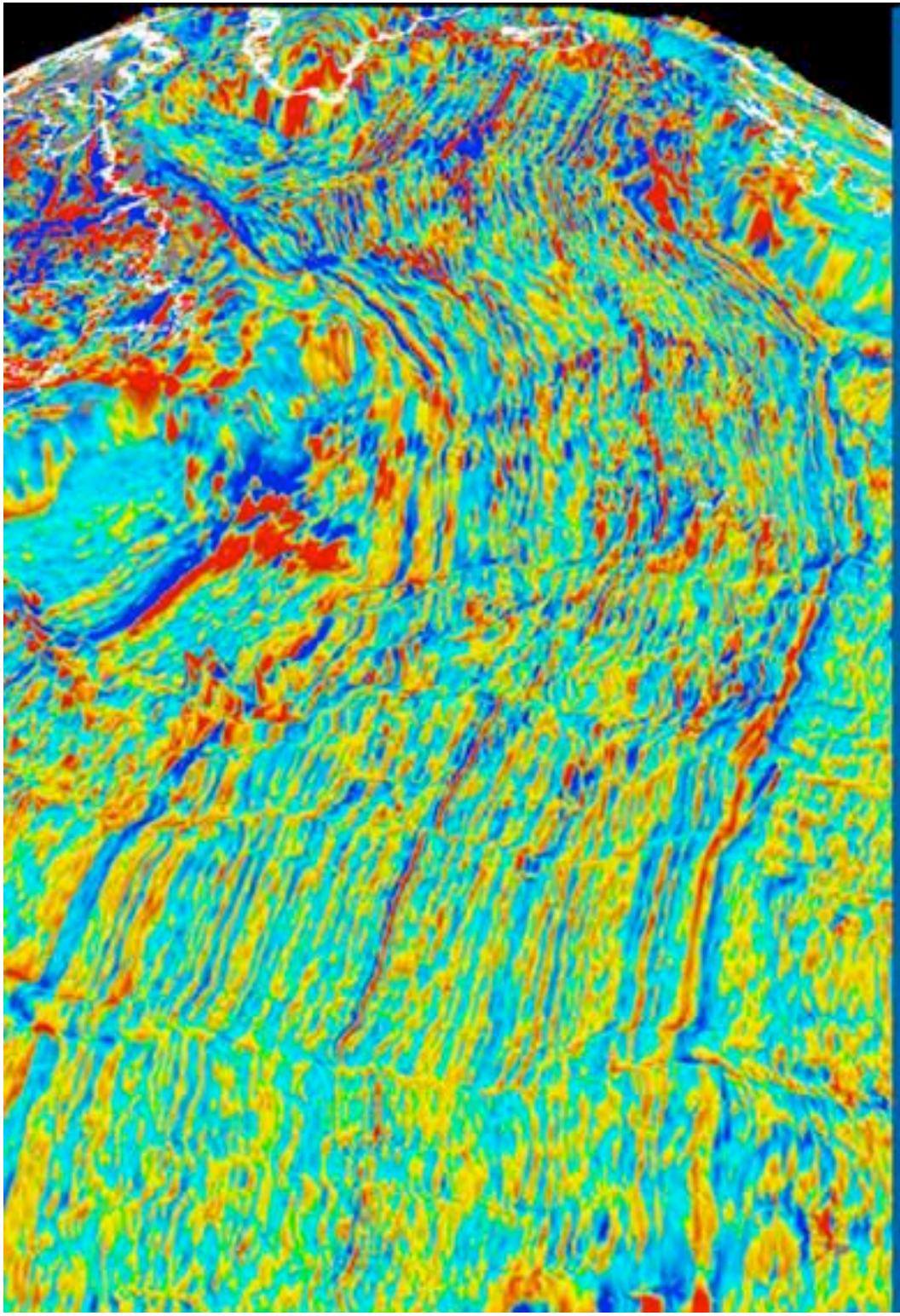


COLLÈGE DE FRANCE
1530

CNEXO and Ifremer: over fifty years of worldwide marine scientific research and exploration of the French EEZ

Walter Roest
Ifremer, France

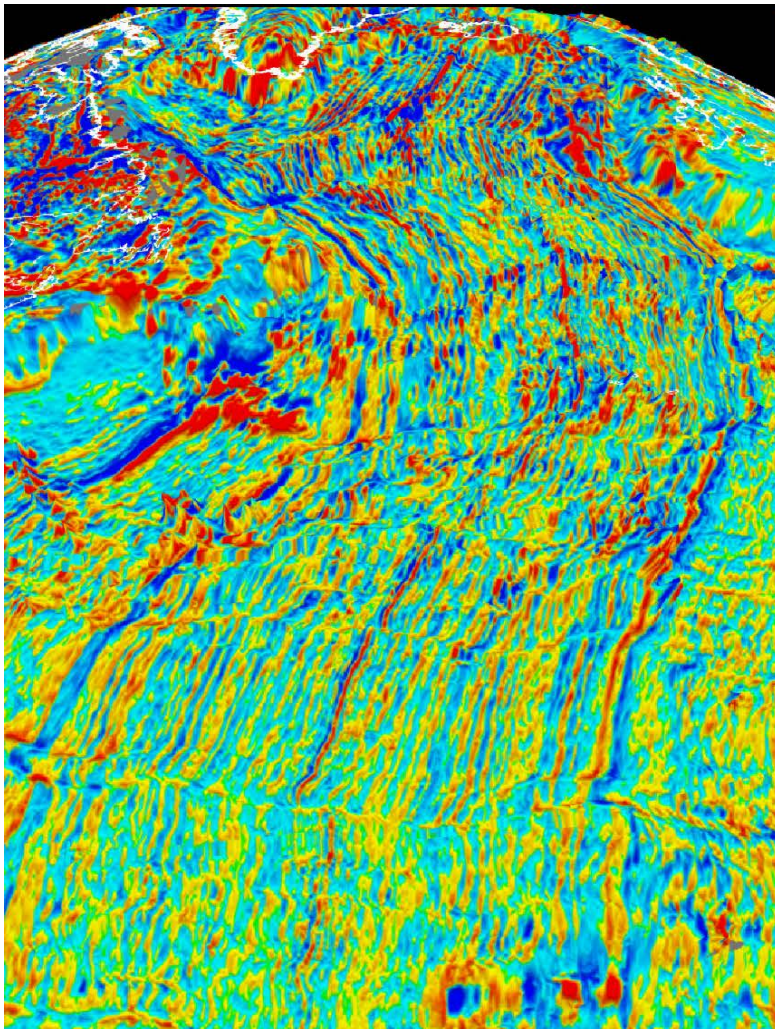
50 Years of Plate Tectonics: Then, Now, and Beyond
Paris, 5 – 26 June 2018

When I started my research career in 1959, we did not even know about the mid-ocean ridge, the largest structure on our planet, 60,000 kilometers long. […] It was the ***exploration of the oceans*** *that led to the development of plate tectonics in the 1960s, offering for the first time* ***a coherent quantitative model*** *of the evolution of our planet. Paradoxically, this model, still very schematic,* ***relied on entirely oceanic data***

Citation: X. Le Pichon, date ?

CNEXO and Ifremer

- Early days
- Plate Tectonics: from the global scale to in situ observations
- Science and technology for exploration of the ocean
- Law of the sea and the continental shelf
- Conclusion



JOURNAL OF GEOPHYSICAL RESEARCH VOL. 73, NO. 12, JUNE 15, 1968

Sea-Floor Spreading and Continental Drift[1]

XAVIER LE PICHON[2]

Lamont Geological Observatory, Columbia University
Palisades, New York 10962

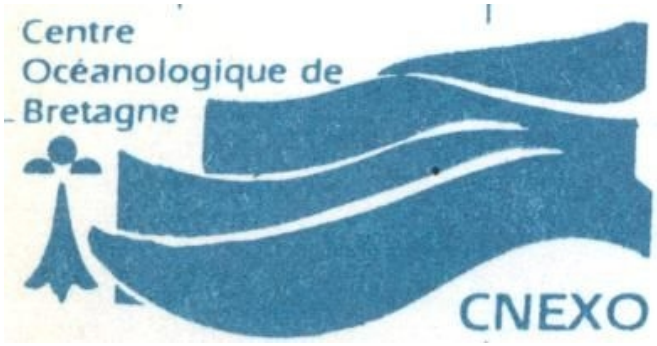
[1] Lamont Geological Observatory Contribution 1197.

[2] Now at CNEXO, 39 Avenue d'Iéna, Paris, 16, France.

CNEXO

Centre National pour l'EXploitation des Océans

- CNEXO was one of several research institutions created by law n ° 67-7 of January 3, 1967 by General de Gaulle and Georges Pompidou
- CNEXO was a public institution of industrial and commercial character
- The mission of the CNEXO was to develop knowledge of the oceans and research studies aimed at exploiting the resources contained on their surface, in their mass, their soil and their subsoil.



Oceanographic Vessel Jean Charcot

Launched in 1965 for Comexo (Oceans Exploitation Committee), which became CNEXO and then Ifremer

Creation of Ifremer Décret n°84-428, 5 juin 1984

The mission of Ifremer (merger of CNEXO and ISTPM) is to lead and promote fundamental and applied research, expertise and technological and industrial development actions in order to:

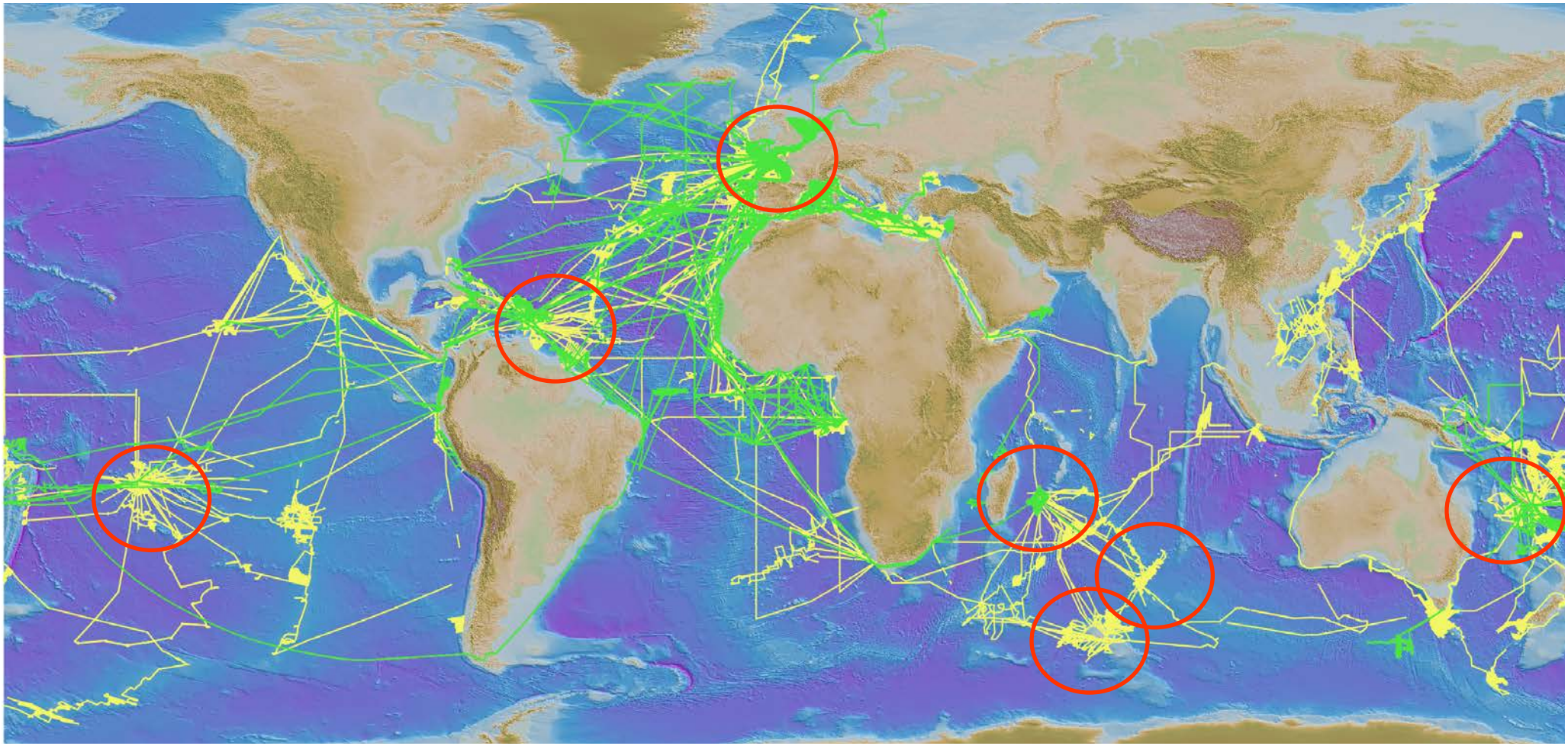
1 Understand, evaluate and develop the resources of the oceans and to allow their sustainable exploitation;

