THE MAJOR STAGES IN THE DISCOVERY OF THE SEA FLOOR (THE HISTORY OF SEA FLOOR EXPLORATION)

Angelo Camerlenghi

National Institute of Oceanography and Applied Geophysics


Dark
Silent
Far
Corrosive
Cold
Huge Pressure
DEEP
Courtesy JAMSTEC

Dark

Silent

Far

Corrosive

Cold

Huge Pressure

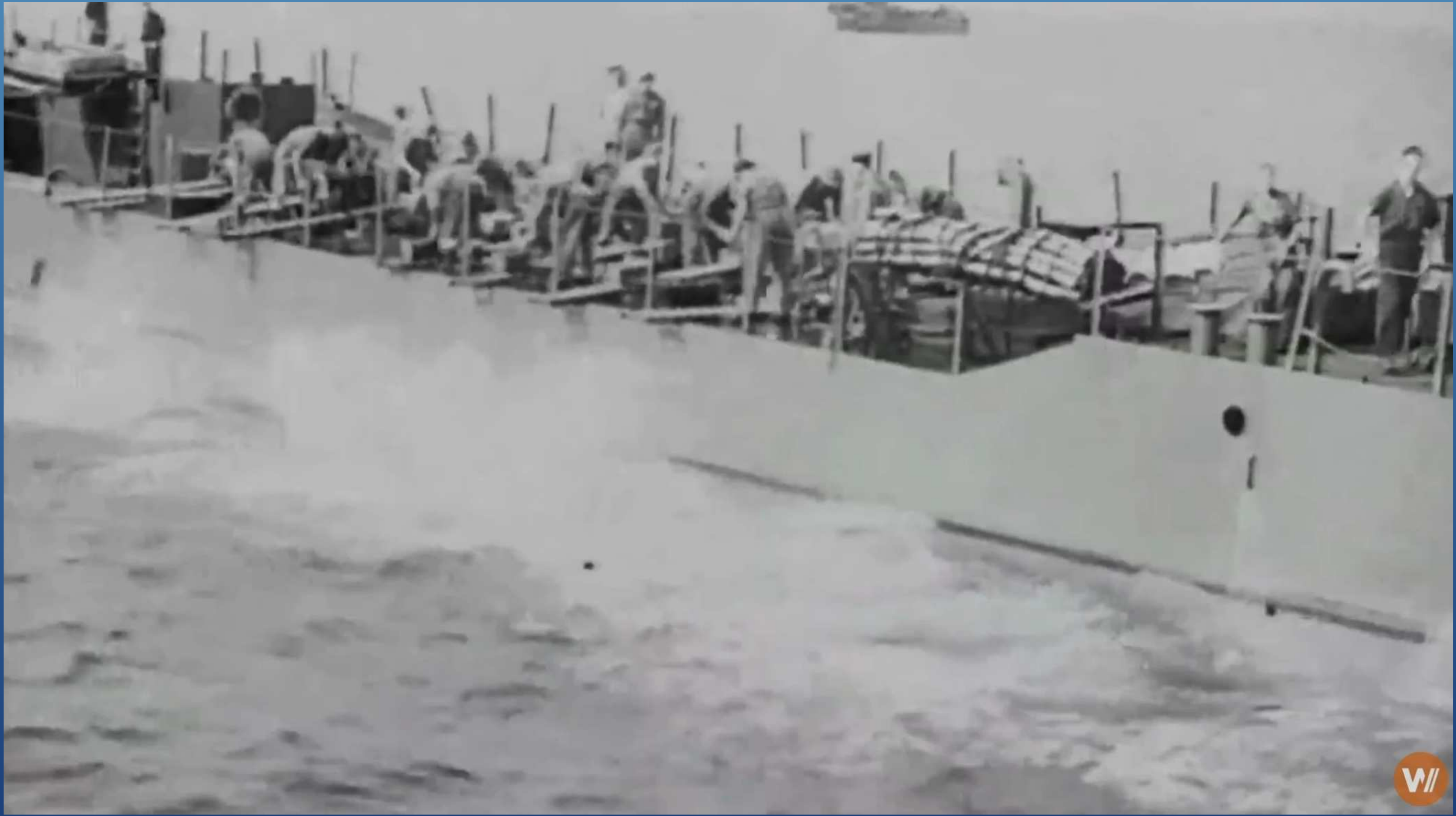
3,682.2 m

Courtesy JAMSTEC

MARINE MONSTERS

PLANETARY WASTE DISPOSAL

Courtesy: JPI Oceans

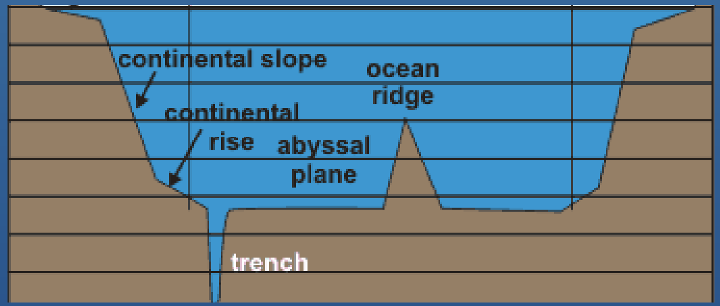


YouTube·wocomoHISTORY·17 gen 2022Pentagon documents reveal: 30 tons of "special" weapons ...

HOW DEEP IS THE OCEAN?

Curiosity: Song “**How Deep Is the Ocean (how high is the sky)**”, by Irving Berlin, 1932
Featured, among many others, by Ella Fitzgerald, Fank Sinatra, Eric Clapton, Barbara Streisand

Thousands of kilometers



Thousands of meters

HORIZONTAL	EXPLORATION OF SEAS AND OCEANS	10^6 m	Throughout the history of humankind
