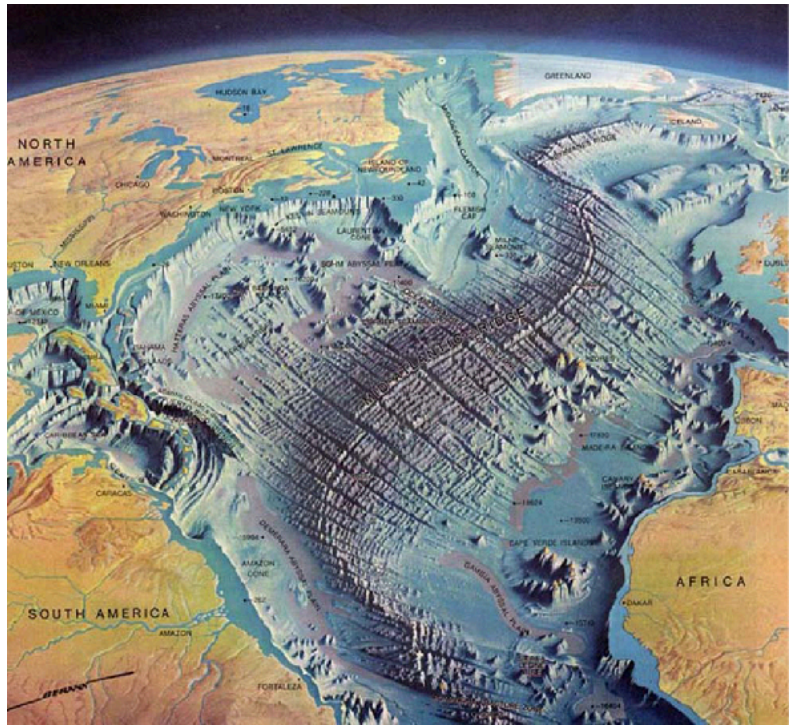
Marie Tharp: Seafloor mapping and ocean plate tectonics

Mathilde Cannat, Debbie Smith, Daniel Fornari, Vicki Ferrini and Javier Escartin

The pioneering seafloor mapping by Marie Tharp played a key role in the acceptance of the plate tectonic theory. Her physiographic maps, published with Bruce Heezen, covered the Earth's oceans and revealed with astonishing accuracy the submarine landscape.

