# Insights into Asymmetric Back-Arc Basin Formation in the Mariana Trough at 17° N from Traveltime Tomography

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## Geological Context and Study Area

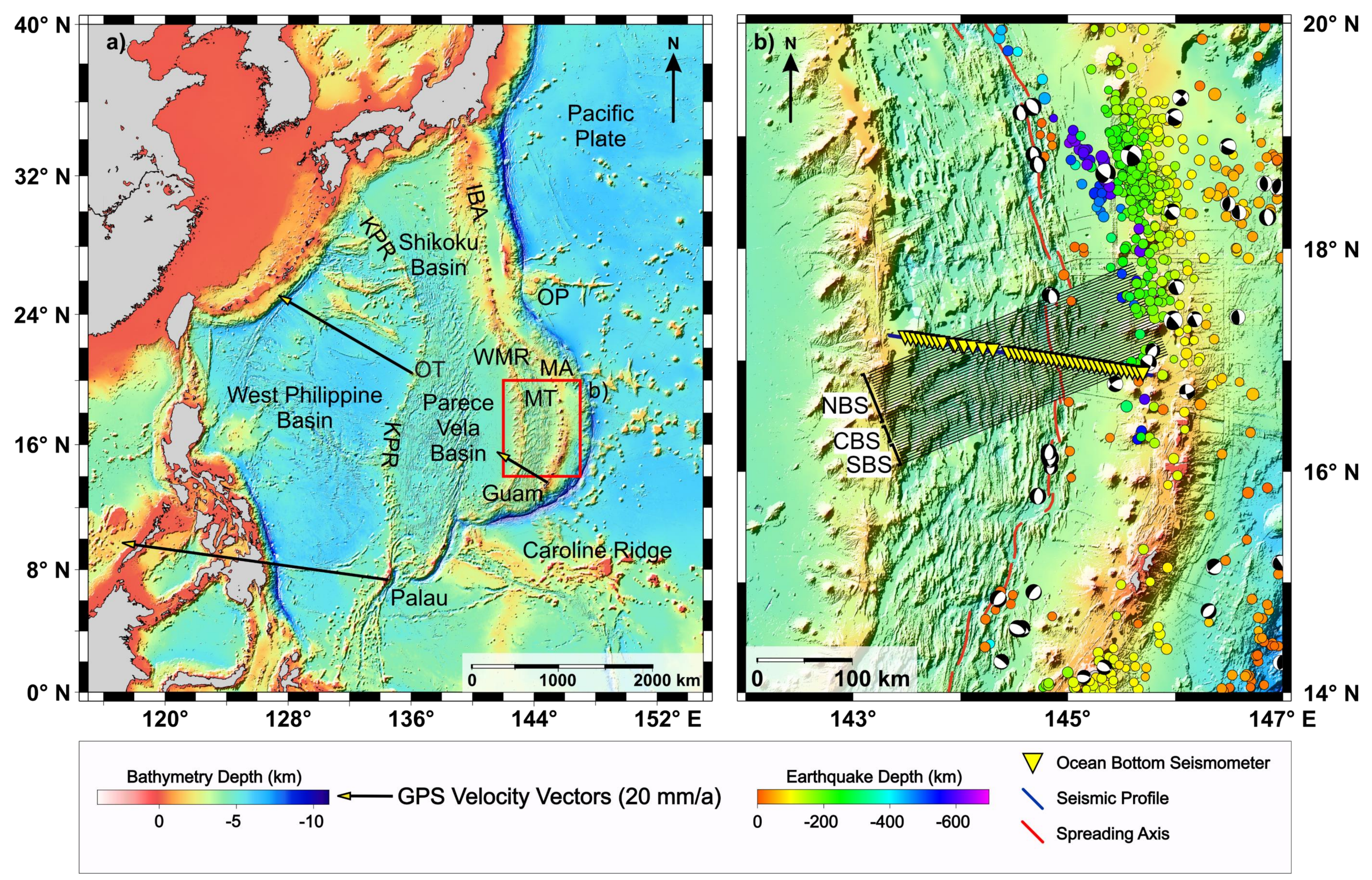


**Figure 1:**
a) Present-day Philippine Sea tectonic setting. Red rectangle marks the study area. GPS velocity vectors relative to stable Eurasia from Kato et al. (1998).
b) Study Area, the Mariana Trough - Black thin lines represent bathymetric profiles used. Coloured dots represent epicentres from the ISC-Bulletin and black-white beach balls show focal mechanisms from Global Centroid-Moment Tensor catalogue. IBA, Izu-Bonin Arc; KPR, Kyushu-Palau Ridge; MA, Mariana Arc; MT, Mariana Trough; OP, Ogasawara Plateau; OT, Okino-Torishima; WMR, West Mariana Ridge.

- Youngest and currently active back-arc basin on the Philippine Sea Plate
- Mariana Trough extends in a crescent shape from 12° N to 24°N
- Exhibits a pronounced asymmetry with the spreading axis located closer to the Mariana Arc
- Predecessor basins (West Philippine, Shikoku, and Parece Vela Basin) have a rather symmetric shape
