A Tribute to Marie Tharp: Mapping the seafloor of back-arc basins, mid-ocean ridges, continental margins & plate boundaries

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CSIC
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The first steps of Marie Tharp

Fig. 1. A young Marie in the field helping his father, William E. Tharp, a soil surveyor for *United States Dpt. of Agriculture*. Marie often helped him with this task, which gave her an introduction to map-making. *From book "Soundings" by Hali Felt (2012*).

- **Marie Tharp,** July 30, 1920 (Ypsilanti, Michigan) – August 23, 2006 (Nyack, New York) was an American geologist & oceano-graphic cartographer who, in partnership with Bruce Heezen, created the first scientific map of the Atlantic Ocean floor.

- Tharp's work revealed the **detailed topography** and multi-dimensional geographical landscape of the ocean bottom.

- Her work revealed the presence of a **continuous rift-valley** along the axis of the Mid- Atlantic Ridge, causing a paradigm shift in Earth Sciences that led to acceptance of **Plate Tectonics** and Continental Drift.

Working at Columbia University Lamont Geological Observatory (NY)

Fig. 2. Marie at streets of New York, after she was hired to work by Dr. Maurice Ewing', at the newly-formed Geophysical Institute at Columbia University.

From book "Soundings" by Hali Felt (2012).

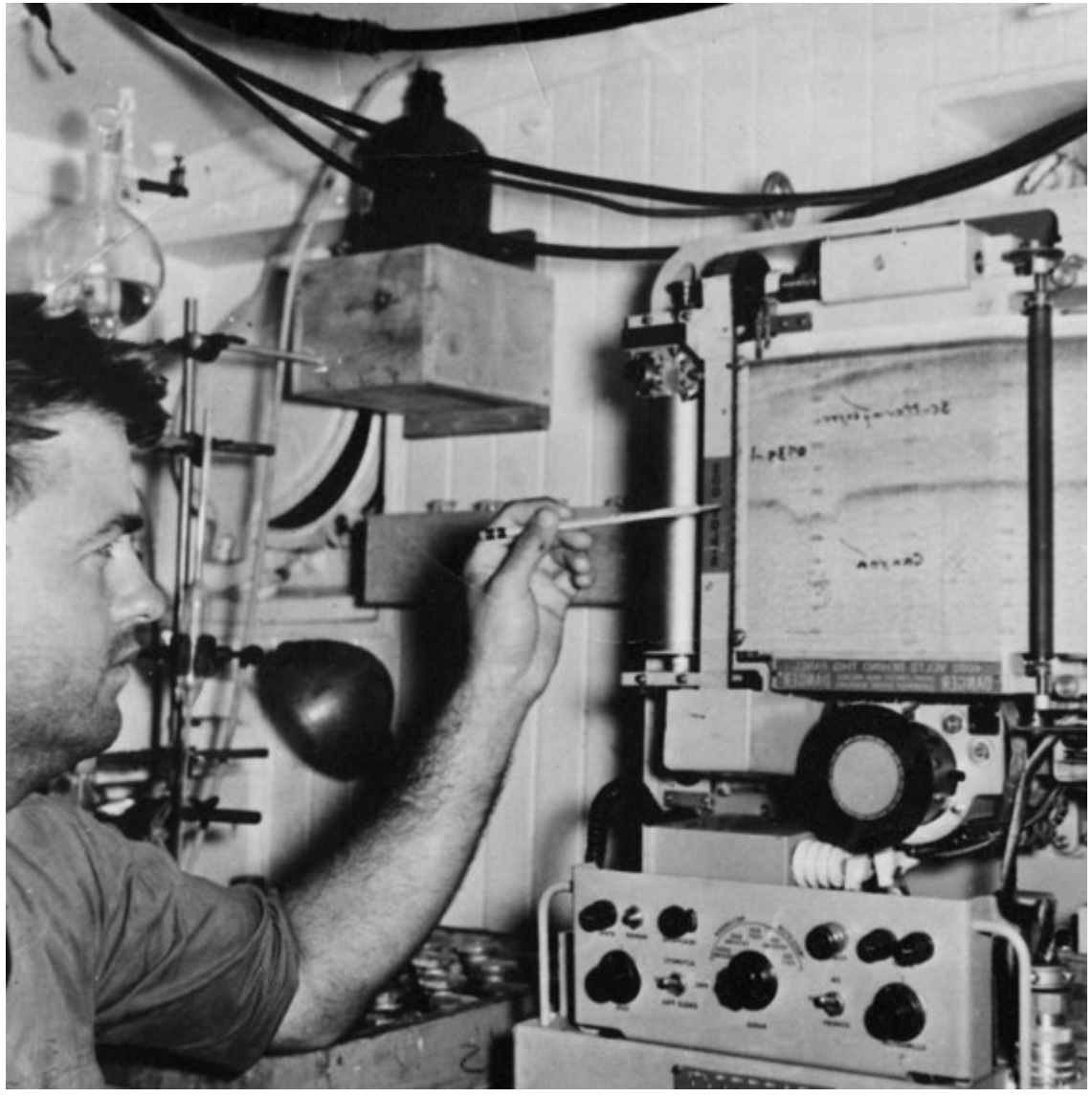


Fig. 3. Bruce Heezen looking at a fathogram being produced by an early echosounder (year 1940).

From book "Soundings" by Hali Felt (2012).

The first North Atlantic profiles: From Martha's Vineyard to Recife

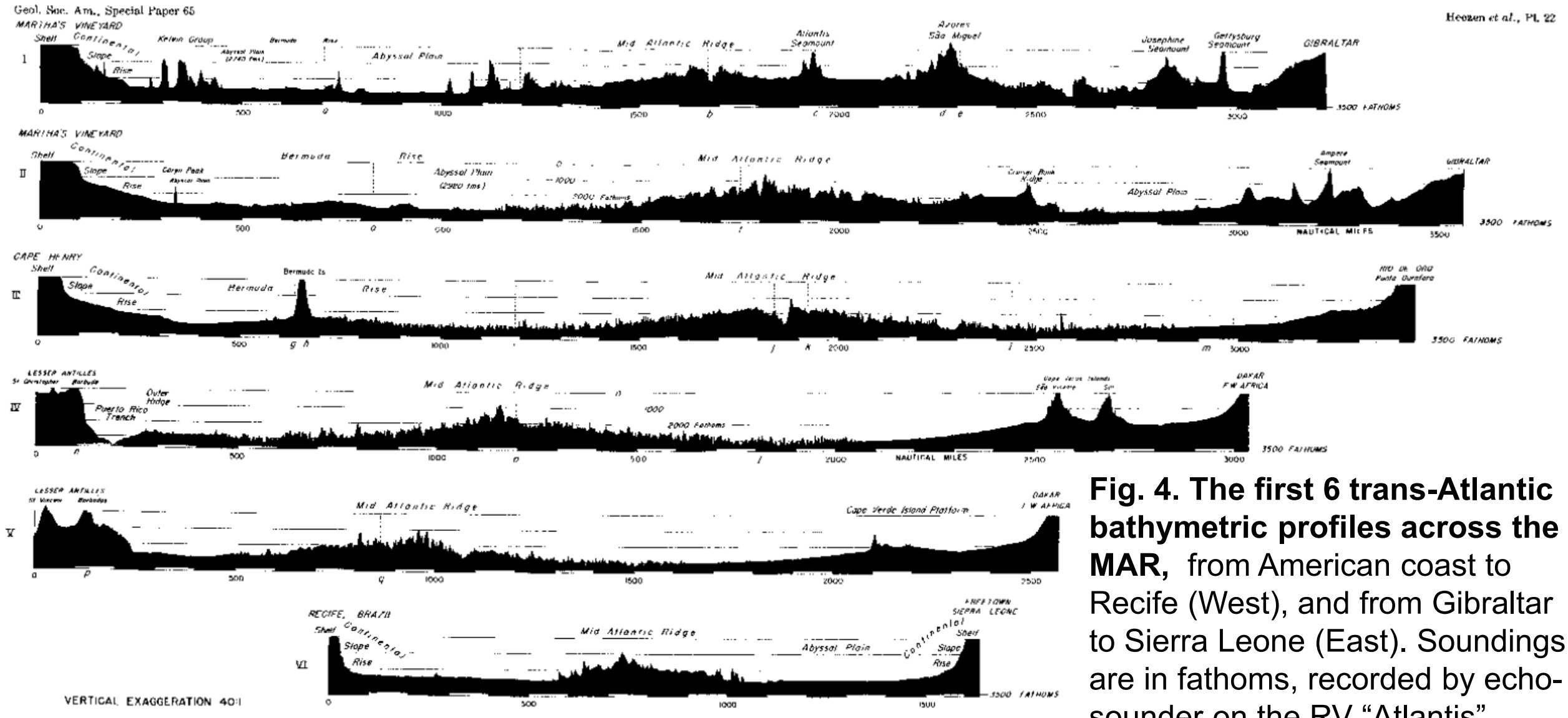


Fig. 4. The first 6 trans-Atlantic bathymetric profiles across the MAR, from American coast to Recife (West), and from Gibraltar to Sierra Leone (East). Soundings are in fathoms, recorded by echo-sounder on the RV "Atlantis".