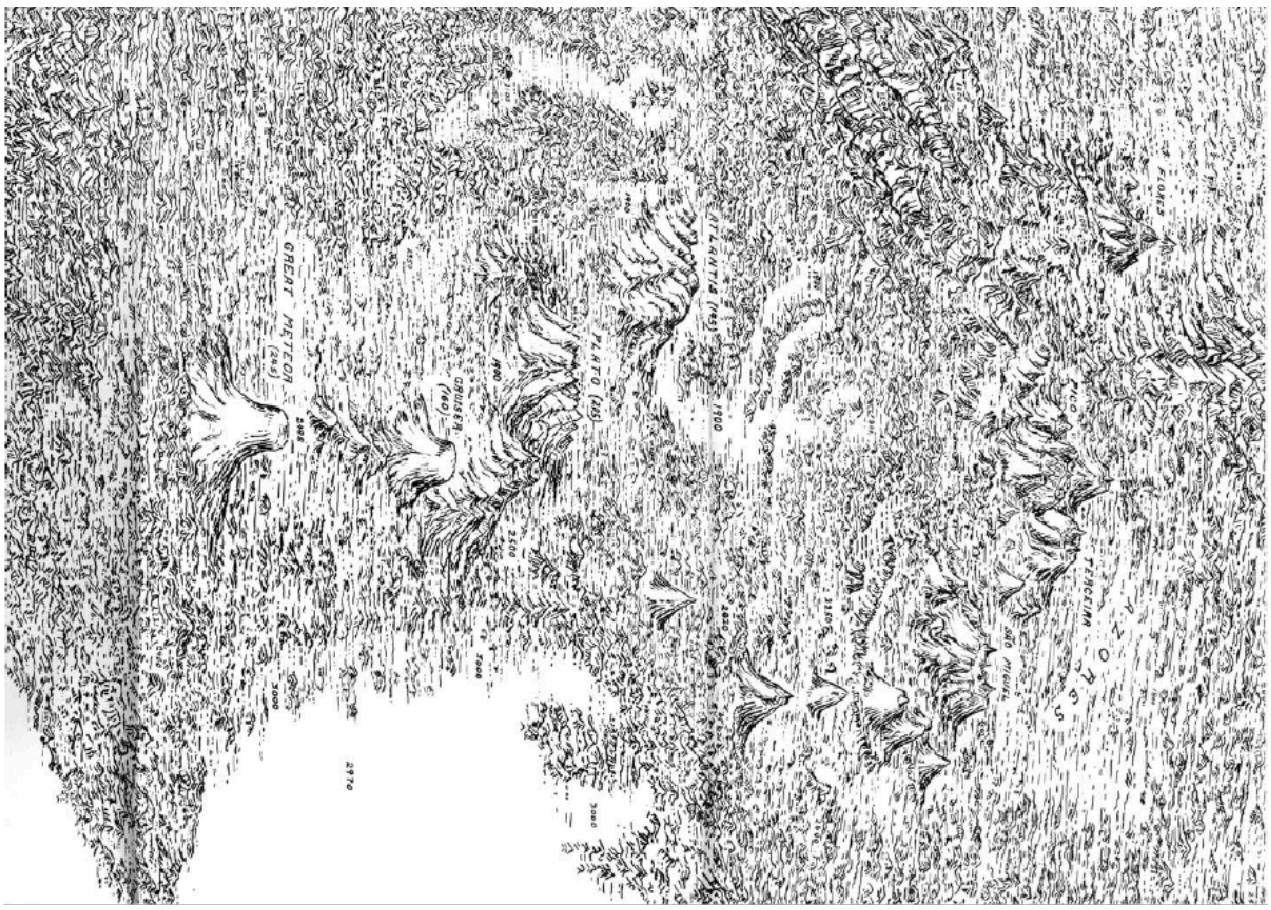
Marie Tharp exposed the full extent of the global mid-ocean ridge system, documented features such as seamounts and volcanic chains, trenches, and transform faults. She co-authored the first papers describing the major fracture zones in the Central Atlantic. In 1952, she discovered that the Atlantic ridge has a central valley, and convinced her colleague Bruce Heezen that it, which corresponds to sustained seismicity (highlighted by other researchers at the same time thanks to the worldwide networking of seismological stations), is a rift that separates the eastern and western provinces of the Atlantic Ocean.

Tharp and Heezen were not yet talking about plate tectonics at this time, (although they played a key role in documenting continental drift). But when, at the beginning of the 1960s, the first magnetic anomaly maps showed that the oceans were "young", and that the age of the seabed increased with the distance from the ridges, their physiographic map became an essential element in understanding the role that these ridges play, as well as the distribution of the main current terrestrial plates.