- **It is assumed that asymmetric back-arc basins evolve from highly asymmetric rifting to more symmetric spreading** (e.g. Martínez et al., 1995; Baker et al., 1996)

## Data & Methods

**Data:**
- Refraction and wide-angle reflection data from 41 ocean bottom seismometers (OBSs)
- High-resolution gridded bathymetric surveys from NOAA NCEI and GEBCO to fill the gaps

**Methods:**
- Handpicking of refracted P-waves (Pg, Pn) and wide-angle reflections (PmP)
- Joint refraction and reflection tomography with tomo2D (Korenaga et al., 2000)
- Non-linear Monte Carlo approach (set of 100 2-D start models) for the crustal structures
- Extraction of bathymetric profiles and alignment of the spreading centre
- Calculation of theoretical subsidence curves after Stein & Stein (1992)

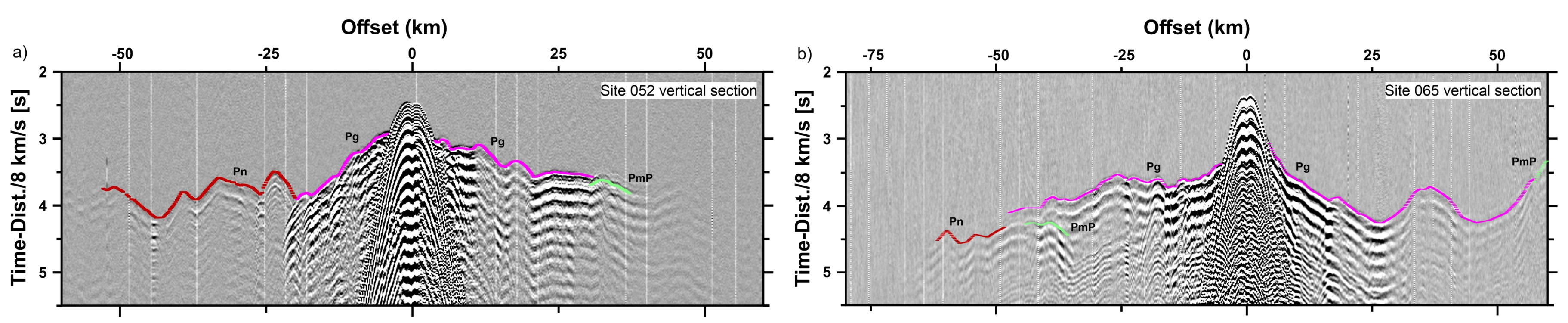


**Figure 2:**
Examples of vertical component of OBSs deployed on sites a) 052 and b) 065 in the Mariana Trough. All traces are unfiltered and traveltimes on the time-axis [s] reduced by 8 km/s. Horizontal axis is given as offsets to the station (km).