(Published at the Geological Society of America's Special Paper #65-The Floors of the Ocean: I. North Atlantic).

The first map of Atlantic Ocean: Reykjanes Ridge to South Atlantic

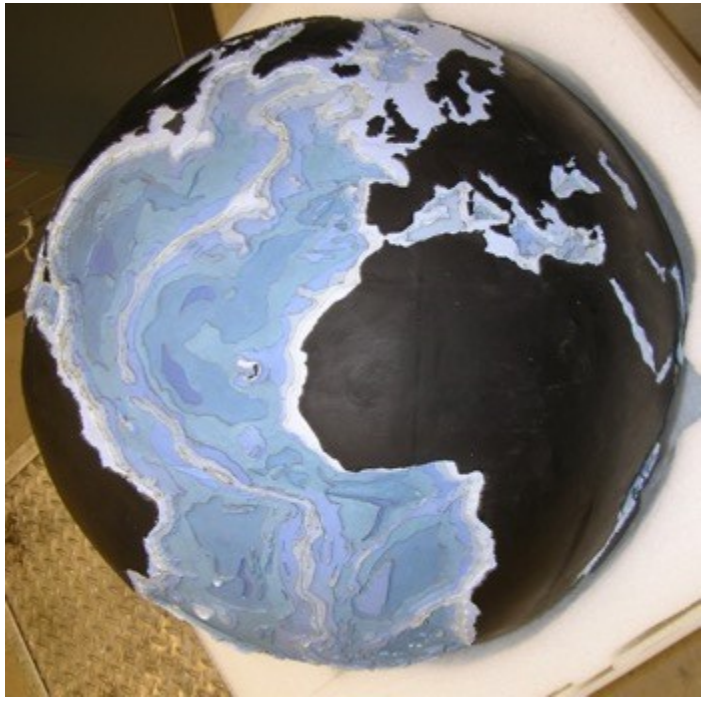


Fig. 5. Marie together with Bruce made the first map of the oceans. In 1957 she demonstrated the existence of the mid-ocean ridge, a large submarine mountain range along the Atlantic ocean, from Iceland (North Atlantic), Azores, Equatorial Atlantic FZs (Romache & St. Paul), South Atlantic to Bouvet Triple junction. This was a finding of great relevance for the theory of plate tectonics. She also discovered the rift valley, a great deep valley structure all along the Mid-Atlantic Ridge.

From book "Soundings" by Hali Felt (2012).

The latest world maps: The Indian Ocean and World Ocean Floor

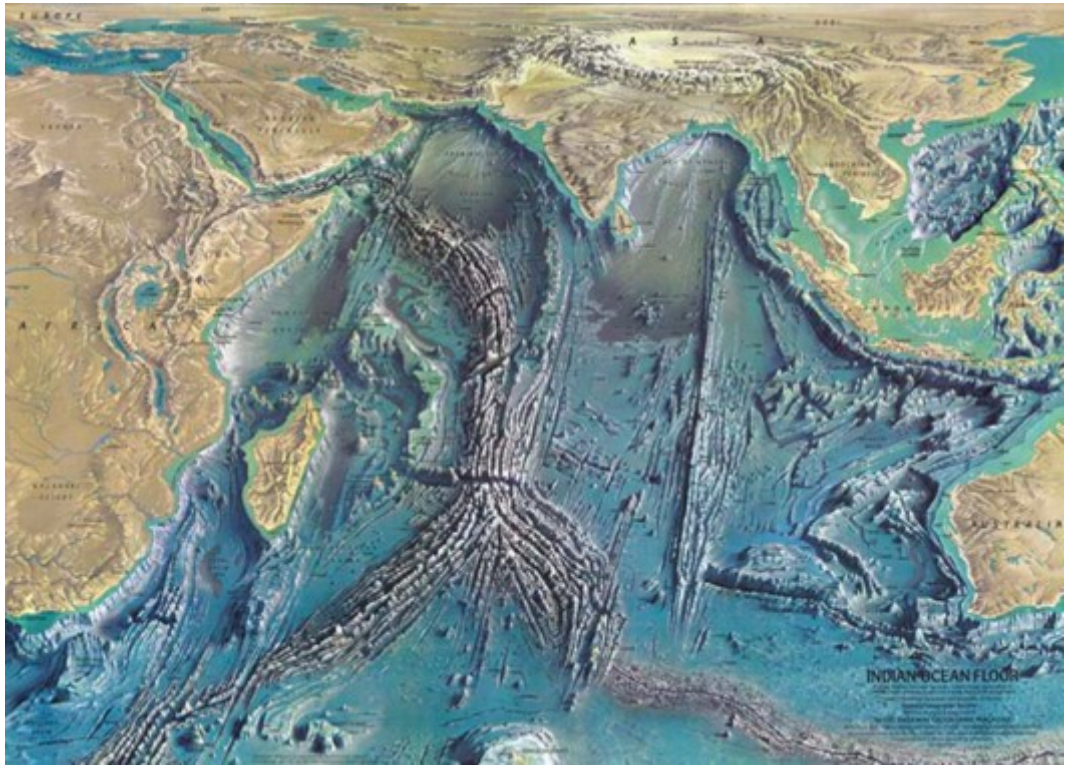


Fig. 6. The 1967 Marie & Bruce's first contribution with "National Geographic" magazine. Together with Heinrich Berann, they published an insert to the magagzine in October 1967, accompanying the article "*Science explores the Monsoon Sea*".