2 Improve the methods of monitoring, forecasting evolution, protection and enhancement of the marine and coastal environment;

3 Promote the socio-economic development of the maritime world.

Note: Marine Geosciences represents ~ 6% of human resources

CNEXO/Ifremer geoscience ship tracks



Crustal structure of the mid-ocean ridges

Journal of Geophysical Research 1965 - 1966

1. Seismic refraction measurements LE PICHON, HOUTZ, DRAKE and NAFE

2. Computed model from gravity and seismic refraction data TALWANI, LE PICHON and EWING

3. Magnetic anomalies over the mid-Atlantic ridge HEIRTZLER AND LE PICHON

4. Sediment distribution in the South Atlantic Ocean and the Cenozoic history of the Mid-Atlantic Ridge EWING, LE PICHON AND EWING

5. Heat flow through the Atlantic Ocean floor and convection currents LANGSETH, LE PICHON AND EWING

Crustal structure of the mid-ocean ridges

Journal of Geophysical Research 1965 - 1966

1. Seismic refraction measurements LE PICHON, HOUTZ, DRAKE and NAFE observations […] should be taken into account in any theory on the formation of the mid-ocean ridge
2. Computed model from gravity and seismic refraction data TALWANI, LE PICHON and EWING
3. Magnetic anomalies over the mid-Atlantic ridge HEIRTZLER AND LE PICHON
4. Sediment distribution in the South Atlantic Ocean and the Cenozoic history of the Mid-Atlantic Ridge EWING, LE PICHON AND EWING
5. Heat flow through the Atlantic Ocean floor and convection currents LANGSETH, LE PICHON AND EWING

Crustal structure of the mid-ocean ridges

Journal of Geophysical Research 1965 - 1966

1. Seismic refraction measurements LE PICHON, HOUTZ, DRAKE and NAFE

   observations […] should be taken into account in any theory on the formation of the mid-ocean ridge

2. Computed model from gravity and seismic refraction data TALWANI, LE PICHON and EWING

   the anomalous mantle, which provides compensation in the axial zone of the ridge, is postulated to extend to the flanks below the normal mantle observed

3. Magnetic anomalies over the mid-Atlantic ridge HEIRTZLER AND LE PICHON

4. Sediment distribution in the South Atlantic Ocean and the Cenozoic history of the Mid-Atlantic Ridge EWING, LE PICHON AND EWING

5. Heat flow through the Atlantic Ocean floor and convection currents LANGSETH, LE PICHON AND EWING

Crustal structure of the mid-ocean ridges

Journal of Geophysical Research 1965 - 1966

1. Seismic refraction measurements LE PICHON, HOUTZ, DRAKE and NAFE

   observations […] should be taken into account in any theory on the formation of the mid-ocean ridge

2. Computed model from gravity and seismic refraction data TALWANI, LE PICHON and EWING

   the anomalous mantle, which provides compensation in the axial zone of the ridge, is postulated to extend to the flanks below the normal mantle observed

3. Magnetic anomalies over the mid-Atlantic ridge HEIRTZLER AND LE PICHON

   The high heat flow belt has a detectable effect on the magnetic field.

4. Sediment distribution in the South Atlantic Ocean and the Cenozoic history of the Mid-Atlantic Ridge EWING, LE PICHON AND EWING

5. Heat flow through the Atlantic Ocean floor and convection currents LANGSETH, LE PICHON AND EWING

Crustal structure of the mid-ocean ridges

Journal of Geophysical Research 1965 - 1966

1. Seismic refraction measurements LE PICHON, HOUTZ, DRAKE and NAFE

   observations […] should be taken into account in any theory on the formation of the mid-ocean ridge

2. Computed model from gravity and seismic refraction data TALWANI, LE PICHON and EWING

   the anomalous mantle, which provides compensation in the axial zone of the ridge, is postulated to extend to the flanks below the normal mantle observed

3. Magnetic anomalies over the mid-Atlantic ridge HEIRTZLER AND LE PICHON

   The high heat flow belt has a detectable effect on the magnetic field.

4. Sediment distribution in the South Atlantic Ocean and the Cenozoic history of the Mid-Atlantic Ridge EWING, LE PICHON AND EWING

   […] late Cenozoic […] there is no reason to believe that significant continental drift or expansion occurred during this time

5. Heat flow through the Atlantic Ocean floor and convection currents LANGSETH, LE PICHON AND EWING

Crustal structure of the mid-ocean ridges

Journal of Geophysical Research 1965 - 1966

1. Seismic refraction measurements LE PICHON, HOUTZ, DRAKE and NAFE

   observations […] should be taken into account in any theory on the formation of the mid-ocean ridge

2. Computed model from gravity and seismic refraction data TALWANI, LE PICHON and EWING

   the anomalous mantle, which provides compensation in the axial zone of the ridge, is postulated to extend to the flanks below the normal mantle observed

3. Magnetic anomalies over the mid-Atlantic ridge HEIRTZLER AND LE PICHON

   The high heat flow belt has a detectable effect on the magnetic field.

4. Sediment distribution in the South Atlantic Ocean and the Cenozoic history of the Mid-Atlantic Ridge EWING, LE PICHON AND EWING

   […] late Cenozoic […] there is no reason to believe that significant continental drift or expansion occurred during this time

5. Heat flow through the Atlantic Ocean floor and convection currents LANGSETH, LE PICHON AND EWING

   absence of a wide heat-flow maximum […] precludes the possibility of continuous continental drift during the Cenozoic by the spreading-floor mechanism in the Atlantic

JOURNAL OF GEOPHYSICAL RESEARCH VOL. 73, NO. 12, JUNE 15, 1968

Sea-Floor Spreading and Continental Drift[1]

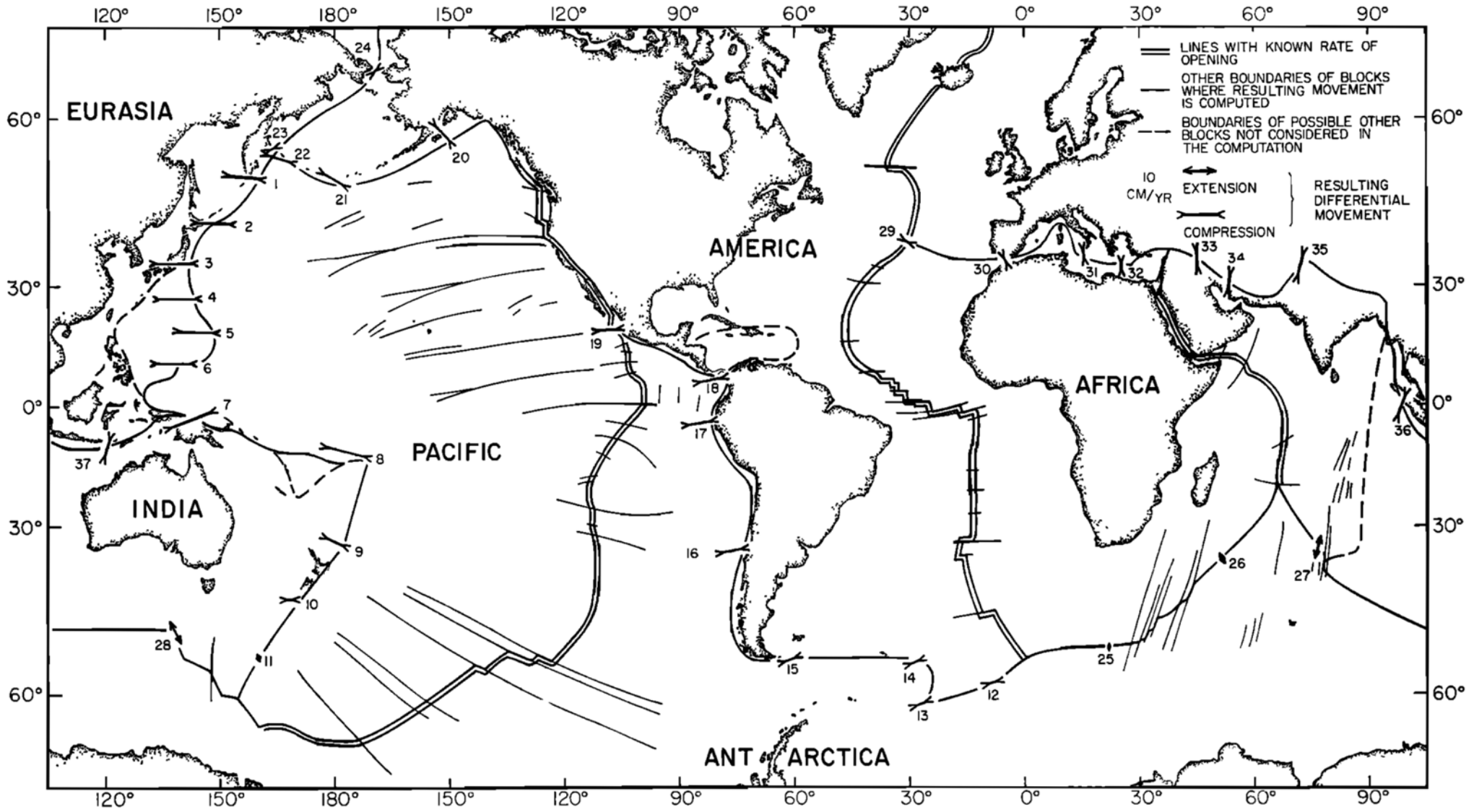
XAVIER LE PICHON[2]

~ 30 spreading rate determinations from magnetic anomalies

~ 60 spreading azimuths from fracture zones

Best fit model for 6 rigid plates

Sea-floor spreading and continental drift



Le Pichon, JGR, 1968

Plate Tectonics

- A coherent quantitative model of the evolution of our planet
- Tectonic plates include continents and oceans
- Ability to make predictions and test hypothesis
- Largely beyond geology
  - Hazards
  - Paleo circulation
  - Paleo climate
  - Marine biology
  - Natural resources

Expansion of the French Fleet

- In 1965, *Coriolis* for the Pacific Ocean, then in 1966 *Pélagi*a to support coastal research.
- In 1968 *Capricorn* began work in the tropical Atlantic, then the *Cryos* to support the fishing effort in the mouth of the St. Lawrence and off Newfoundland.
- In 1971, the first multipurpose vessel was commissioned, *Le Noroît*, and four years later *Le Suroît* was built to facilitate exploration surveys with light submersibles.
- Finally in 1974, the *Nadir* was launched to support heavier gear, such as the Archimedes bathyscaphe or the Cyana manned submersible.