VERTICAL		**10^3 m**	**Mainly since the 19th century**

HOW DEEP IS THE OCEAN?

Sixth century B.C.

Sounding lead or **sounding weigh**

In use in the Mediterranean area for maritime navigation since at least the sixth century B.C.
It is the oldest known marine navigational instrument and it remained a primary navigational aid in coastal waters and rivers well into the twentieth century

HOW DEEP IS THE OCEAN?

A **fathom** is a unit of length in the imperial and the U.S. customary systems equal to 6 feet (1.8288 m), used especially for measuring the depth of water.

Originally the span of a man's outstretched arms

Royal Museums Greenwich

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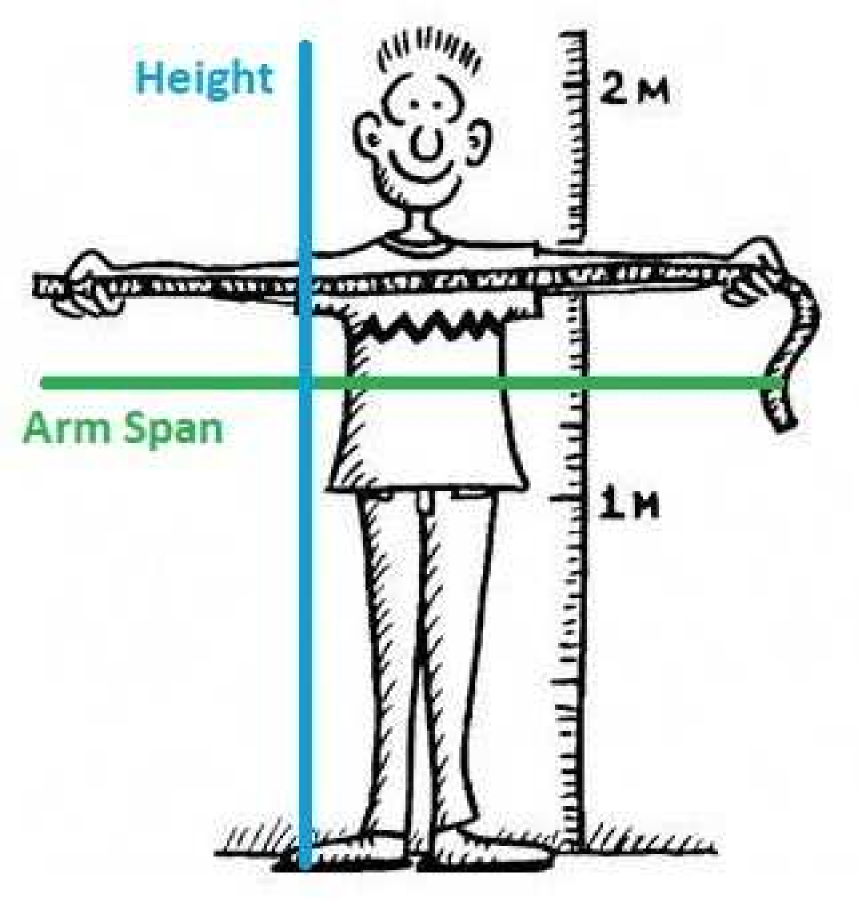


https://lab13network.wordpress.com/

Orguia (Ancient Greek: ὀργυιά, orgyiá, lit. "outstretched")