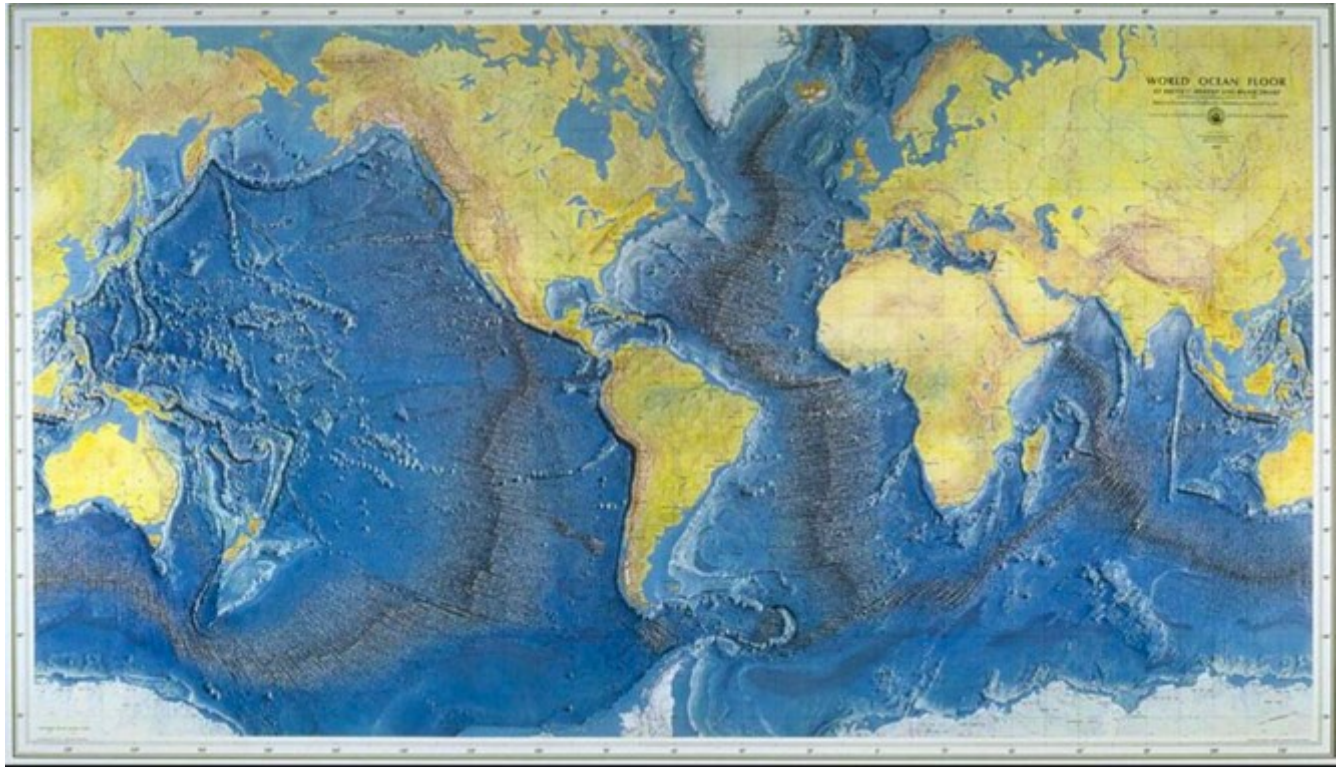


Fig. 7. The 1977 World Ocean Floor Panorama, painted by Heinrich Berann (Austria) and based on the 25 years of Marie Tharp's work. Image courtesy of Marie Tharp maps.

(by Marie Tharp, Bruce Heezen & Heinrich Berann)

Marie Tharp mapping contributions & key articles on Plate Tectonics

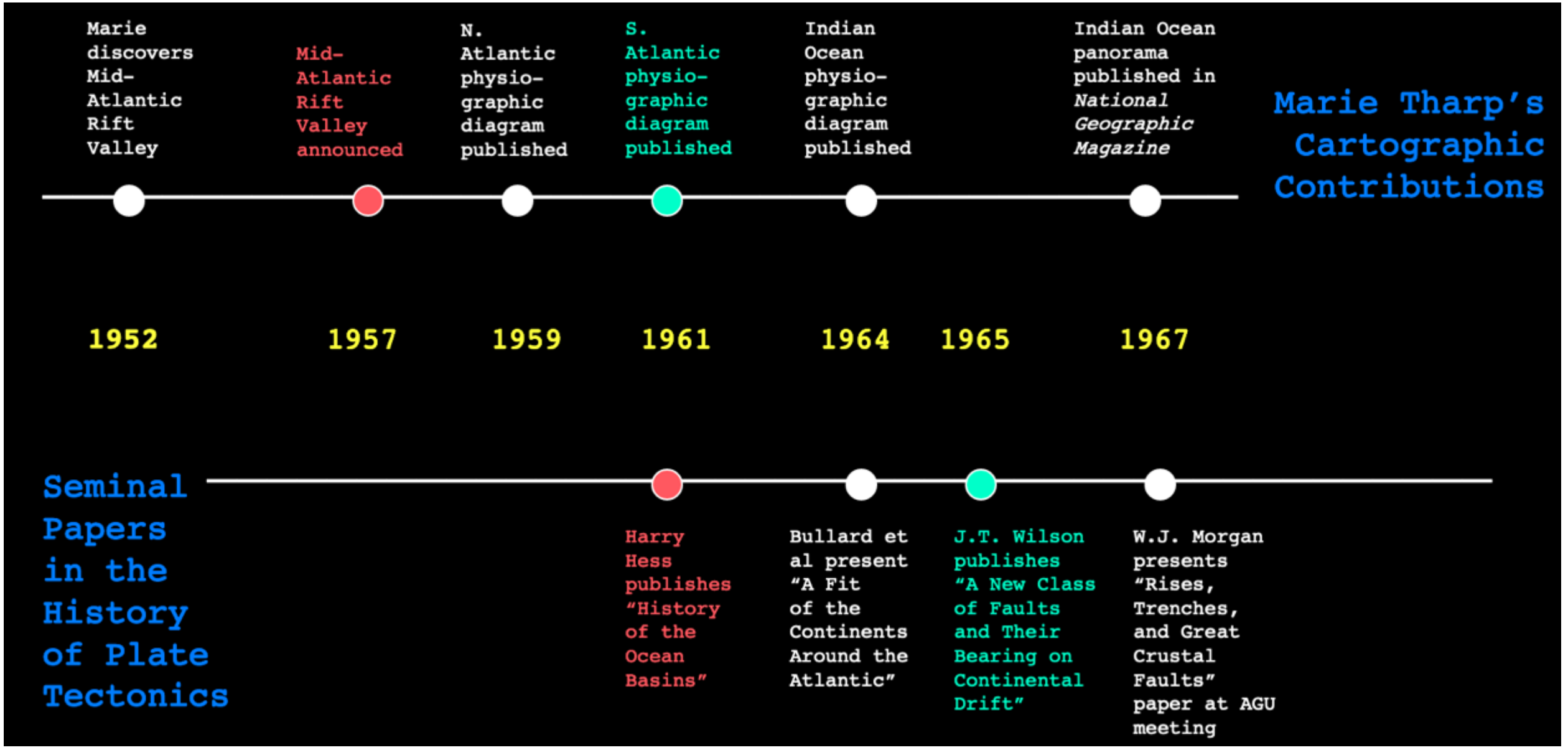


Fig. 8. Marie Tharp maps & Plate Tectonics articles (1961-67). *From "Soundings" by Hali Felt (2012).*

An Hommage to Marie Tharp: A Pioneer in Marine Geosciences

Marie Tharp (1920-2006) was at the *avant-garde* of modern oceanography. She was an American geologist and oceanographic cartographer who, together with his partner **Bruce Heezen**, generated the first bathymetric map of the Atlantic Ocean floor. Tharp's work revealed the detailed topography and geological landscape of the seafloor.

Her work revealed the presence of a continuous rift valley along the **Mid-Atlantic Ridge axis**, causing a paradigm in Earth Sciences that led to the acceptance of plate tectonics and continental drift theories. In the late 1940s and early 1950s, Marie and Bruce discovered the **75.000 km underwater ridge bounding around the globe**. By this finding, they laid the conclusión, from geophysical data, that the seafloor spreads from mid-ocean ridges and that continents are in motion with respect to one another—a revolutionary geological theory at that time. Many years later, satellite images demonstrate that Tharp's maps were accurate.

Now, we will focus on **bathymetric maps** that we collected from year 1992 to now, which include bathymetric maps from different parts of the world. For instance, we will show:

- a) Back-arc basins (i.e. the Bransfield Basin, Antarctica; & the North Fiji Basin, SW Pacific);
- b) Mid-ocean ridges and fracture zones (i.e. the MAR at the South of Azores, the MAR at the Oceanographer-Hayes, & the St. Paul Fracture Zone at the Equator);
- c) Active tectonic structures in the Alboran Sea, Africa-Eurasia plate boundary (Gibraltar Arc).

The Mid-Atlantic Ridge: Three areas explored at the North M.A.R.