Exploring the oceans

NESTLANTE II, Jean CHARCOT, 1970

Most of the program has been carried out in the deep sea area and in the Barents Sea despite serious technical difficulties and sometimes difficult conditions.

The buoy test last night was disastrous.

The airgun, which had been made to work for 3 hours, died again. A leak in the chamber. We will take it apart again today.

The magnetometer is still broken.

The results obtained with the buoys in particular are clearly superior to those of Lamont and should allow a fairly clear structural interpretation.

Chief Scientist, Le Pichon

Exploring the oceans

CYANHEAT, Nadir, 1979

© Ifremer

© Ifremer - Vic CHAPRON

FAMOUS

- In 1971, Xavier Le Pichon, head of the Scientific Department, COB, CNEXO wrote a letter to Woods Hole geologist Ken Emery and proposed a joint U.S.-French expedition to explore the axis of the Mid-Atlantic Ridge using manned submersibles (two years after Apollo 11)
- France had the 200-ton bathyscaphe *Archimède* operated by the Navy and was building a smaller submersible called *Cyana*. The U.S. had the Navy-owned, 15-ton *Alvin*, developed by engineers at Woods Hole
- After significant resistance, operations started in 1973

Source: WHOI, 2017

FAMOUS

Xavier Le Pichon with Claude Riffaud, Director of the COB, in front of the world ocean floor map

© CNEXO/Ifremer

- French-American Mid-Ocean Undersea Study
- Intense investigation of the Mid-Atlantic Ridge between 36° and 37° N
- Chief Scientists: Jim Heirtzler and Xavier Le Pichon
- Search for evidence of hydrothermal vents

FAMOUS

Archimède and *Cyana* completed 27 dives, *Alvin* 17, collecting 100,000 photos and 1500 kg of rock samples

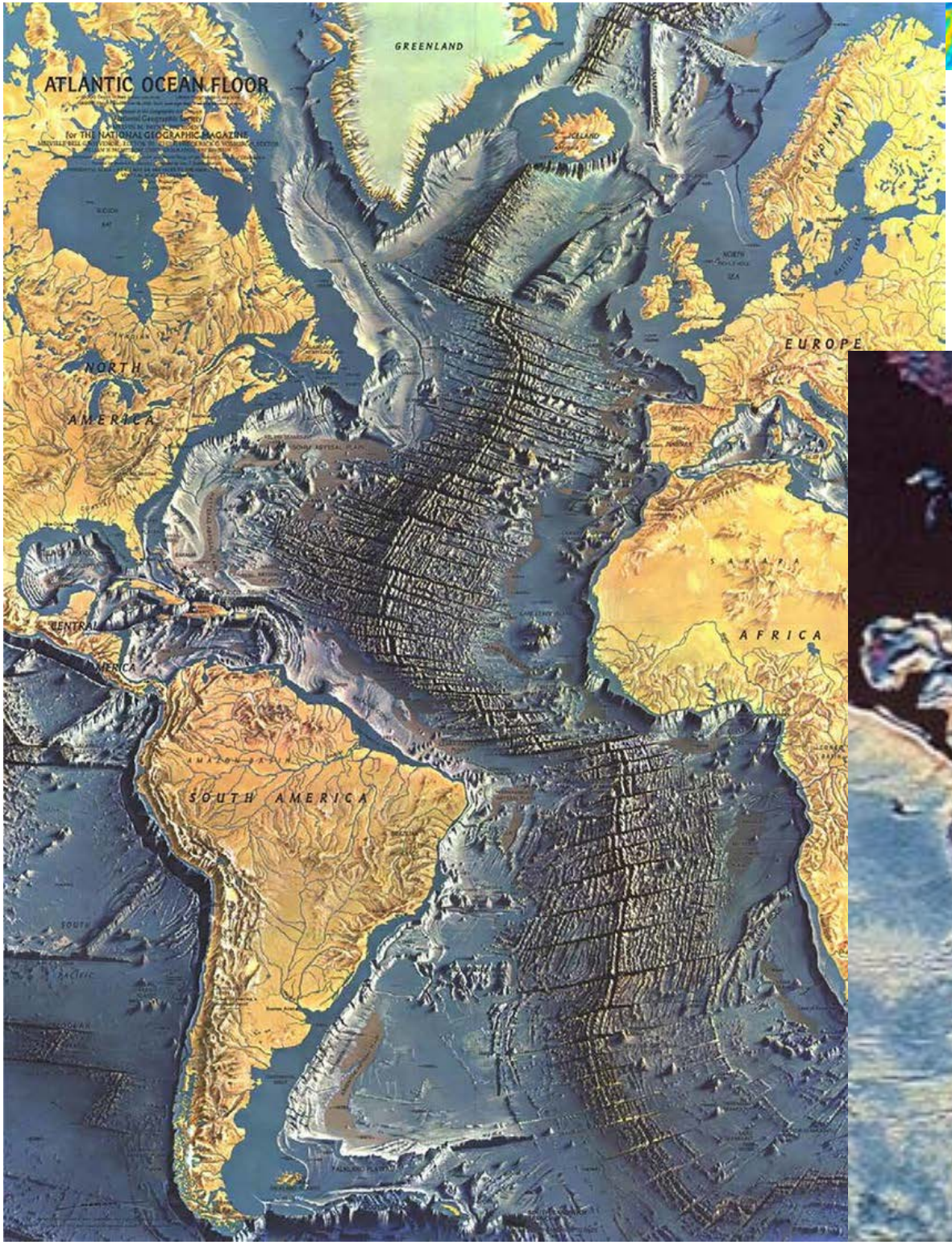
Le Noroît and *Cyana* at night in the harbor, Ponta Delgada, Açores, 1974 *© Ifremer - Alain MASSOL*

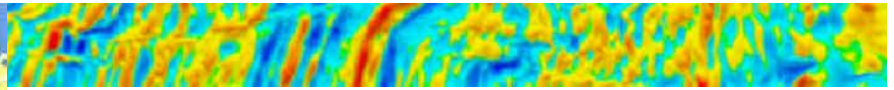
© Ifremer

Atlantic Ocean floor

A map of the ocean floor, published in 1968 based on deep ocean soundings compiled and interpreted by Bruce Heezen and Marie Tharp, Lamont

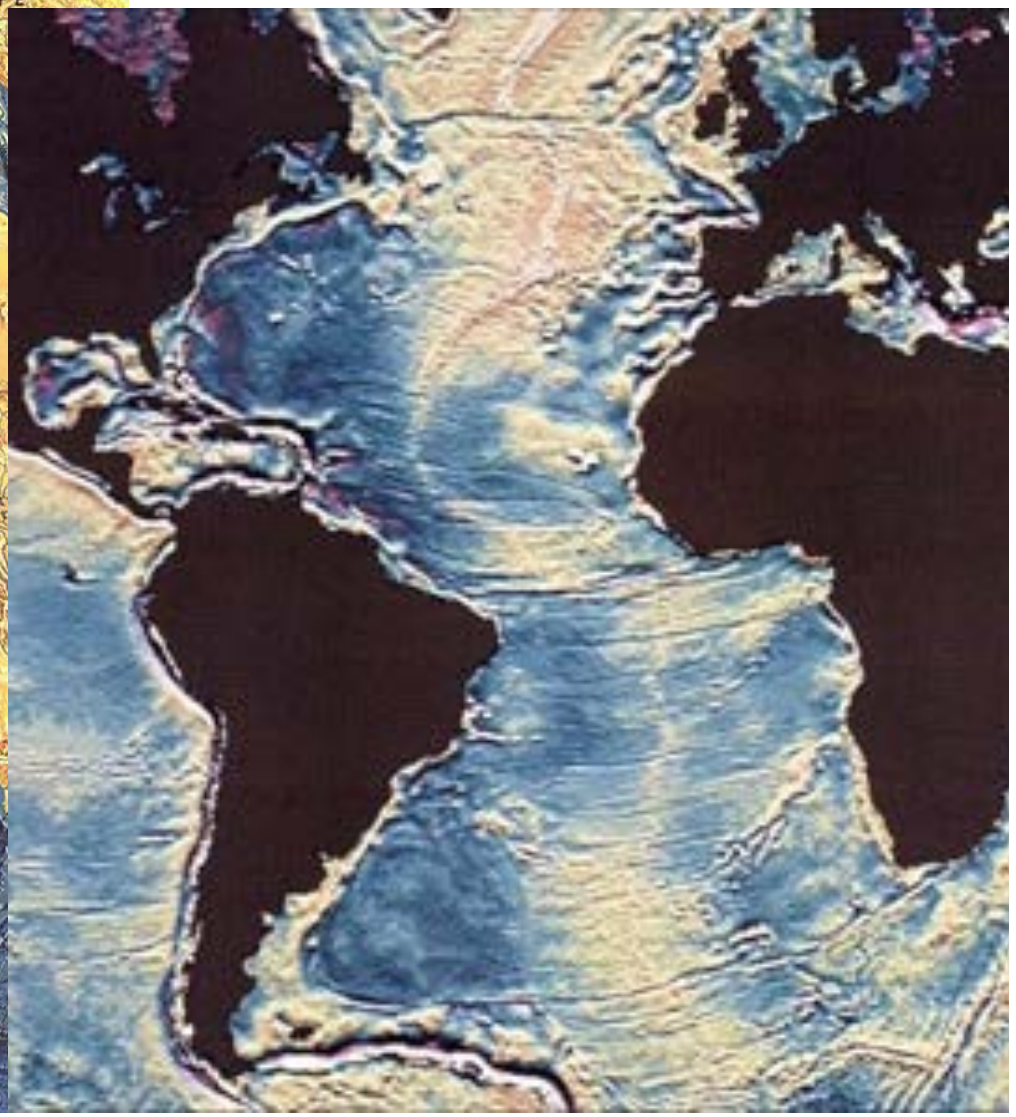
Painted by Berann for National Geographic Magazine





