwelling to decouple from the overlying lithosphere. The WMR was probably created under such circumstances when a large volume of rising magma leaked out along the strike-slip plate boundary linking the spreading centers in the NGB and MB. An alternative view is that the WMR represents a magmatically robust segment of the spreading axes. The further docking of Finisterre–Huron Range with the New Guinea Highlands allowed the South Bismarck Plate to open faster toward the east in the MB, and at a certain point, the spreading center jumped to the present–day BSSL. The Willaumez Transform is a manifestation of this most recent plate–boundary reorganization. Seafloor spreading commenced in the Manus Spreading Center of MB $<$ 0.78 Ma, and the overall pattern suggests that rifting in the Bismarck Sea is propagating eastwards and westwards in the Southeastern Rift and the Western Spreading Ridge, respectively.

One feature that distinguishes the Bismarck Sea from other back–arc spreading systems in the western Pacific, except perhaps for the North Fiji Basin, is the anomalously large distance between the arc and the spreading axis, which becomes almost 400 km in certain parts. We argue that this feature is the combined results of arc–continent collision, mantle upwelling, and rapid back–arc opening that were unique to this region. The observation that lava samples from the central Bismarck Sea contain chemical components characteristic of the lower mantle can be explained by the Melanesian Borderland, long a site of major subduction zones and lithospheric sinking; therefore, the upper mantle carries higher amounts of enriched, subduction–derived components compared to other spreading systems.