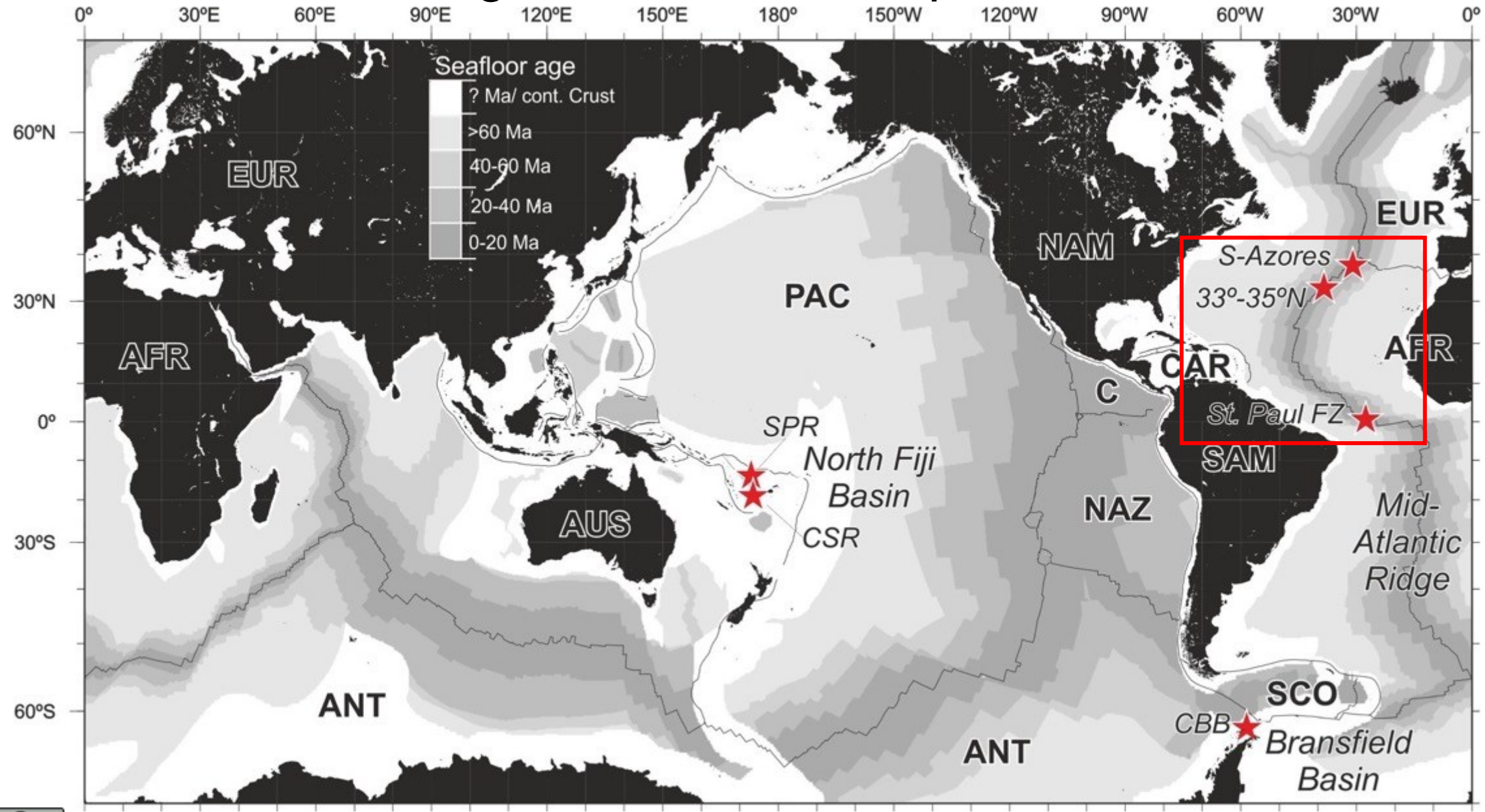
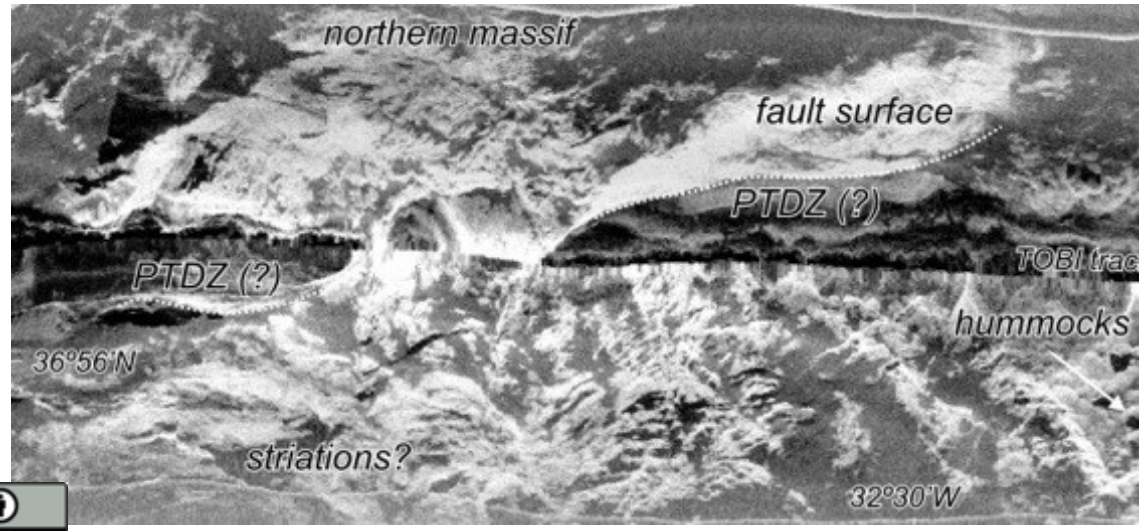


Fig. 9. Map of the world and seafloor age: The Mid-Atlantic Ridge.

The Mid-Atlantic Ridge South of the Azores: 38º-34ºN



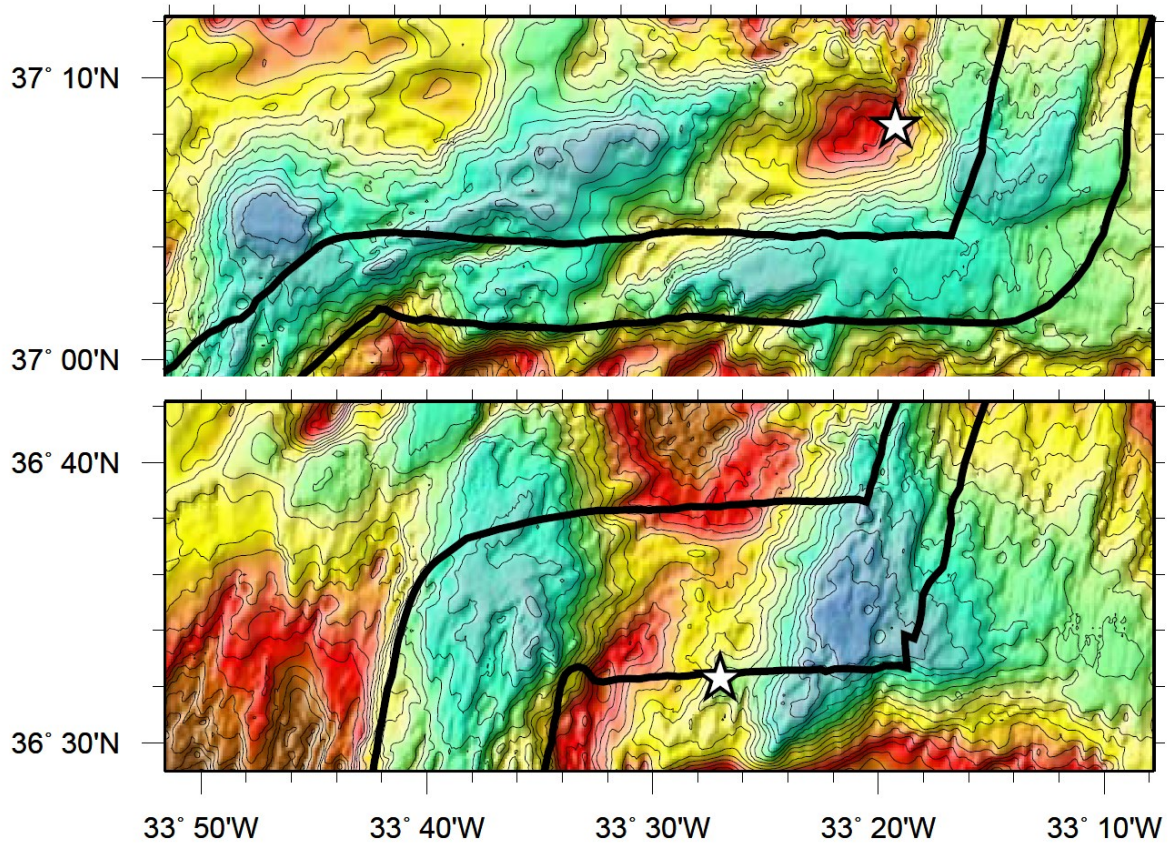
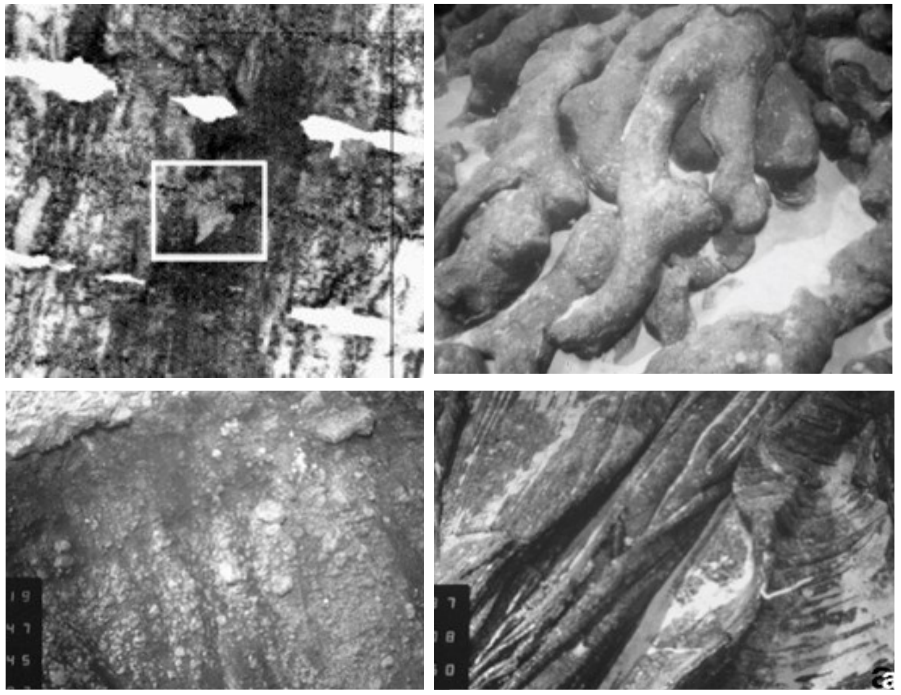