## Results

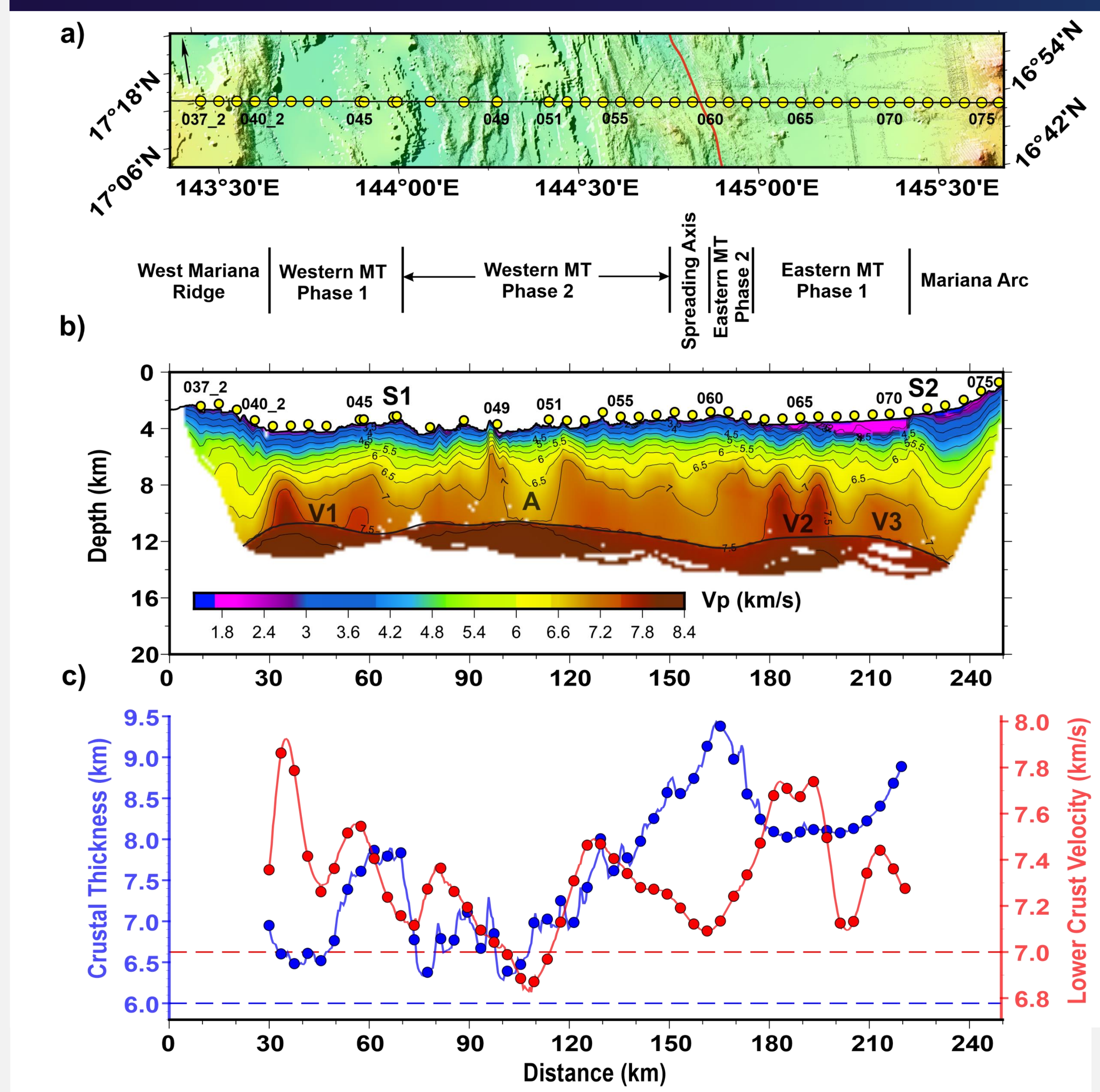


**Figure 3:**
a) Bathymetric map with the OBS locations. b) P-wave velocity model. Thick black line represents Moho. c) Crustal thickness (blue line) and lower crustal velocity (250 m above the Moho depth; red line). Reference lines for oceanic crust formed at mid-ocean ridges.