HMS Challenger Expedition 1872–1876

Sir Charles Wyville Thomson—of the University of Edinburgh and Merchiston Castle School

[Royal Museums Greenwich](https://www.rmg.co.uk)

ROYAL MUSEUMS GREENWICH

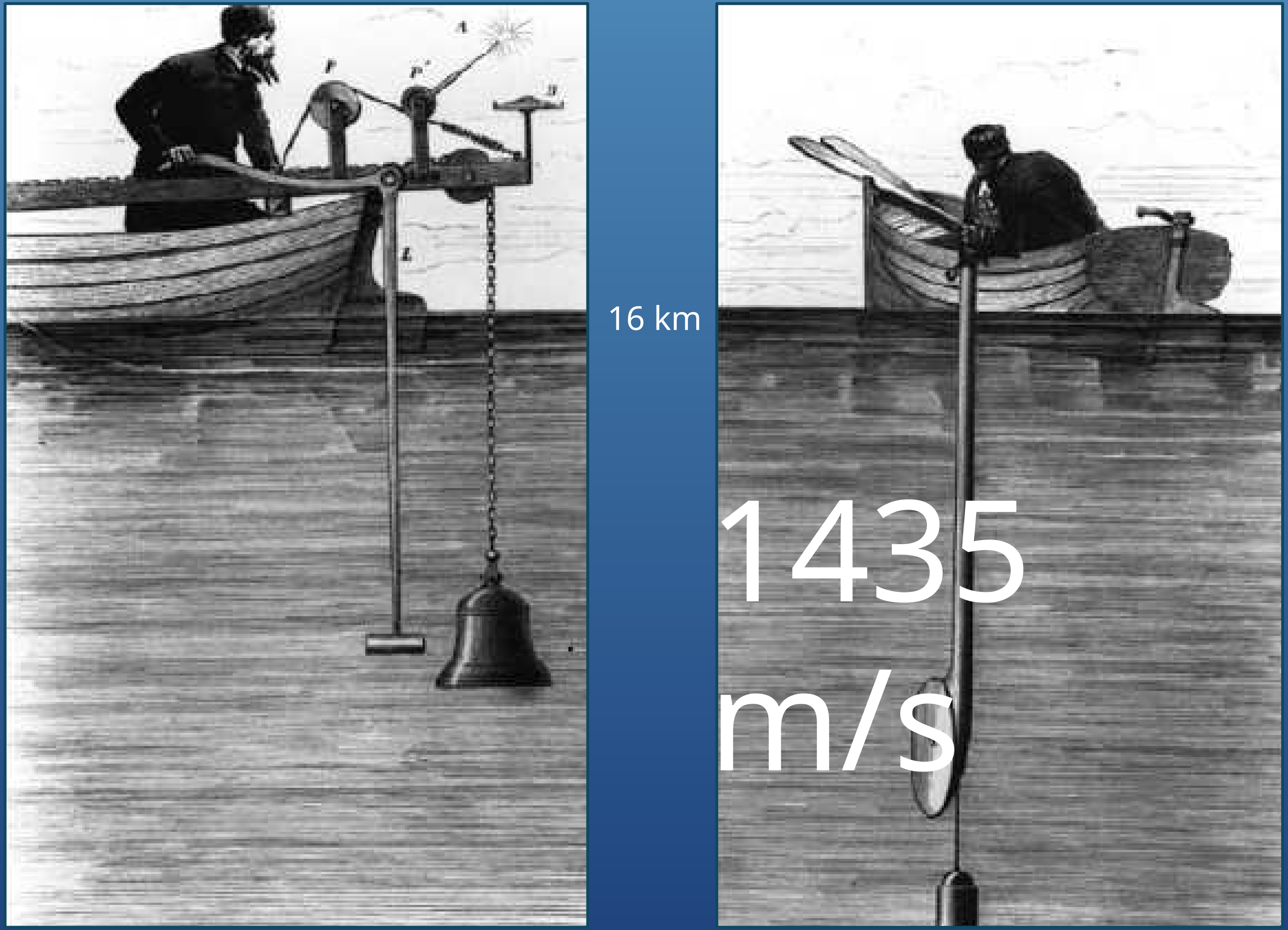
374 deep sea Soundings

On 23 March 1875, at sample station number 225 located in the southwest Pacific Ocean between Guam and Palau, the crew recorded a sounding of 4,475 fathoms (26,850 ft; 8,184 m)

https://www.rmg.co.uk/stories/blog/library-archive/telling-story-challenger-expedition-1872-76

1862 Lake Geneva
First measurement of the speed of sound in water

Colladon and Sturm's 1862 experiment to measure the speed of sound in Lake Geneva J. D. Colladon: Souvenirs et Memoires, Impr. Albert-Schuchardt, Geneva, 1893.