Fig. 10. Bathymetric data & high resolution "TOBI" sidescan sonar map of the Mid-Atlantic ridge, South of the Azores. TOBI allowed to map volcanic, tectonic structures and hydrothermal vents with unprecedented resolution. We show non-transform offsets (NTOs) located between 38ºN-34ºN. These offsets includes detached massifs showing a complex fabric. Mantle outcrops with high-temperature hydrothermal vents were detected.

Gràcia et al. EPSL, 2000; Parson et al. EPSL, 2000

The Mid-Atlantic Ridge at Oceanographer-Hayes FZ: 35º-33ºN



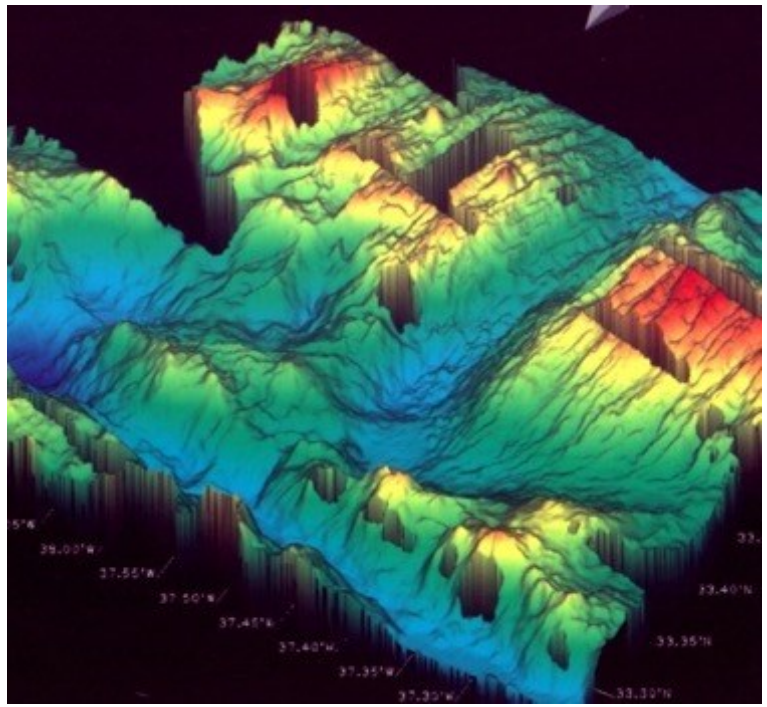
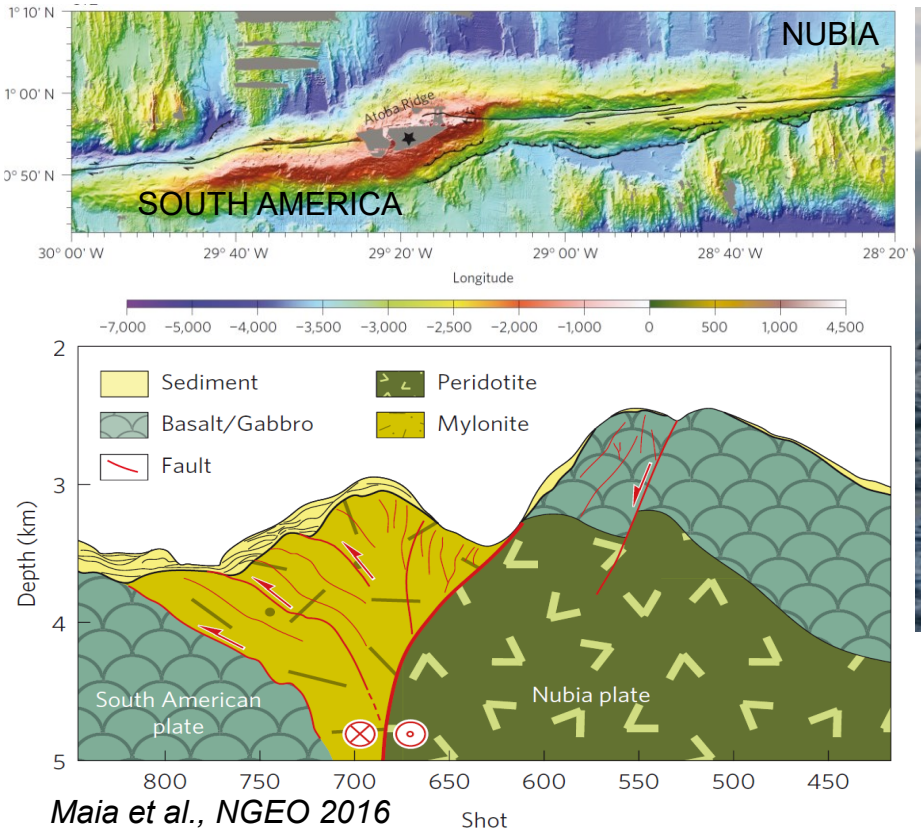


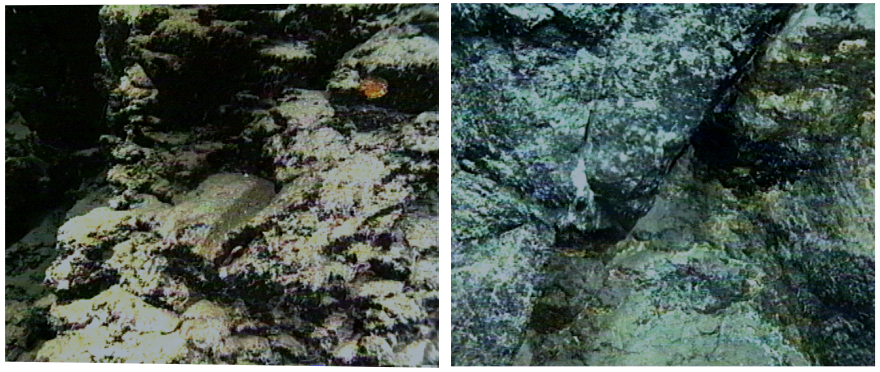
Fig. 11. The OCEANAUT campaign (1995) leaded by Roger Hekinian & Daniel Bideau. It took place on the Medio-Atlantic Ridge between the Oceanographer & Hayes fracture zones, making it possible to dive on board the submersible *Nautile (Fr)*. An important point was the existence of an area of low reflectivity at the central ridge. Indeed, geochemical studies and submersible observations will showed that this ridge was formed not only of effusive volcanism (pillow lavas), but also of deposits related to explosive volcanism (hyaloclastites & pyroclasts) at the top of the ridge.