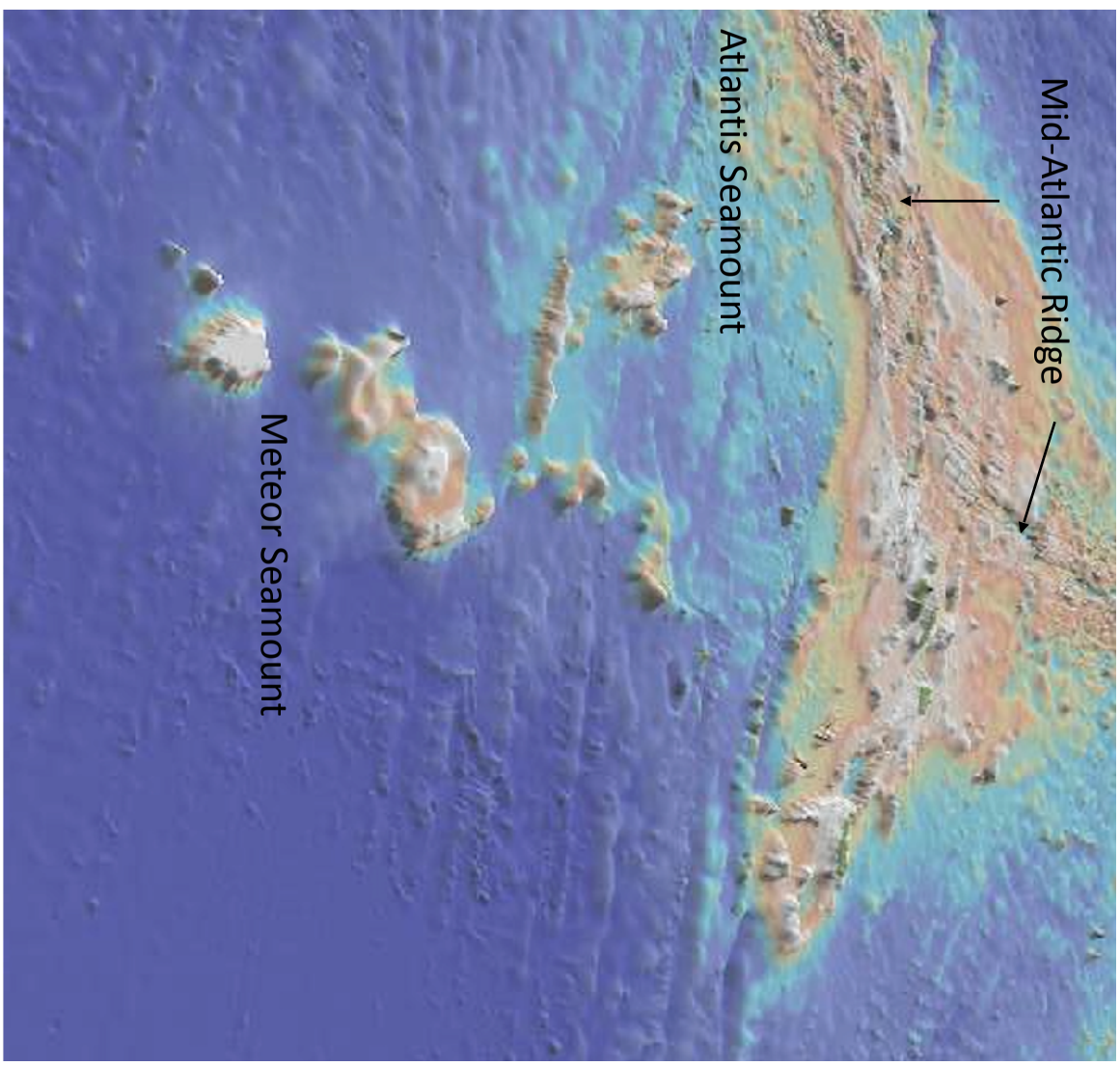
Heezen &Tharp physiographic diagram of the North Atlantic, painted by H.C. Berann in 1968

1957 Heezen &Tharp physiographic diagram of the Azores region, Atlantic Ocean



2019 GMRT grid Version 3.7

Ryan, W.B.F. et al., 2009, Global Multi-Resolution Topography synthsis, Geochem. Geophys. Geosyst., 10, Q03014, doi: [10.1029/2008GC002332](10.1029/2008GC002332)