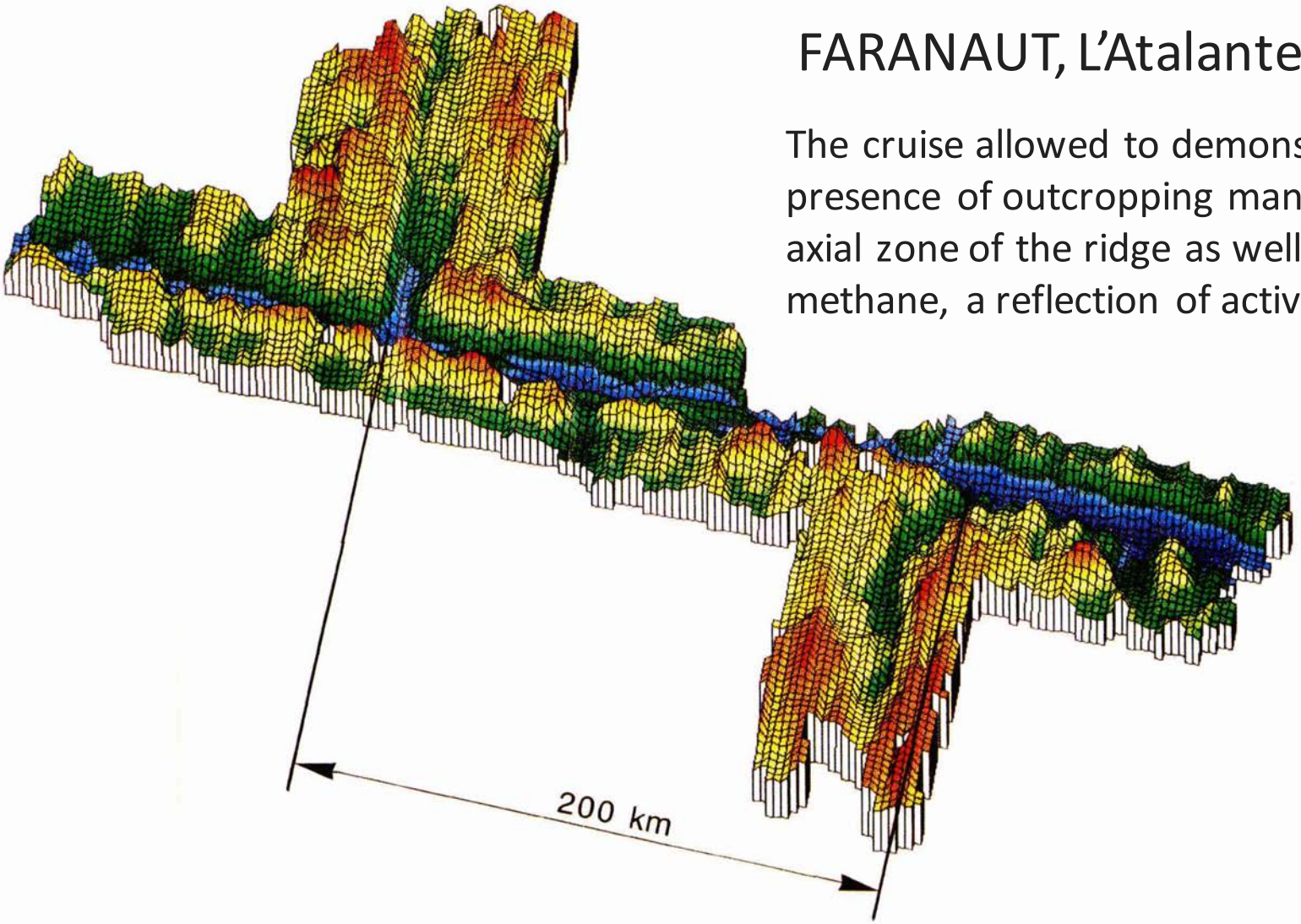
Gravity from Space: Radar Altimetry

William F. Haxby,
Lamont-Doherty Geological Observatory
National Geographic, 1983



FARANAUT, L'Atalante 1992

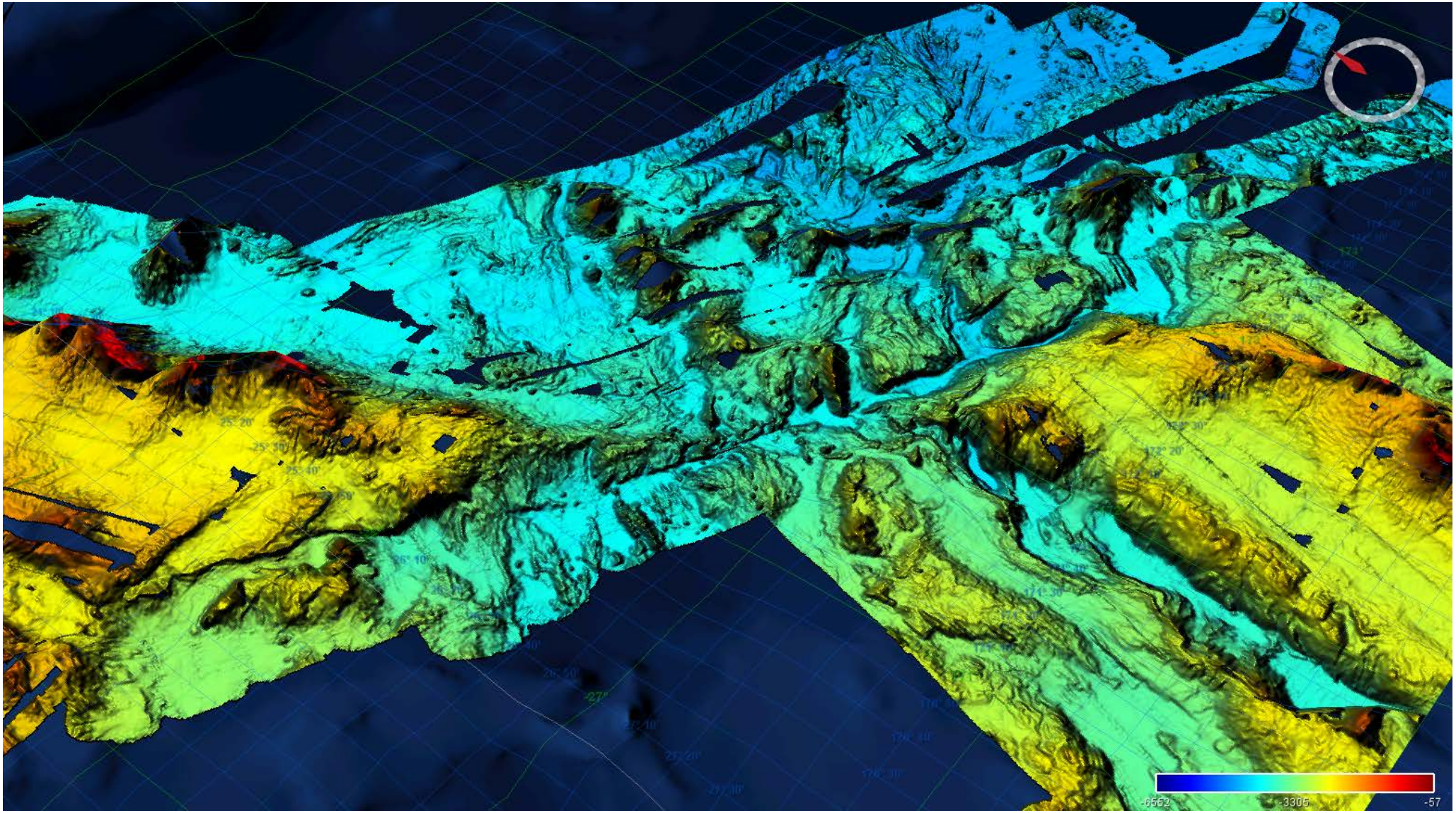
The cruise allowed to demonstrate the presence of outcropping mantle rocks in the axial zone of the ridge as well as the release of methane, a reflection of active processes



Complete map of the 15°20' N fracture zone and the intersections with the mid-Atlantic ridge axis (SIMRAD EM 12 multibeam sounder)