Gràcia et al., GEOLOGY 1997; Bideau et al., MGR 1997; Gràcia et al., JGR 1999

The St. Paul Fracture Zone at the Equatorial Atlantic: 2º-0ºN



Maia et al., NGEO 2016



Hekinian et al., MGR 2000 & JVGR 2000

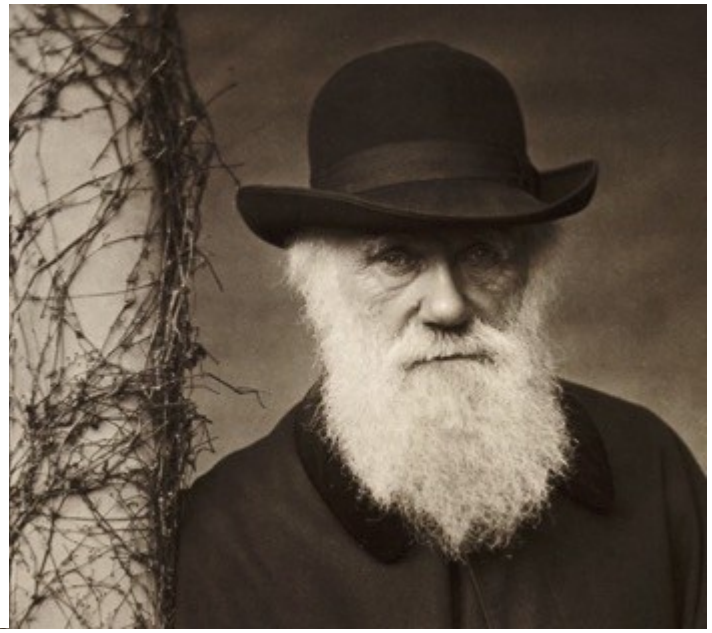


Fig. 12. The St. Paul FZ cruise, led by R. Hekinian & D. Bideau. Using the submersible *Nautile*, we explored St. Pierre & St. Paul Rocks, and the spreading centers located in-between large transform faults of Equatorial Atlantic. *Nautile* dives were carried out at >5000 m depth. We also visited the rocks that Charles Darwin did in 1832 during his *"Beagle voyage*". At that time, Darwin discovered mylonitic rocks of tectonic origin. We also explored Belmonte Island, the largest of St. Paul rocks, to sample & take measurements. The visit was enigmatic: Being at the middle of Atlantic, more than 950 km from land, on a small island with a lighthouse and inhabited only by a seabird colony.

The Back-Arc Basins: The North-Fiji Basin & the Bransfield Basin

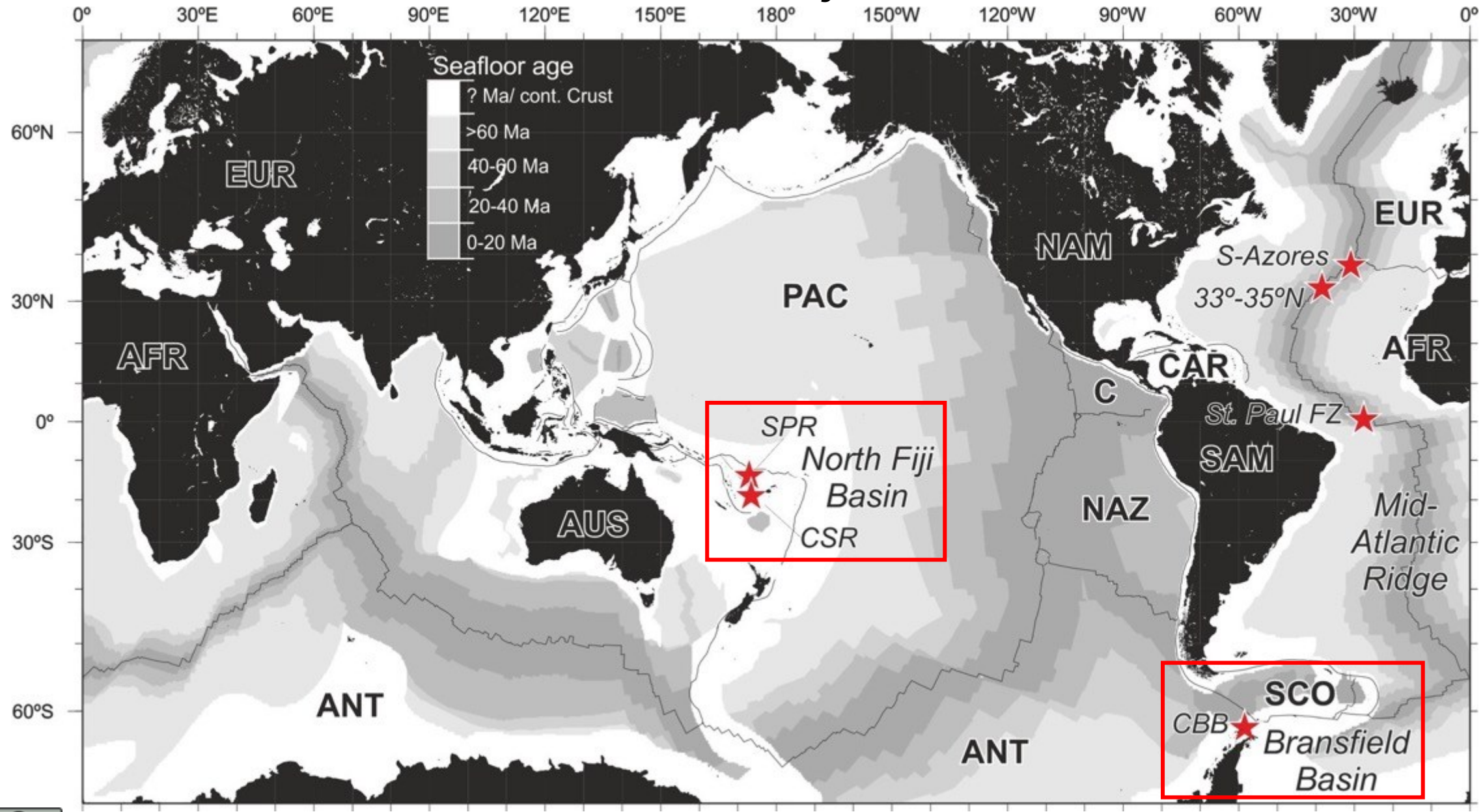


Fig. 13. Map of the world and seafloor age: The North-Fiji and Bransfield back-arc basins.