Dosso, Stan & Dettmer, Jan. (2013). Studying the sea with sound. The Journal of the Acoustical Society of America. 133. 3223. 10.1121/1.4805114.

19th Century, British and U.S. Atlantic coasts

Underwater bells deployed near lighthouses and from (moored) lightships

1912 sinking of the RMS Titani

1912 Fessenden oscillator

Electro-acoustic moving-coil transducer which could produce and receive underwater sound signals at about **1 kHz** He echo-located ice bergs to about 3-km range

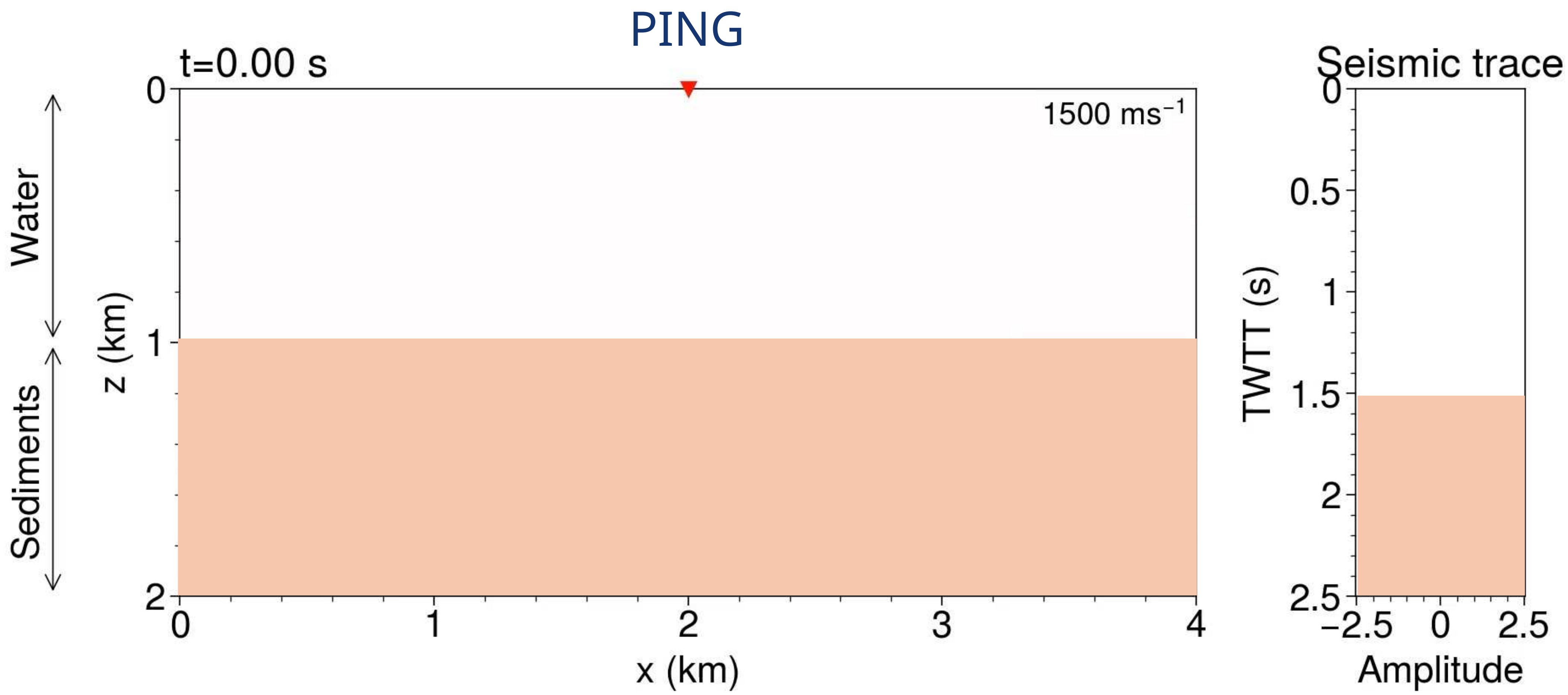
Sound navigation and ranging (SONAR)

Dosso, Stan & Dettmer, Jan. (2013). Studying the sea with sound. The Journal of the Acoustical Society of America. 133. 3223. 10.1121/1.4805114.