Annual report Ifremer 1992

Cook FZ, Zelandia, 2005



2012

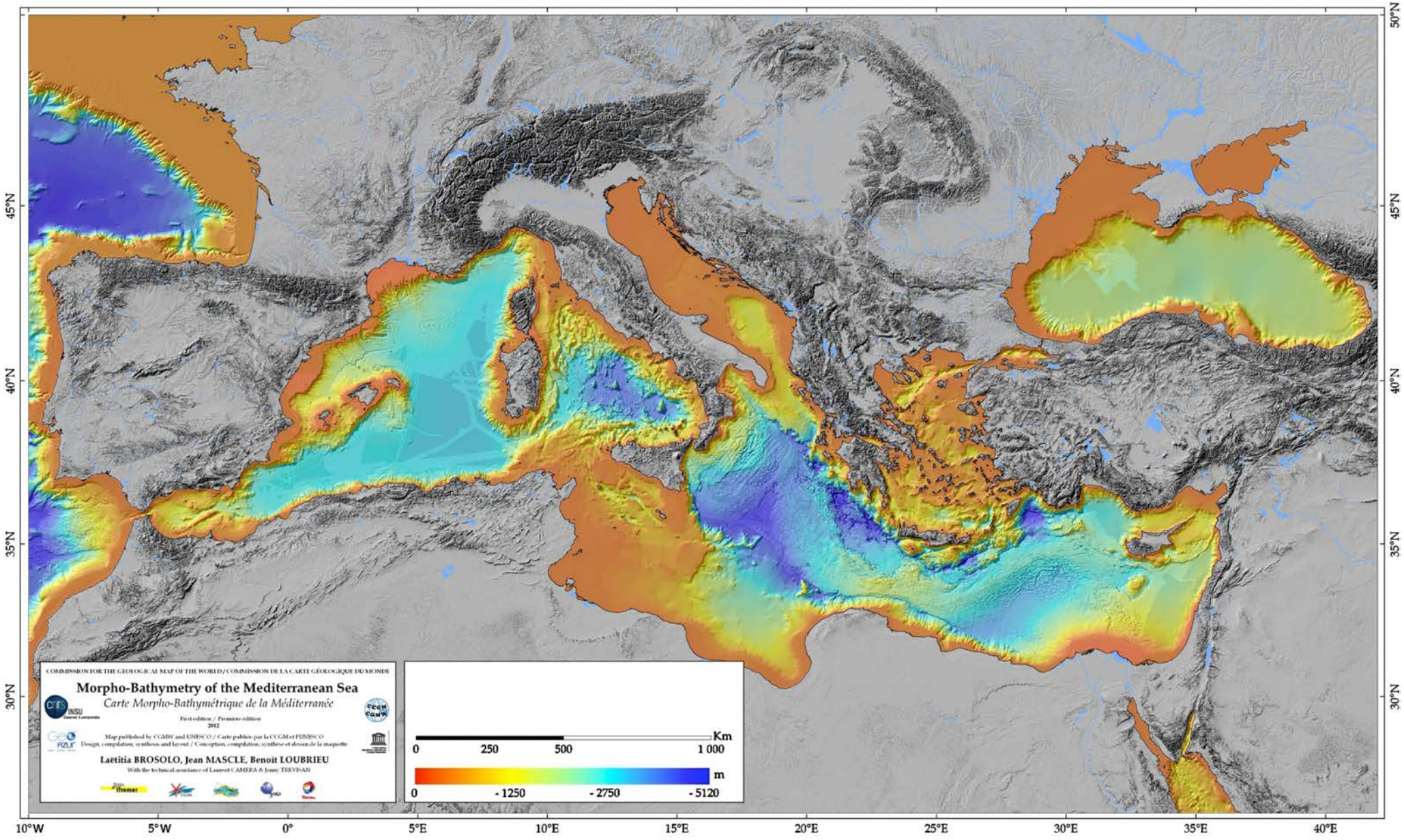
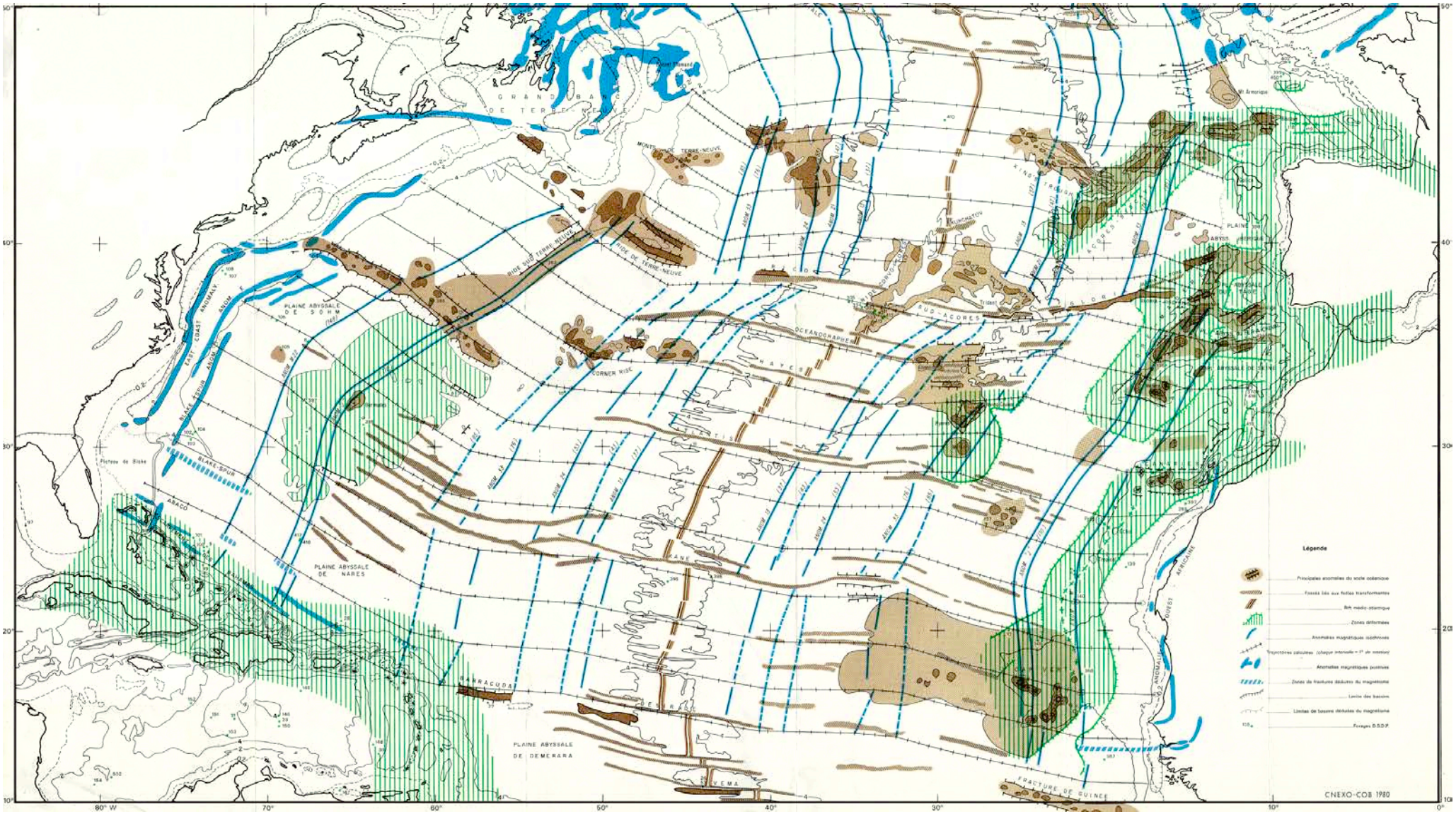
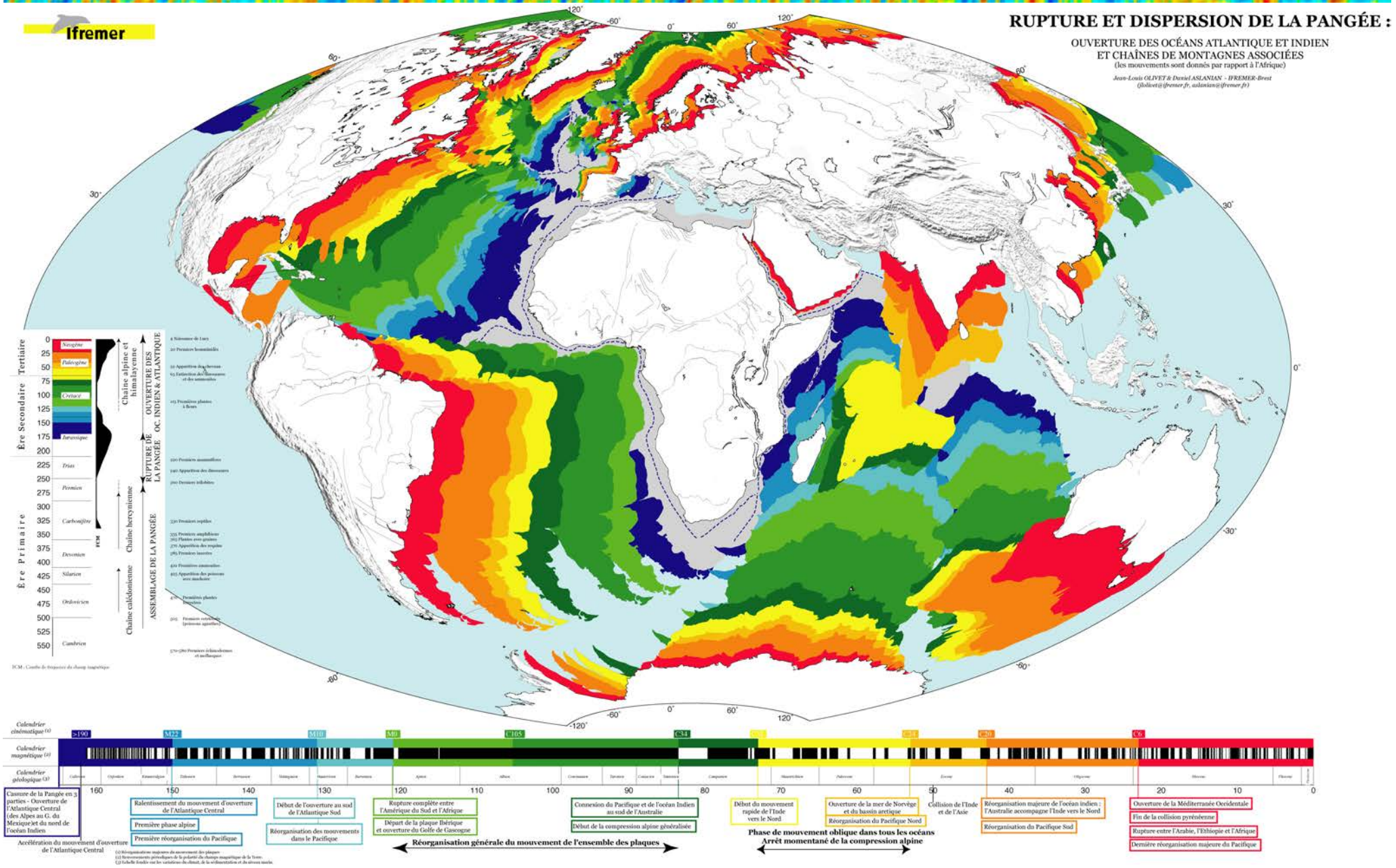

COMMISSION FOR THE GEOLOGICAL MAP OF THE WORLD / COMMISSION DE LA CARTE GÉOLOGIQUE DU MONDE
Morpho-Bathymetry of the Mediterranean Sea
Carte Morpho-Bathymétrique de la Méditerranée
First edition / Première édition
2012
Map published by CGMW and UNESCO / Carte publiée par la CCGM et l'UNESCO
Design, compilation, synthesis and layout / Conception, compilation, synthèse et dessin de la maquette
Laëtitia BROSOLO, Jean MASCLE, Benoit LOUBRIEU
With the technical assistance of Laurent CAMERA & Jenny TREVISAN
Km
0
250
500
1 000
m
0
- 1250
- 2750
- 5120
50°N
45°N
40°N
35°N
30°N
10°W
5°W
0°
5°E
10°E
15°E
20°E
25°E
30°E
35°E
40°E