The Back-Arc Basins: The North-Fiji Basin (SW Pacific)

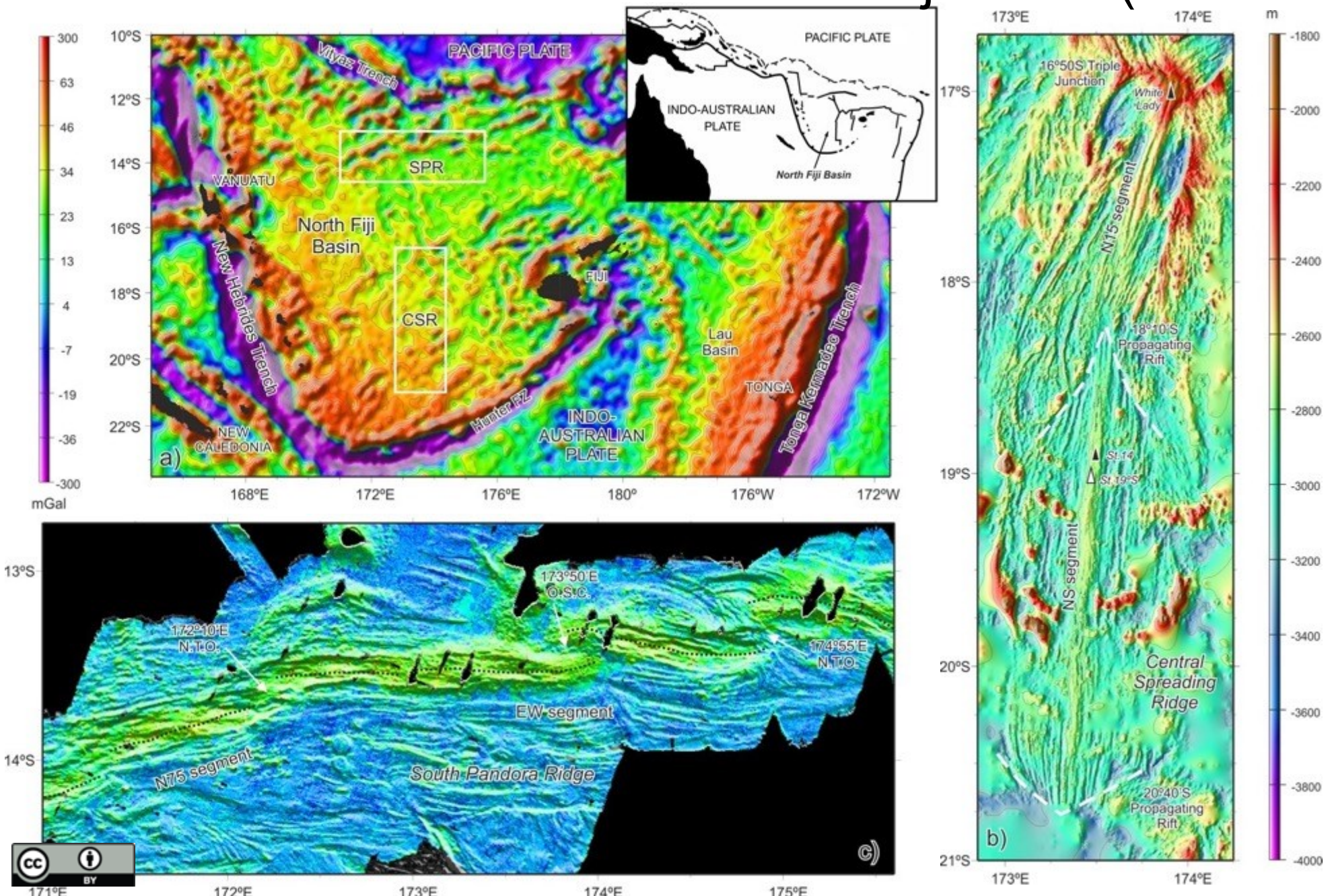
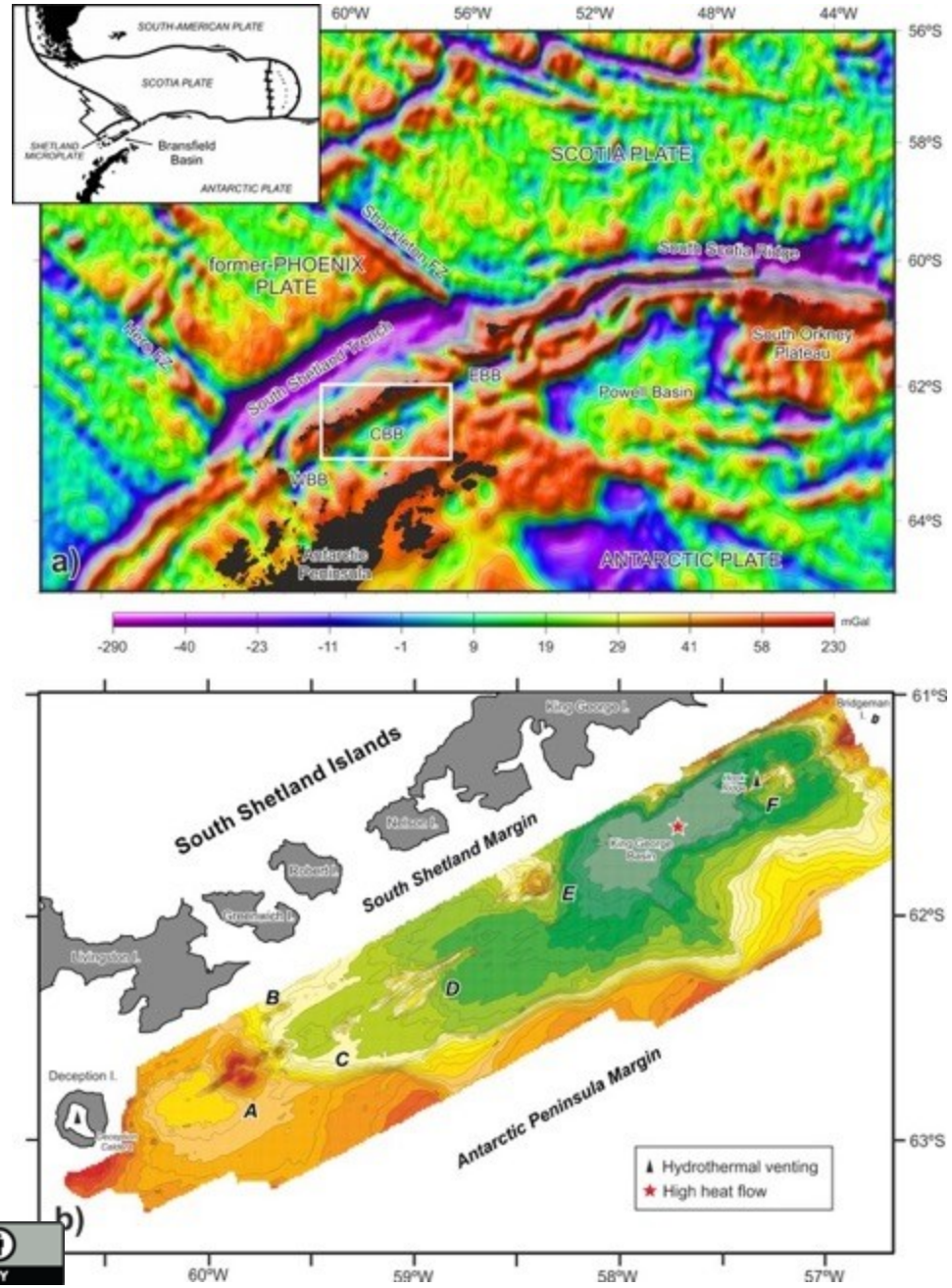
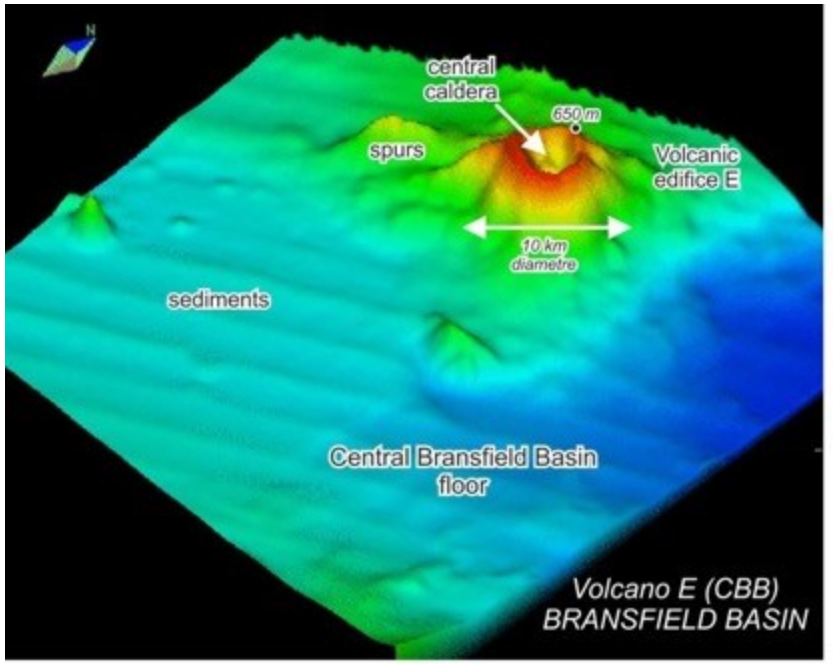


Fig. 14. The North Fiji Basin is a mature back arc basin (10 Ma) with 2 active ridges:
The Central Ridge (3.5 Ma), & the South Pandora Ridge (7 Ma). Both show well-defined segments, high-variability in axial morphology & gravity structure. During this period, we embarked on new missions at the RV "*L'Atalante*": The SOPACMAPS-2 cruise at Solomon Islands (JM. Auzende) & NOFI cruise (Y. Lagabrielle), at the N of North Fiji Basin.