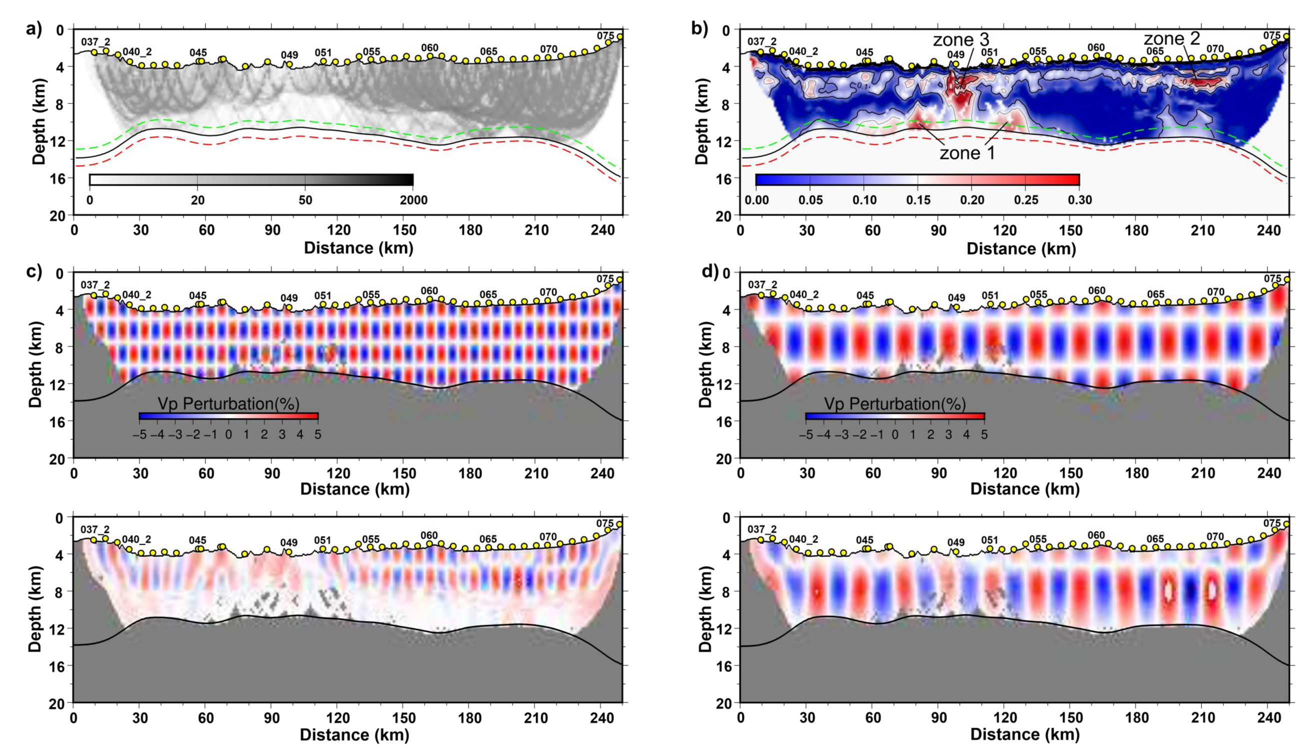


**Figure 4:**
a) Derivative Weight Sum (DWS) for the rays traveling in the crust. b) Standard deviation for the average P-wave velocity model. c) and d) Recovered velocity perturbation from checker board tests with a perturbation anomaly of ±5 % (positive in red, negative in blue). Cells of 5x2.5 km and 10x5 km are shown in c) and d), respectively.