Plate kinematics of North and Central Atlantic

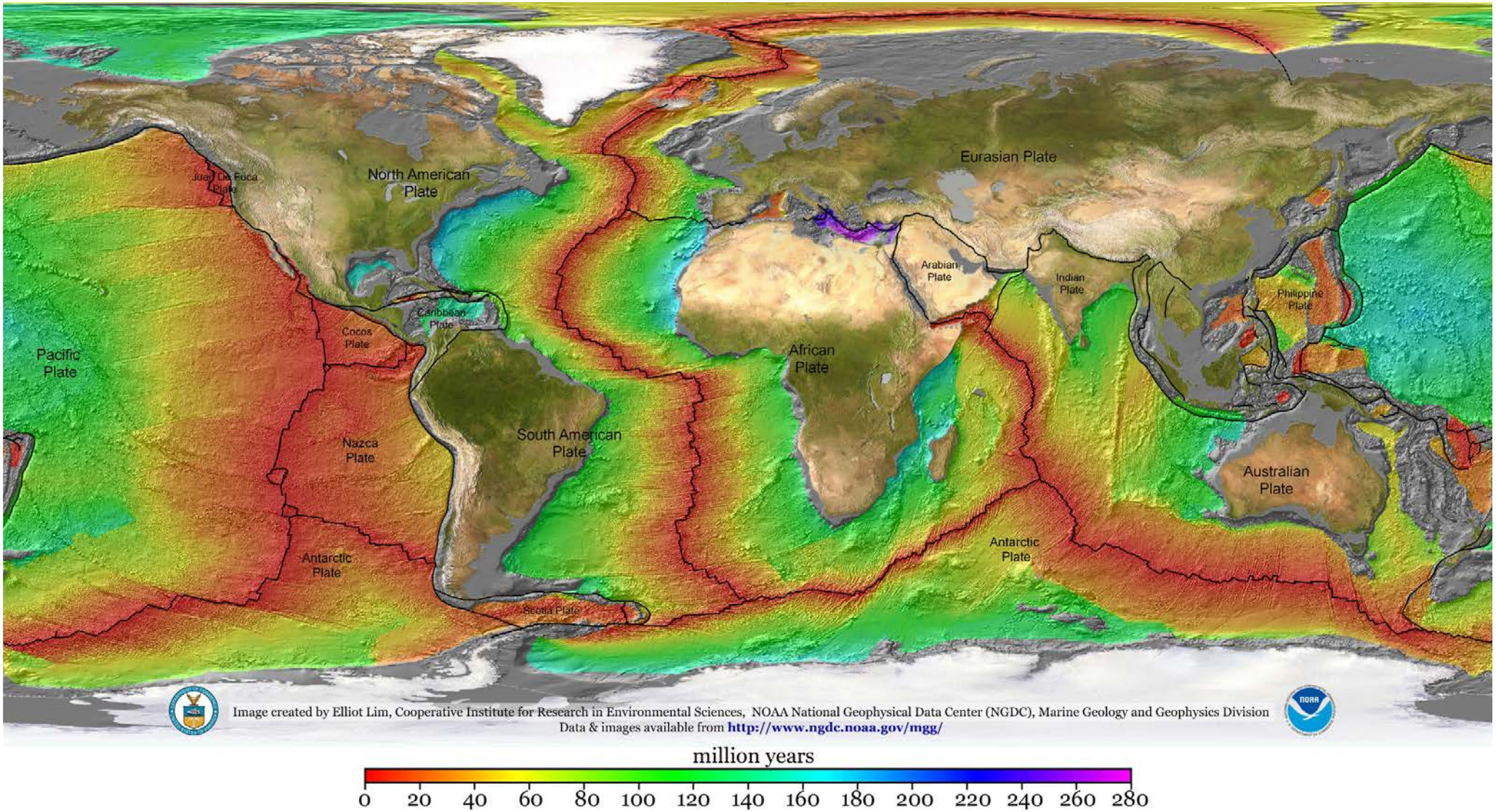


Olivet, 1984



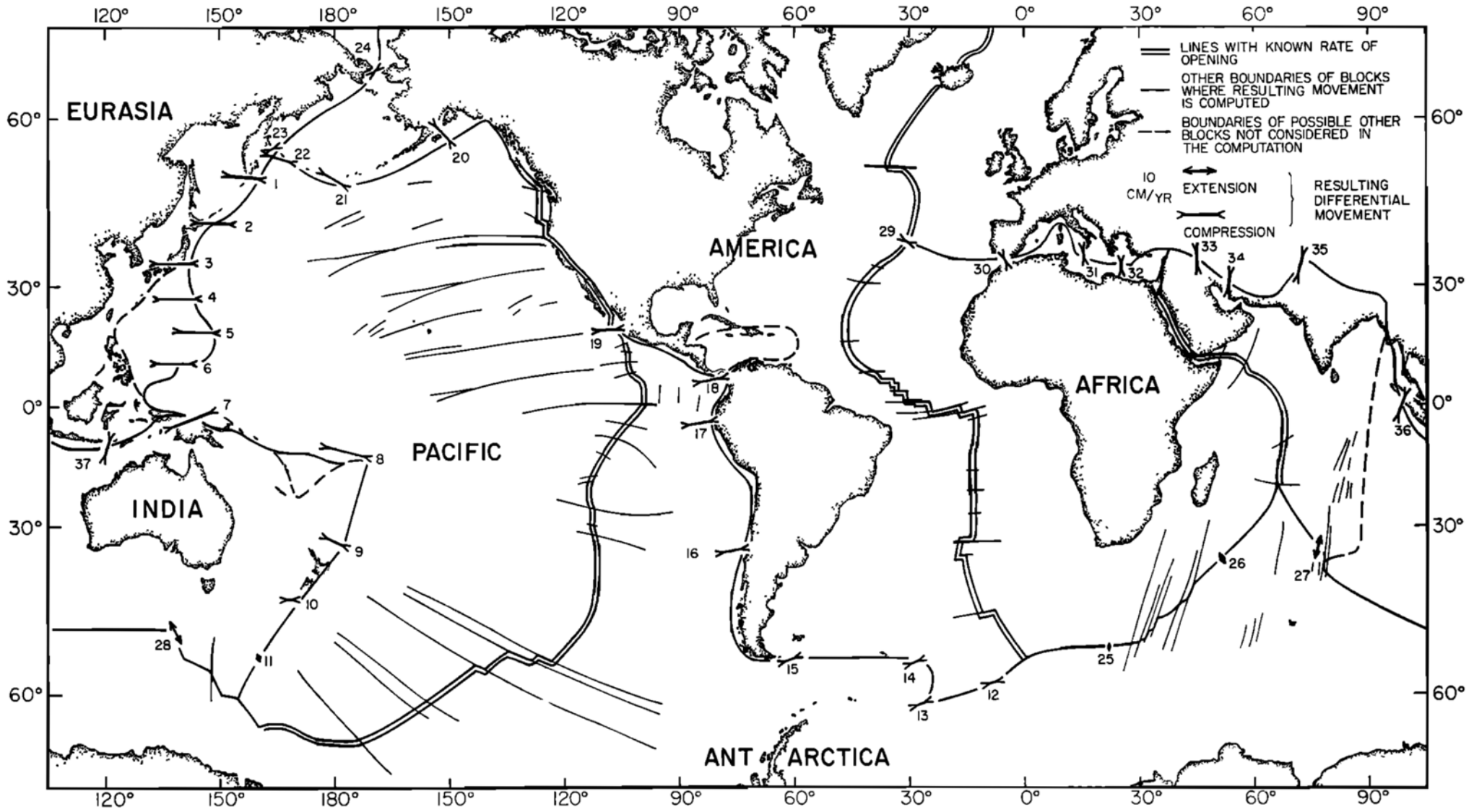
Olivet and Aslanian, 2000

Age of the Oceanic Lithosphere



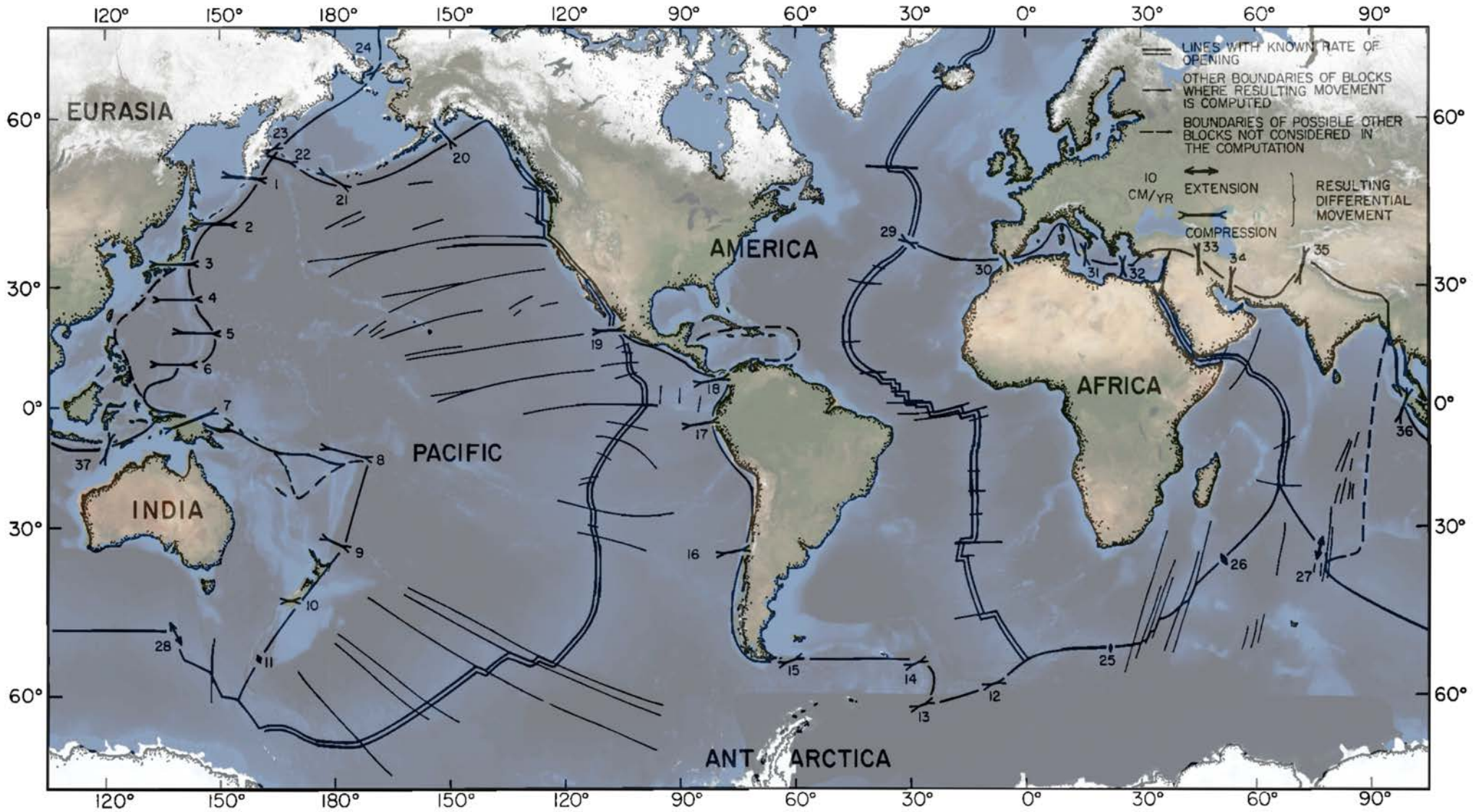
Courtesy NOAA, after Müller et al., 2008

Sea-floor spreading and continental drift

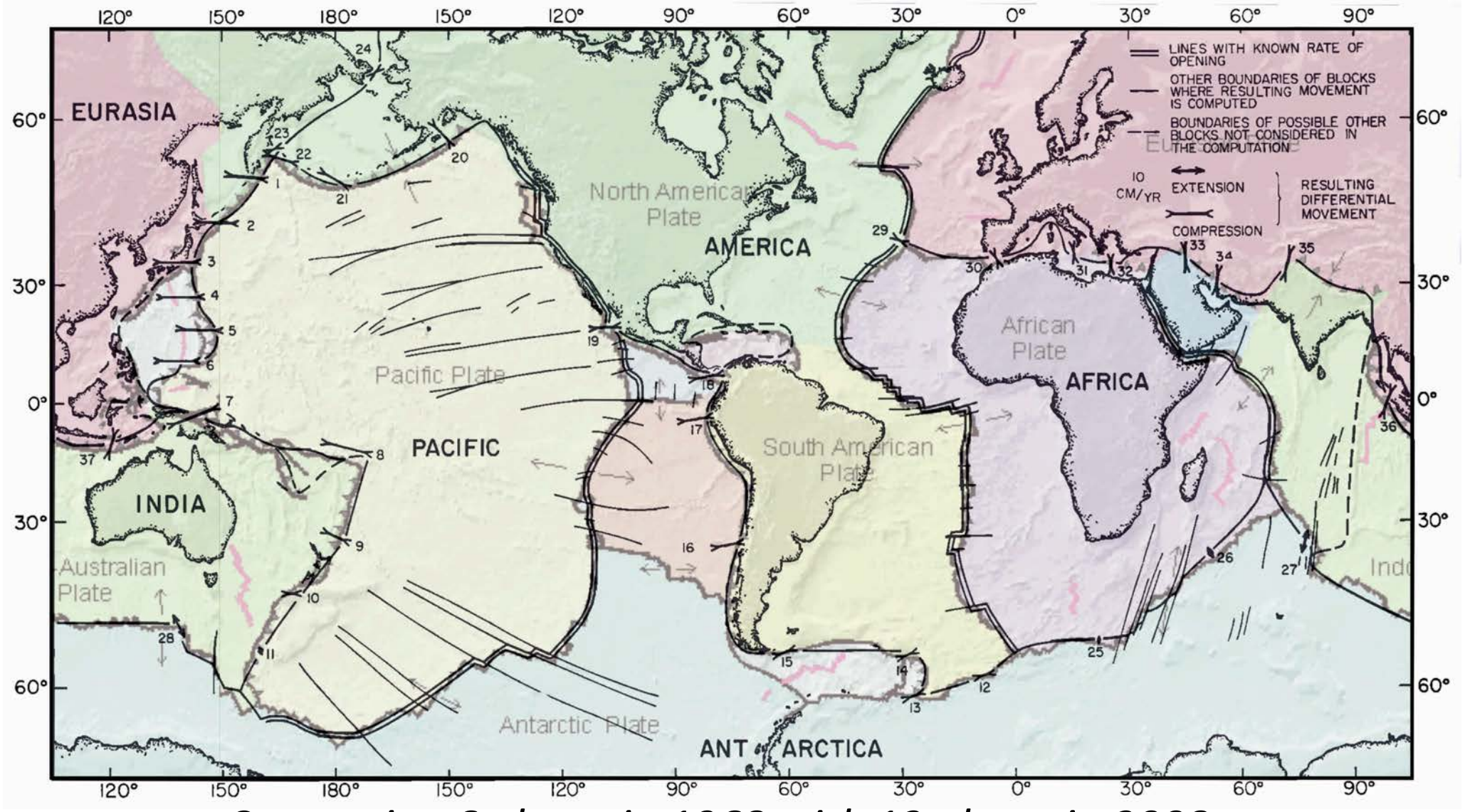


Le Pichon, JGR, 1968

Google


LINES WITH KNOWN RATE OF OPENING
OTHER BOUNDARIES OF BLOCKS WHERE RESULTING MOVEMENT IS COMPUTED
BOUNDARIES OF POSSIBLE OTHER BLOCKS NOT CONSIDERED IN THE COMPUTATION
10 CM/YR
EXTENSION
COMPRESSION
RESULTING DIFFERENTIAL MOVEMENT
EURASIA
AMERICA
AFRICA
PACIFIC
INDIA
ANTARCTICA
120°
150°
180°
150°
120°
90°
60°
30°
0°
30°
60°
90°
60°
30°
0°
30°
60°