Bathymetric sonars

Thanks to Jonathan Ford, OGS

Revolutionary tool, installed on the ship keel or outboard
The measurement is two-way travel time



1925-1927 – German Meteor expedition in the Atlantic Ocean

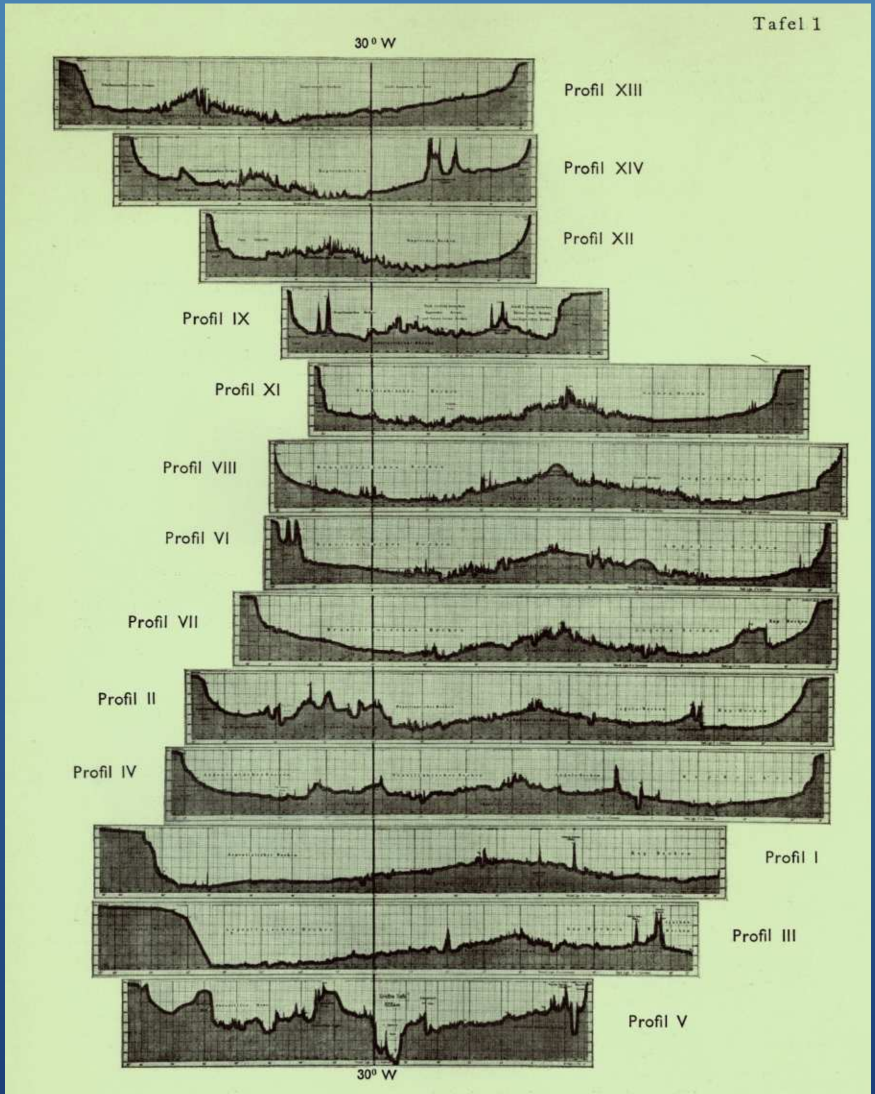


Abb. 1. Die morphologischen Profile (Echolot-Profile) des »Meteor« durch den Südatlantischen Ozean, auf den 30. Grad Westl. Länge ausgerichtet. Überhöhung 1:100
Vgl. die Lageskizze Abb. 1, S. 3