Comments for slide 2

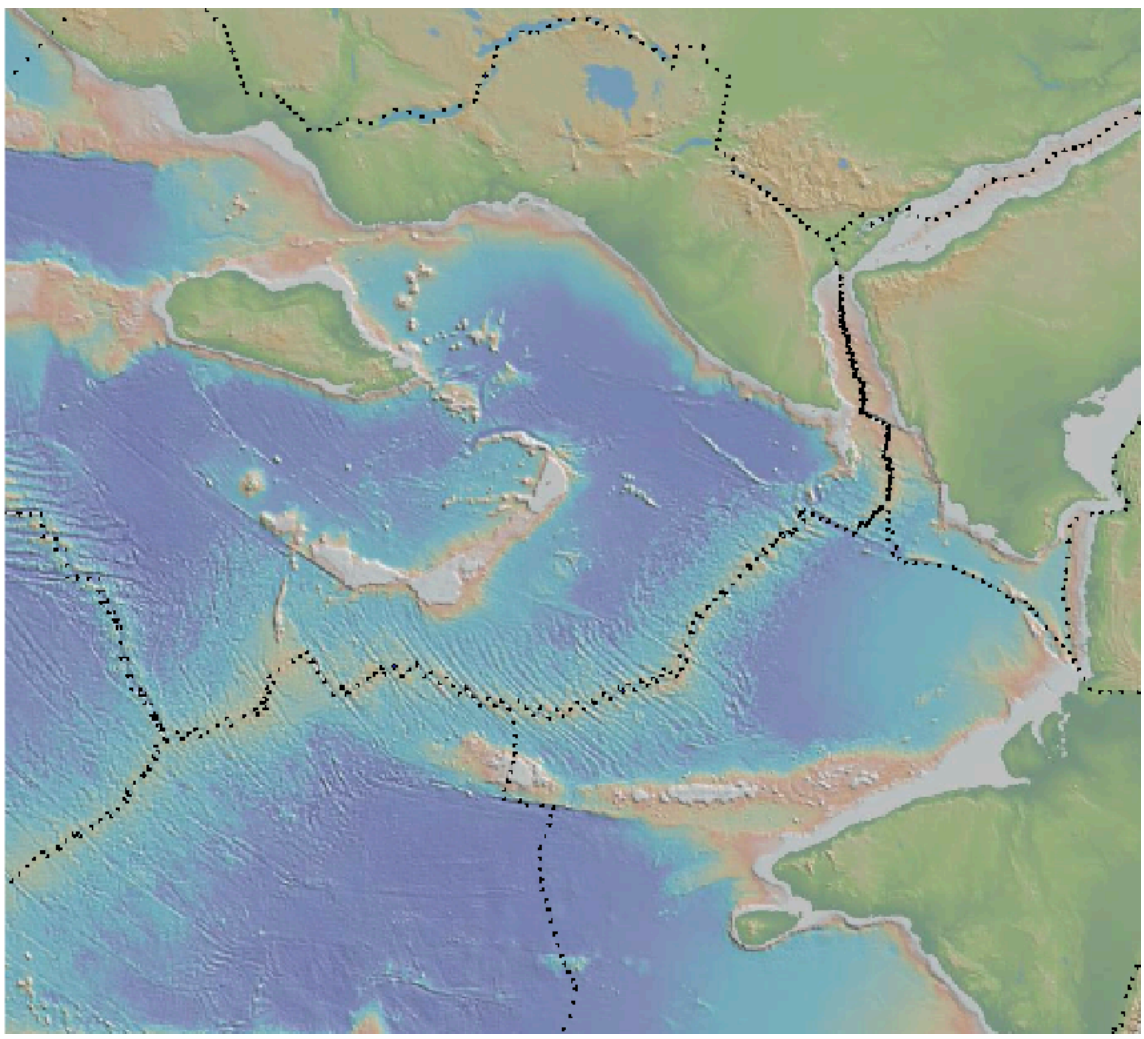
Tharp and Heezen opted for physiographic diagrams instead of maps to represent their bathymetric compilations. This representation may seem very outdated, yet given the scarcity of actual bathymetric soundings Tharp and Heezen had to work with, they are remarkably detailed and probably much more evocative than maps would have been.

As an illustration we show their 1957 physiographic diagram for the Azores region, and as a comparison, a 3D view (vertical exaggeration 8x) over the same region using the most recent global bathymetric mapping document: the 2019 GMRT grid. Tharp and Heezeen diagram resists this comparison remarkably well.

Note for example, the flat top shape of Meteor Seamount, the complex topography of Atlantis Seamount, and of course, the location and topography of the Mid-Atlantic Ridge.

1965 Heezen &Tharp, Tectonic fabric of the Atlantic and Indian oceans and continental drift

2019 GMRT grid Version 3.7 with plate boundaries *by Bird, 2003 An updated digital model of plate boundaries, Geoch, Geol Geosystems, 10.1029/2001GC000252*



Comments for slide 4

Tharp and Heezen achieved a tremendous task mapping the seafloor in the Indian Ocean. In this sketch you see their 1965 interpretation of plate drift in the Northweastern part of this ocean, compared with the 2019 GMRT grid with Bird (2003) plate boundaries. The ridges are there, and properly identified as accommodating divergence. The proposed movements (small white arrows next to the ridges and large black arrows on continents) are quite accurate (they assumed ridge-perpendicular displacement which works well for most ridges in the area except the Southwest Indian).

An amazing thing for us looking at their work 55 years later is why, having identified mid-ocean ridges as places of plate divergence, they did not immediately adopt the Plate Tectonics theory. An element of answer may be found in this same 1965 paper. The emerging plate tectonics theory did at that time emphasize mantle convection as THE cause of plate motion. As a result it predicted that each ridge should correspond with the upwelling limb of a mantle-scale convection.... and this did not fit with the distribution of mid-ocean ridges in regions as tectonically complex as the Indian Ocean.