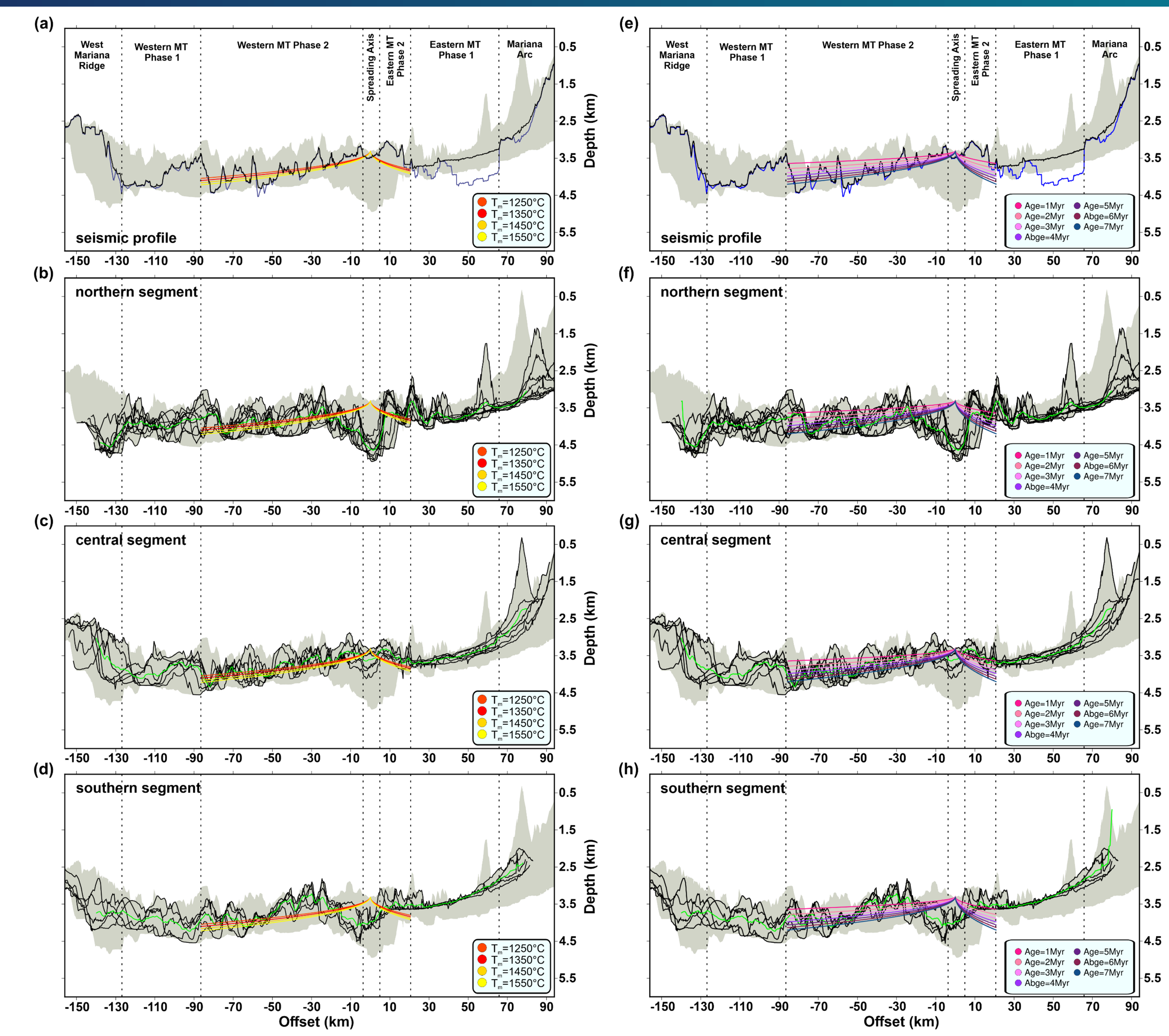


**Figure 5:**
Bathymetric sections across the spreading axis of the central Mariana Trough at 17° N (black lines). Grey shaded areas show the envelope of all bathymetric sections and green lines display the average bathymetry. Coloured lines present subsidence curves for different mantle temperatures (a-d) and different spreading periods for the seafloor spreading phase (e-h).