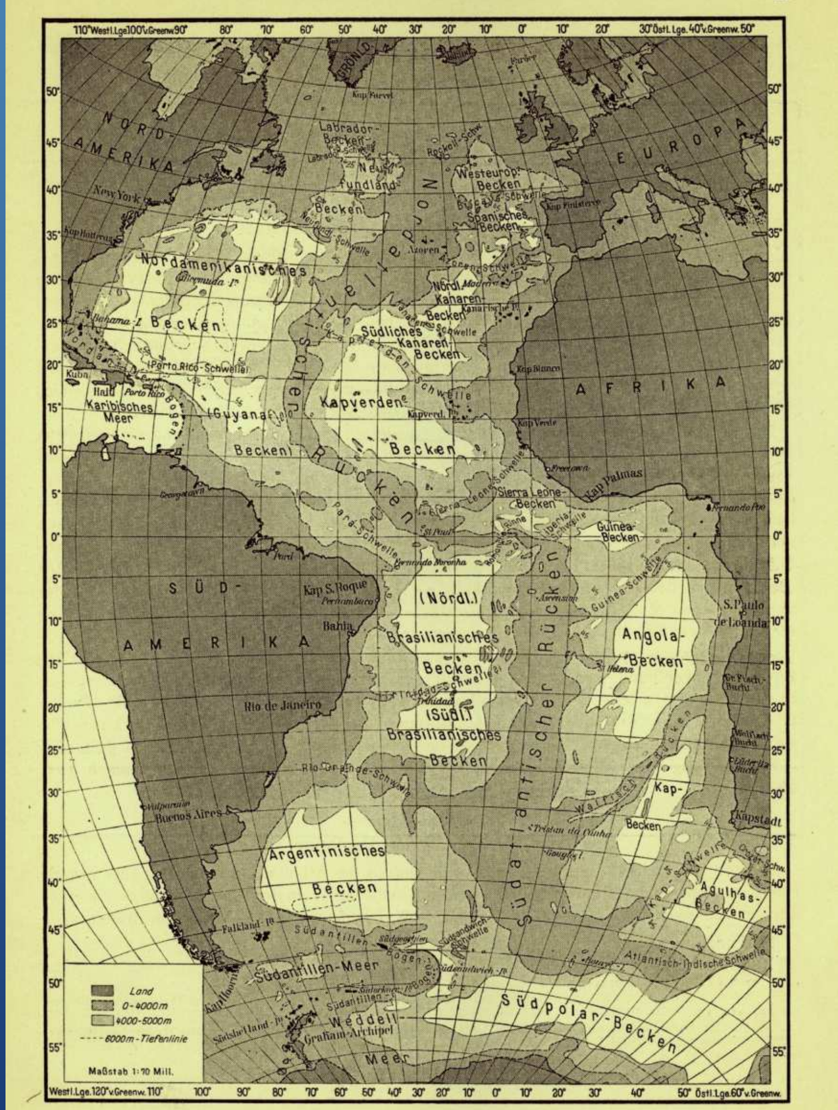
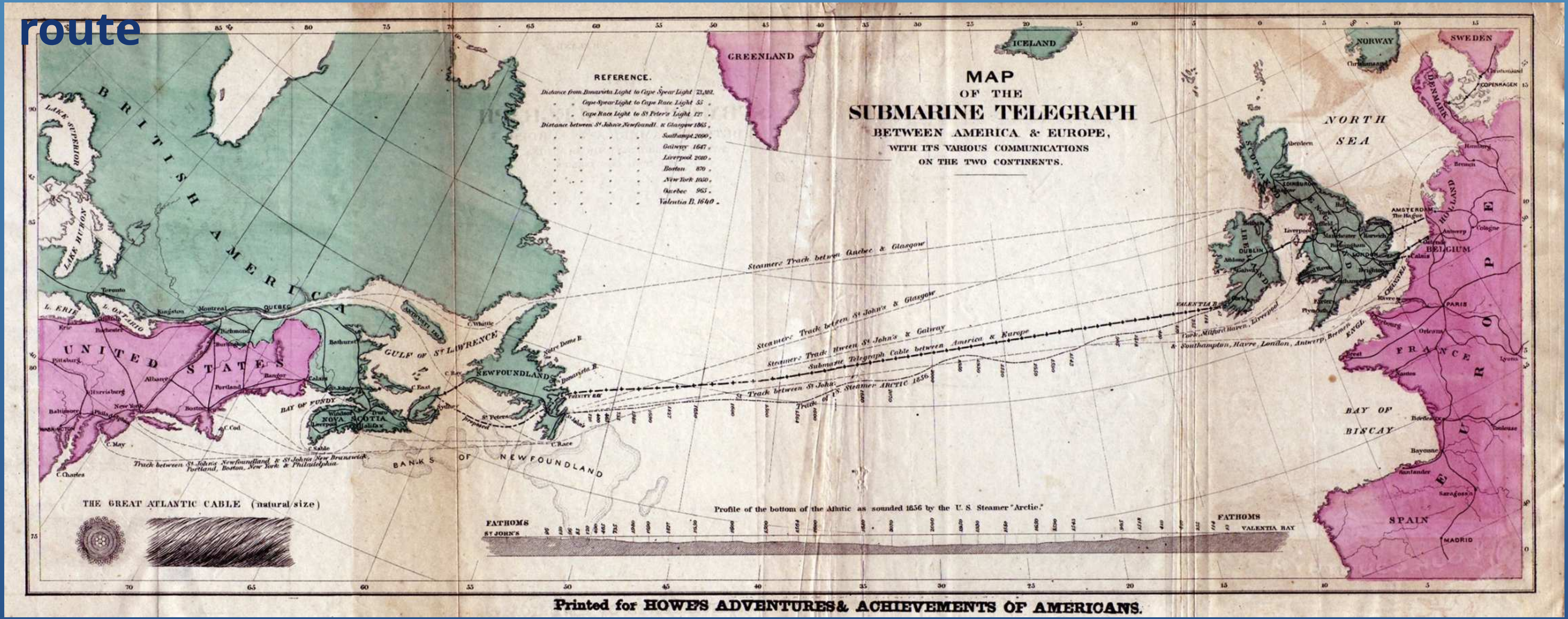
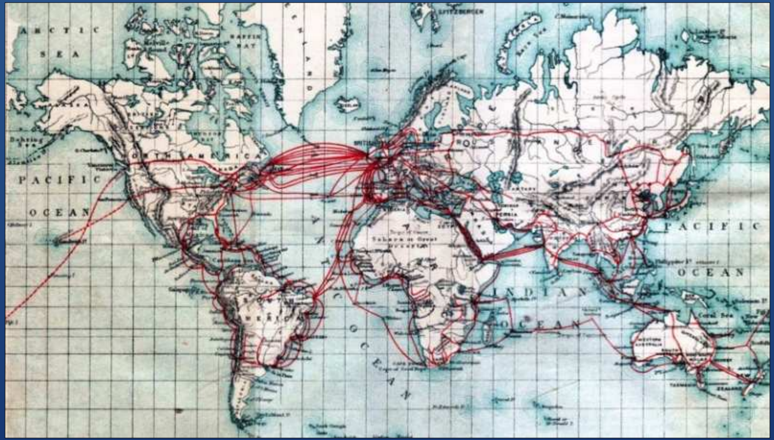