The Back-Arc Basins: The Bransfield Basin (Antarctica)





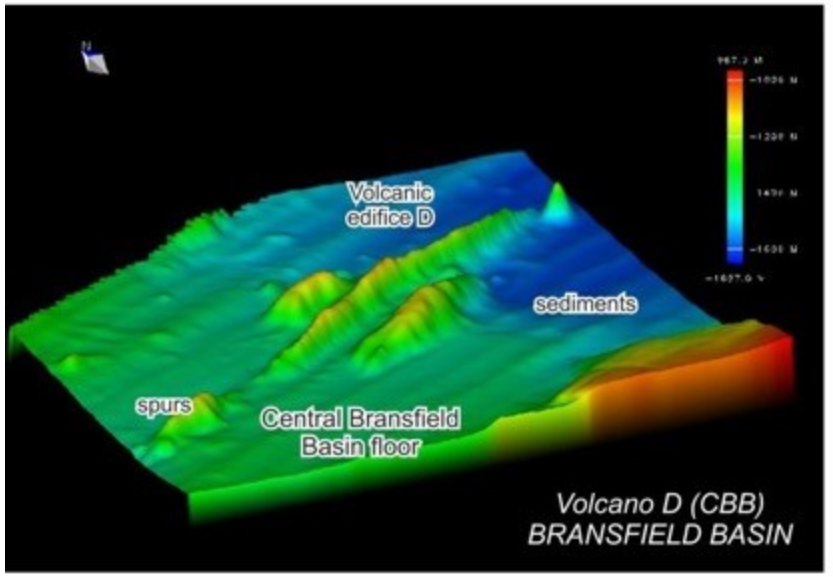
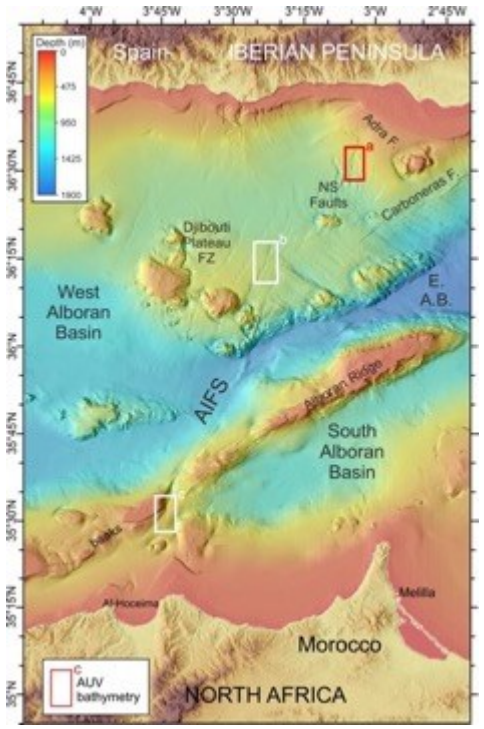
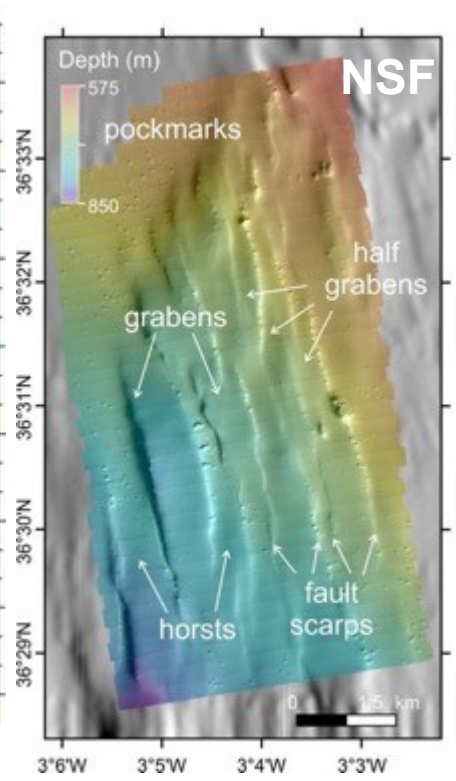


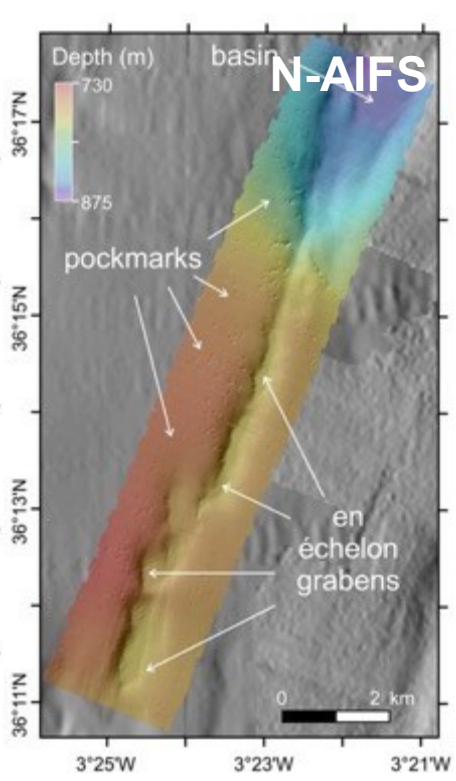
Fig. 15. The Bransfield Basin is a narrow, elongated & young (2 Ma) back-arc basin, showing the early stages of oceanic extension. We carried out the first multibeam bathymetry in this área, with 3 basins: West, Central & East. The Central Basin show the presence of active volcanic edifices that form an alignment along the axis of this Central basin. This basin is considered to represent the initial stages of seafloor spreading.

Gràcia et al., MGR 1996; Gràcia et al., ANT. SCI. 1997; Gràcia & Escartín, C.SCIENCE 1999

The new seafloor mapping instrumentation: The AUVs & ROVs







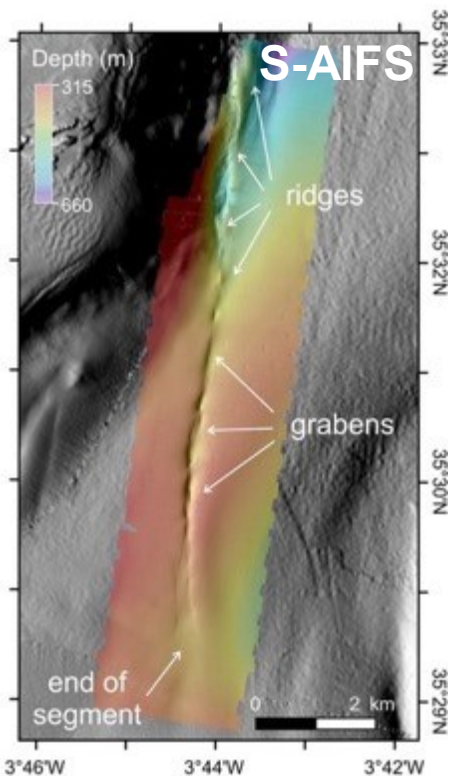


Fig. 16. Top: The AUVs & ROVs are key tolos for video & seafloor mapping, sup-ported by a Reseach Vessel.

Bottom: Map of the central Alboran Sea, with 3 areas:
- The NSF (Almeria Margin)
- The N Al-Idrissi FS (Djibouti Plateau)
- The S Al-Idrissi FS (Moroccan Margin)

Fig. 17. Basaltic rocks of the MAR collected by Hercules ROV during the 2005 Lost City Expedition.