- Two domains on either side of the spreading axis representing different opening phases: MT-1 for rifting and MT-2 for seafloor spreading
- High-velocity zones in the lower crust (V1-V3) with Vp of ~7.4-7.9 km/s (MT-1)
- Central basin (MT-2) shows a 2-layer oceanic type crust
- Crustal thickness ranges between ~6.5-9.5 km with thicker crust in the east
- Strong variability in the thickness and structure of the lower crust
- Asymmetry is visible all over the ridge segment
- The spreading centre forms a deep valley in the north and south, while it is plateau-like in the central part.
- Change in abyssal strike direction from NW-SE to N-S at the transition from MT-1 to MT-2
- Subsidence curves for 1250-1350° C and a period of 5 Myr for seafloor spreading fit best

## Conclusions

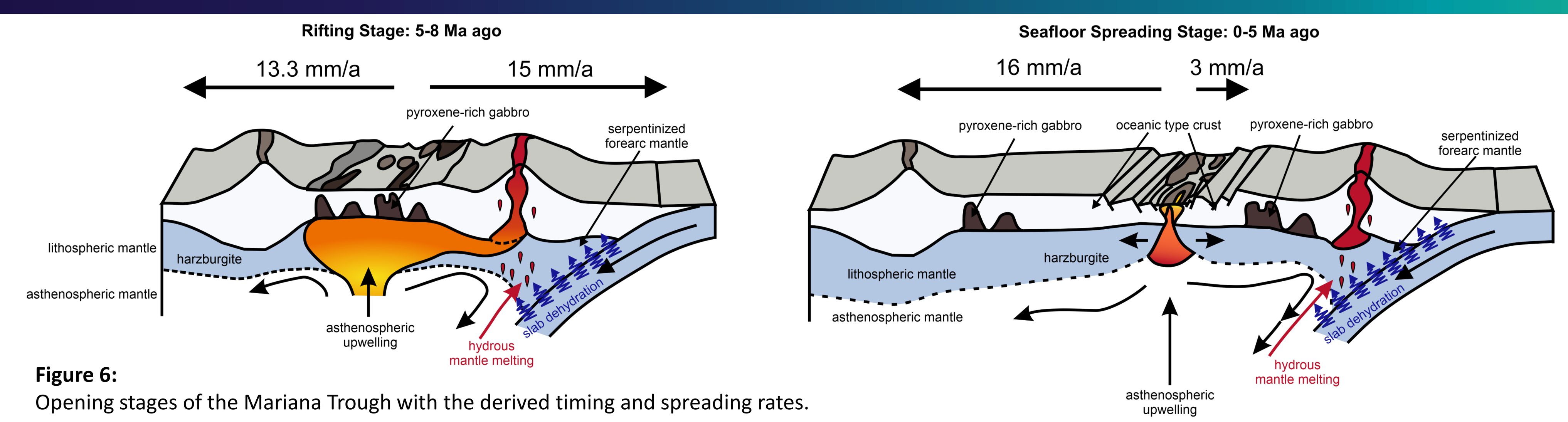


**Figure 6:**
Opening stages of the Mariana Trough with the derived timing and spreading rates.

- Asymmetry in the central Mariana Trough with a ratio of 1:2 along the profile – with a relatively symmetric ratio of 1:0.89 for the rifting phase and a highly asymmetric ratio of 1:5.44 for the seafloor spreading phase
- Change in strike direction correlates with transition from rifting to seafloor spreading indicating a change in the back-arc opening related to a re-arrangement of the Pacific and Philippine Sea Plates motion at ~5 Ma.
- Strong crustal variability indicates the temporal heterogeneity of the mantle composition and its thermal properties
- High-velocity zones (V1-V3) indicate that magma generation and crust formation were highly affected by refertilization of the magma source by slab derived hydrous fluids leading to increased melt production and suppression of plagioclase crystallization during crustal magma evolution.

**References:**
Martínez et al., (1995). Evolution of backarc rifting: Mariana Trough, 20°-24°N. *J. Geophys. Res. Solid Earth*. doi: 10.1029/94JB02466
Baker et al., (1996). Rifting history of the northern Mariana Trough: SeaMARC II and seismic reflection surveys. *J. Geophys. Res. Solid Earth. doi:* 10.1029/95JB02853