Abb. 8. Die Gliederung der Atlantischen Tiefsee (1934)

1858 1st transatlantic cable route





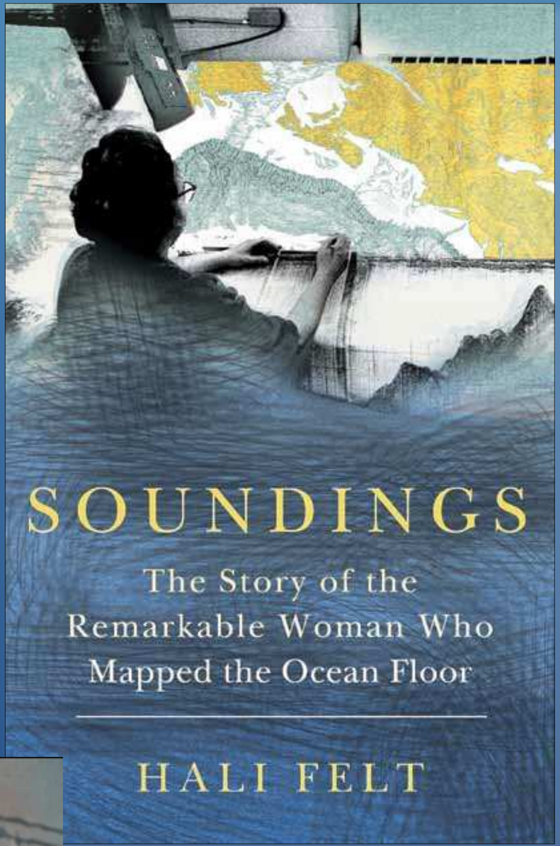
1901: global network of telegraph cables (that often failed)

http://industrialhistoryhk.org/submarine-cables-maps-1901-1991-worldwide-hong-kong-networks/