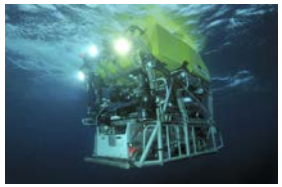
Tectonic Plates

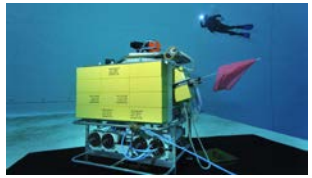


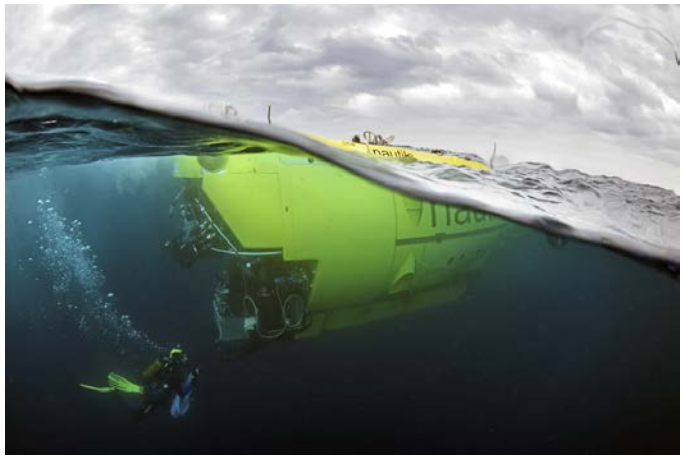
Comparing 6 plates in 1968 with 12 plates in 2008

Ifremer - Marine Geoscience Research

- understanding the geological evolution of the planet, of the mechanisms of formation of margins and of sedimentary transfer balances in relation to climat and tectonic variations;
- exploration dedicated to the understanding of geochemical cycles and the search for mineral resources;
- the study of marine geological hazards and the characterization of dynamic structures (active margins, seismicity, ..);
- participation in the technological developments necessary to undertake this research







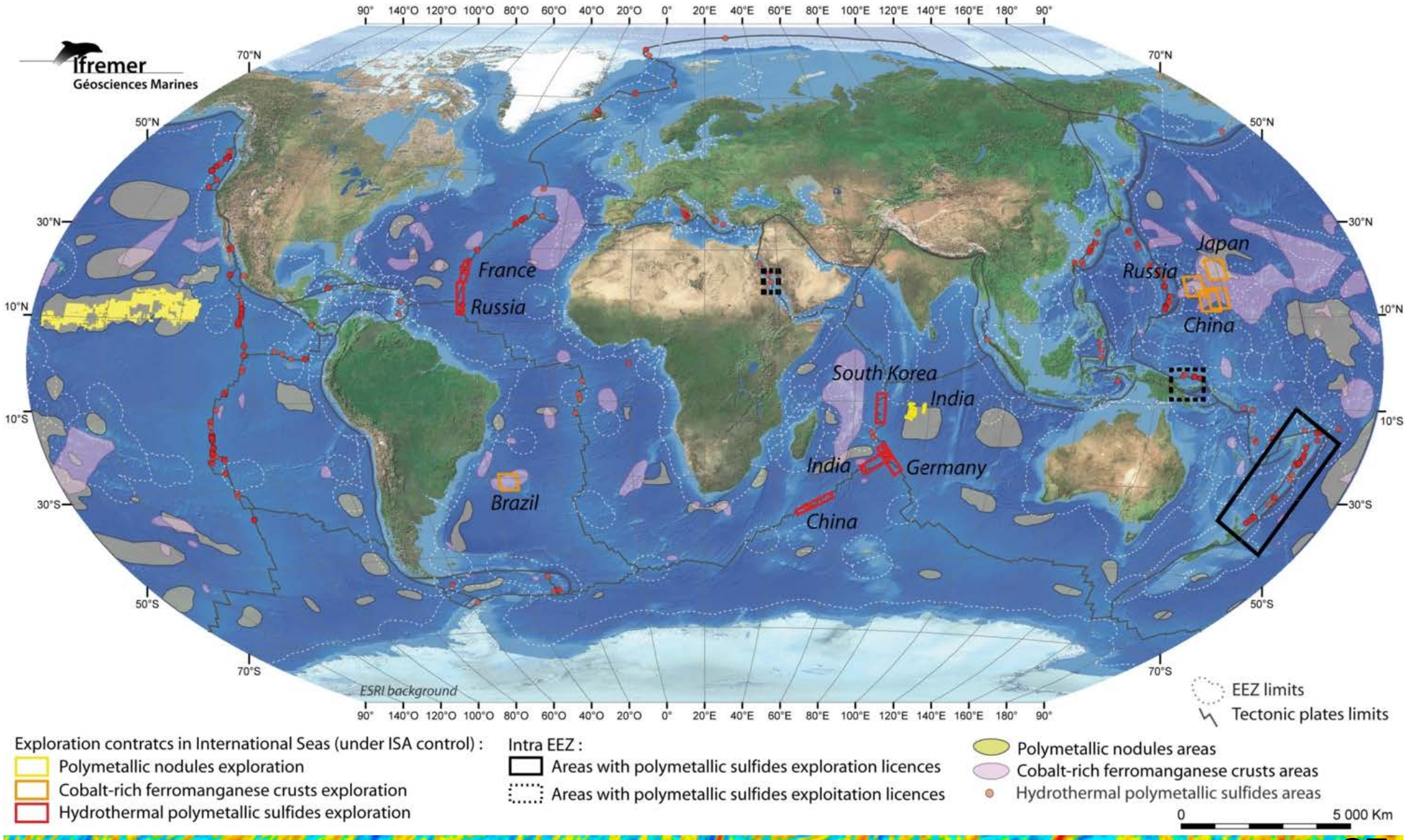
Technical Capabilities

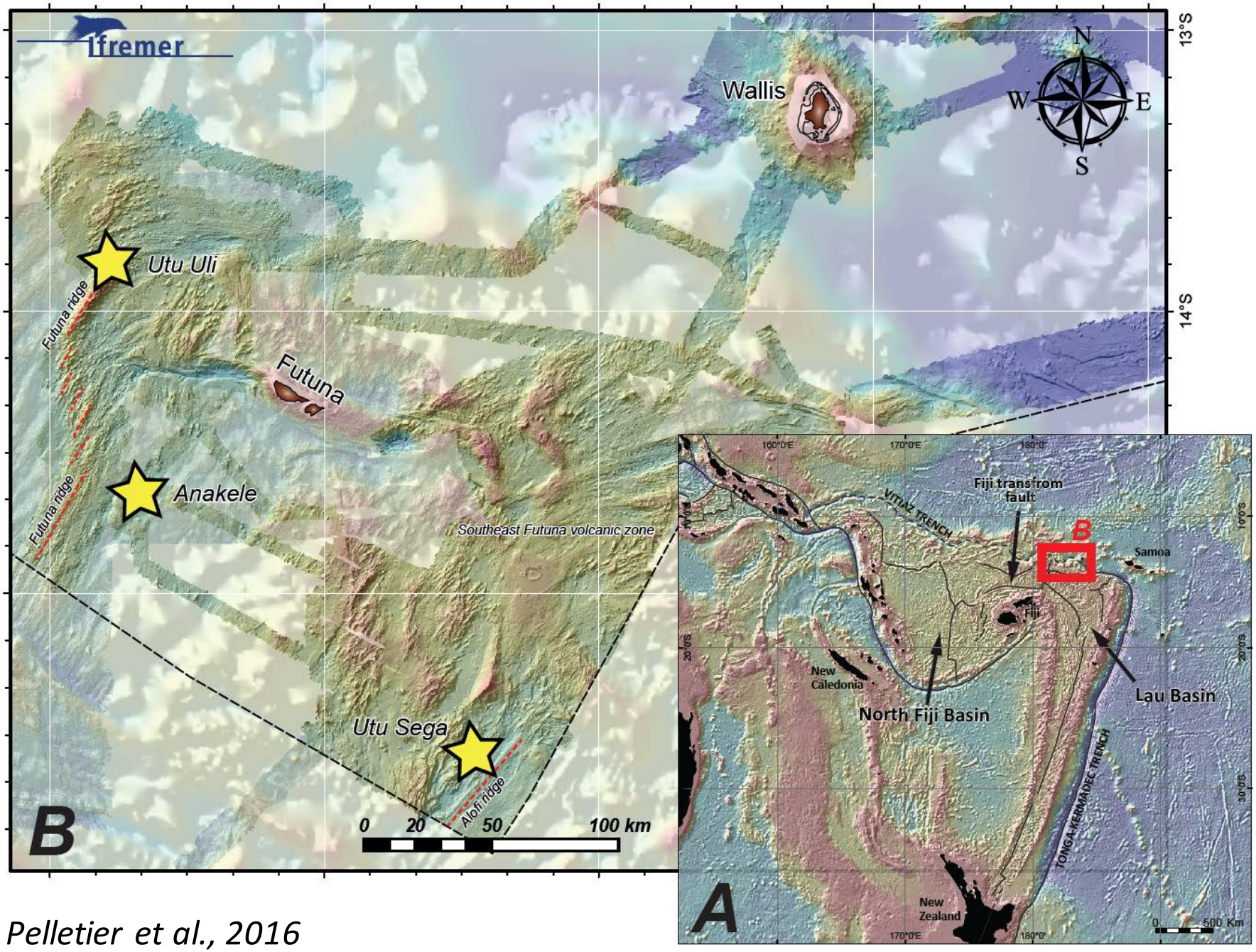
- The Ocean Spectrometry Pole, UBO (IUEM), CNRS and Ifremer
- Large pool of OBS
- Sediment core laboratory and storage facility
- Geotechnical probes and geotechnical laboratory, including gas hydrates research

Recent Activities:

- Marine Minerals (ISA and EEZ)
- UNCLOS continental shelf

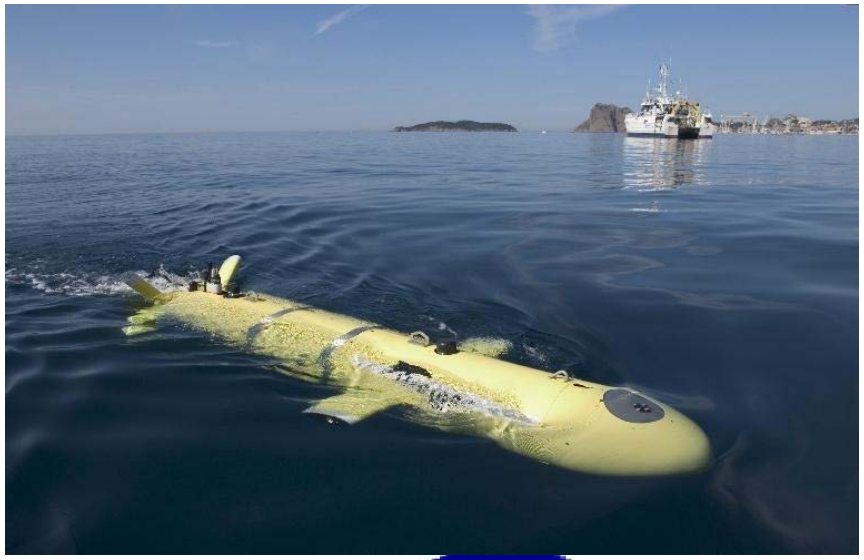
Minerals


Ifremer
Géosciences Marines
France
Russia
Brazil
South Korea
India
India
Germany
China
Russia
Japan
China
ESRI background
EEZ limits
Tectonic plates limits
Exploration contratcs in International Seas (under ISA control) :
Polymetallic nodules exploration
Cobalt-rich ferromanganese crusts exploration
Hydrothermal polymetallic sulfides exploration
Intra EEZ :
Areas with polymetallic sulfides exploration licences
Areas with polymetallic sulfides exploitation licences
Polymetallic nodules areas
Cobalt-rich ferromanganese crusts areas
Hydrothermal polymetallic sulfides areas
0
5 000 Km

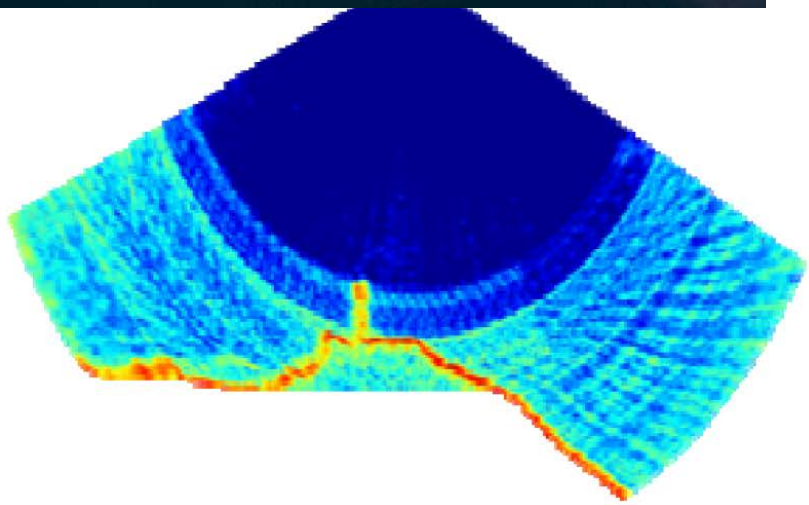


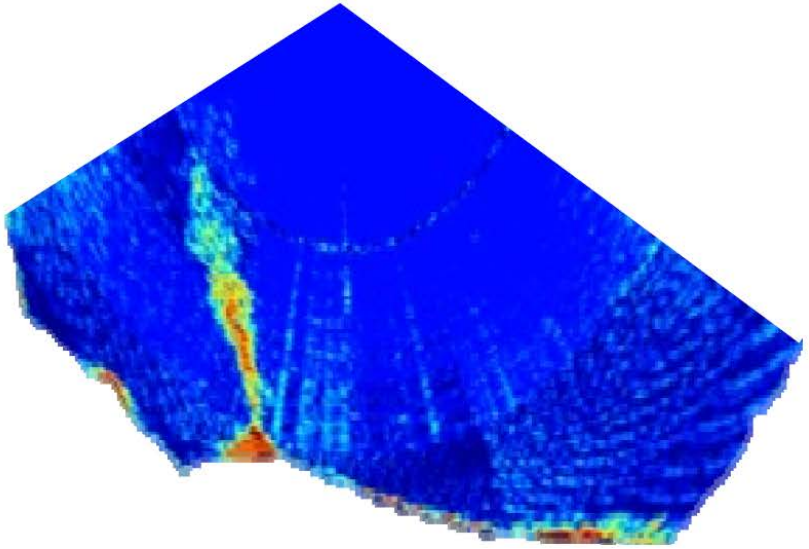
Pelletier et al., 2016

Hydrothermal Vents



© Campagne Serpentine 2007/Ifremer-VICTOR

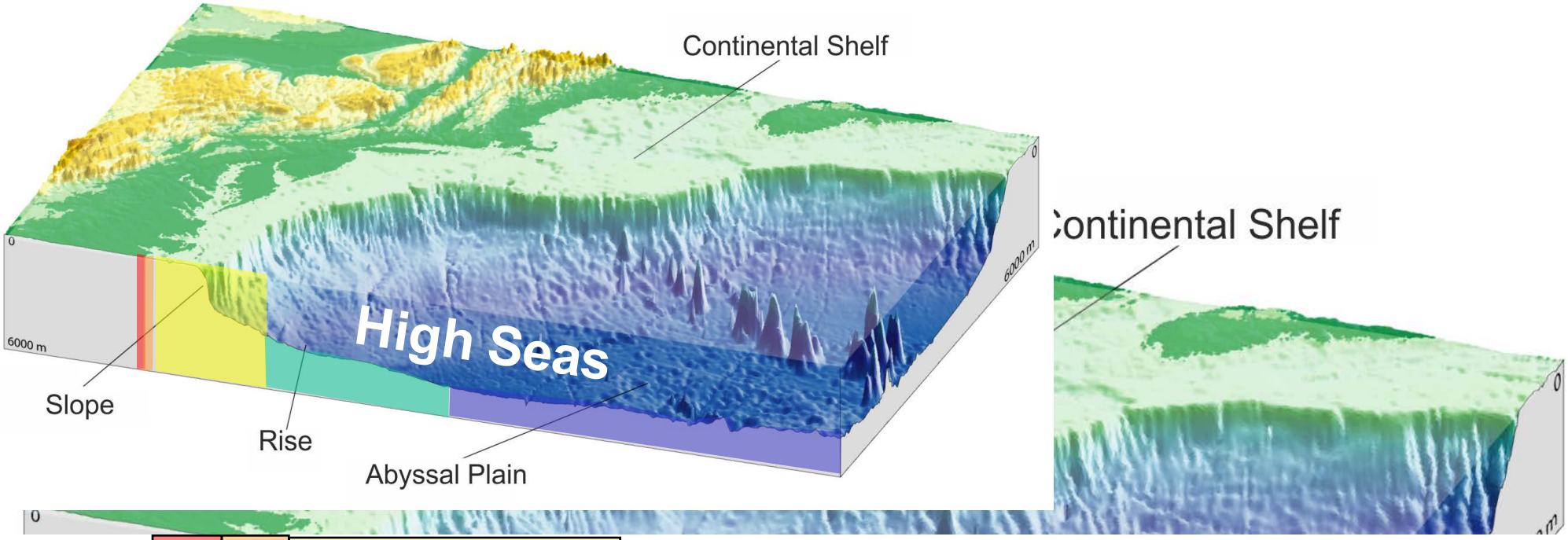


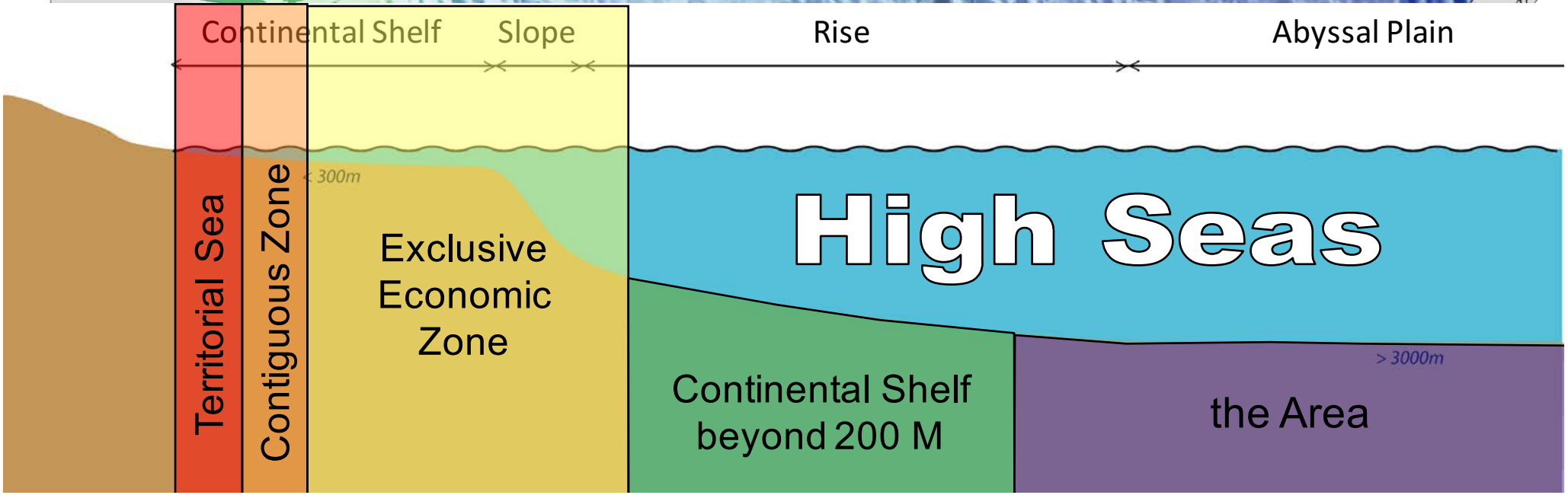


Polar echograms of EM2040 data: inactive chimney (left) and hydrothermal plume above active sulfide mound (right)

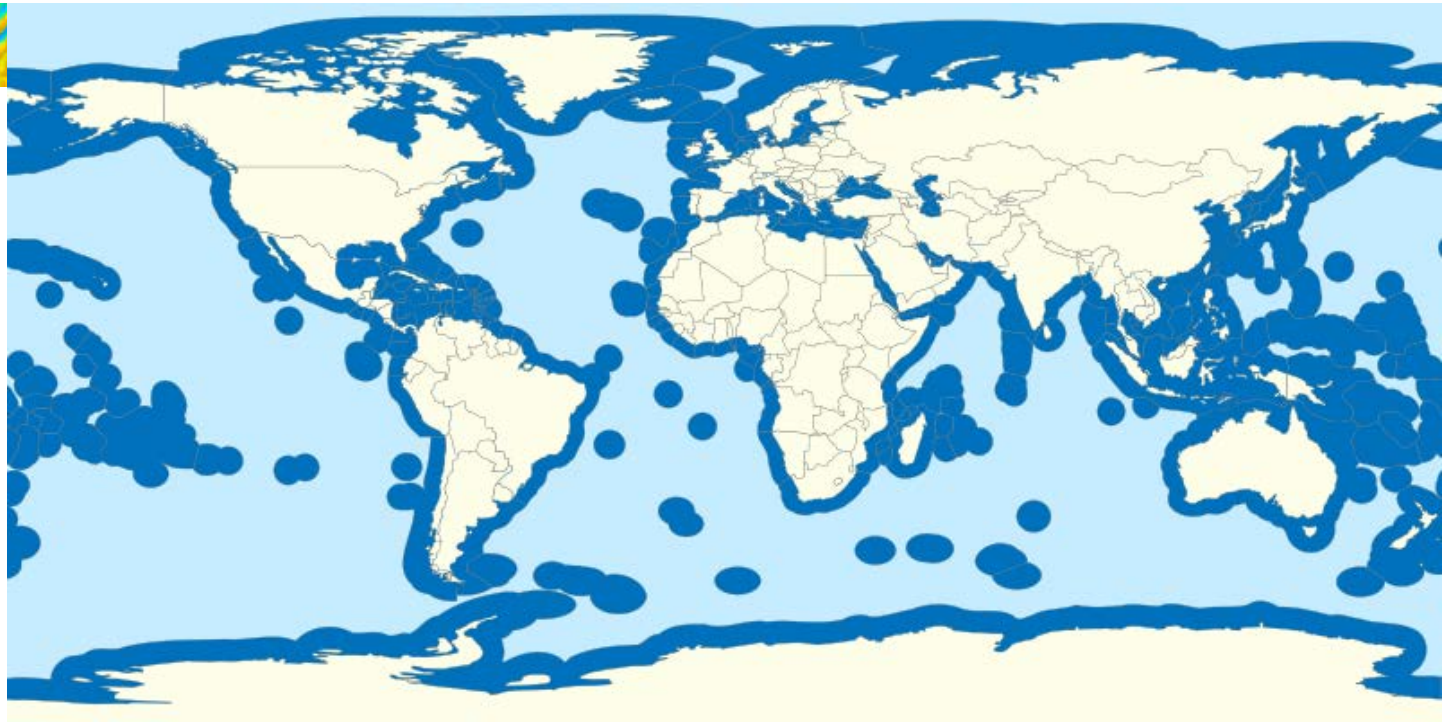
Fouquet et al, 2015 OTC-25933-MS

UNCLOS Article 76: the continental shelf





Some Numbers



- Global EEZ: ~ 120 million km²
- Global Extended Shelf estimated at ~ 25 million km²
- > 70 States have entitlement over continental shelf beyond 200 nautical miles
- 70 Submissions already lodged with the UN

Conclusions

- After 50 years, plate tectonic theory provides fundamentals tool for our understanding of the earth system
- Only a small percentage of the ocean floor is mapped to modern standards
- Therefore, there is a need to continue exploration, using modern tools
- Significant activities related to UNCLOS and the search for minerals

Thank you!