1957

Marie Tharp
Bruce Heezen

Lamont-Doherty Geological Observatory of Columbia University

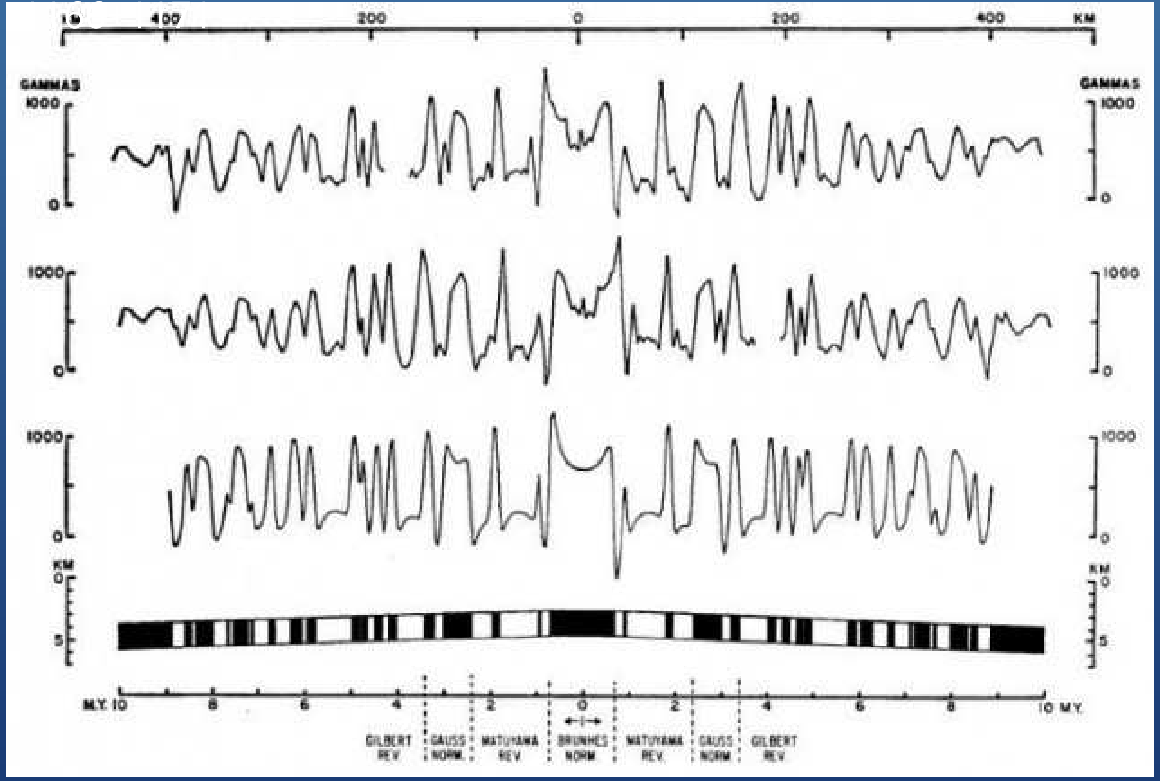


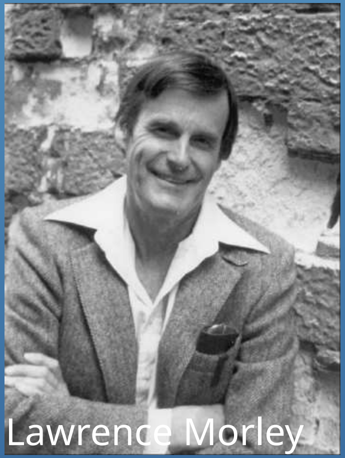
Marie Tharp's first bathymetric map, based on echo-sound data acquired by research vessels after World War II, during the Cold War. At the centre of the ocean, there is a clear feature visible, which is nowadays known as the Atlantic Mid Oceanic Ridge (Heezen et al., 1959).

In 1967, Austrian landscape panoramist and cartographer Heinrich Berann painted the first in a series of plan oblique physiographic maps of the ocean floor which ultimately culminated in the 1977 World Ocean Floor map for Columbia University and the U.S. Navy.

1960s Magnetic Anomalies

Magnetic Anomalies over the Pacific-Antarctic Ridge
Author(s): W. C. Pitman III and J. R. Heirtzler Source: Science, New Series, Vol. 154, No. 3753 (Dec. 2, 1966), pp. 1164-





Lawrence Morley

Frederick Vine

Drummond Matthews

Walter Pitman and the Eltanin 19 Profile

No. 4897 September 7, 1963 NATURE 947

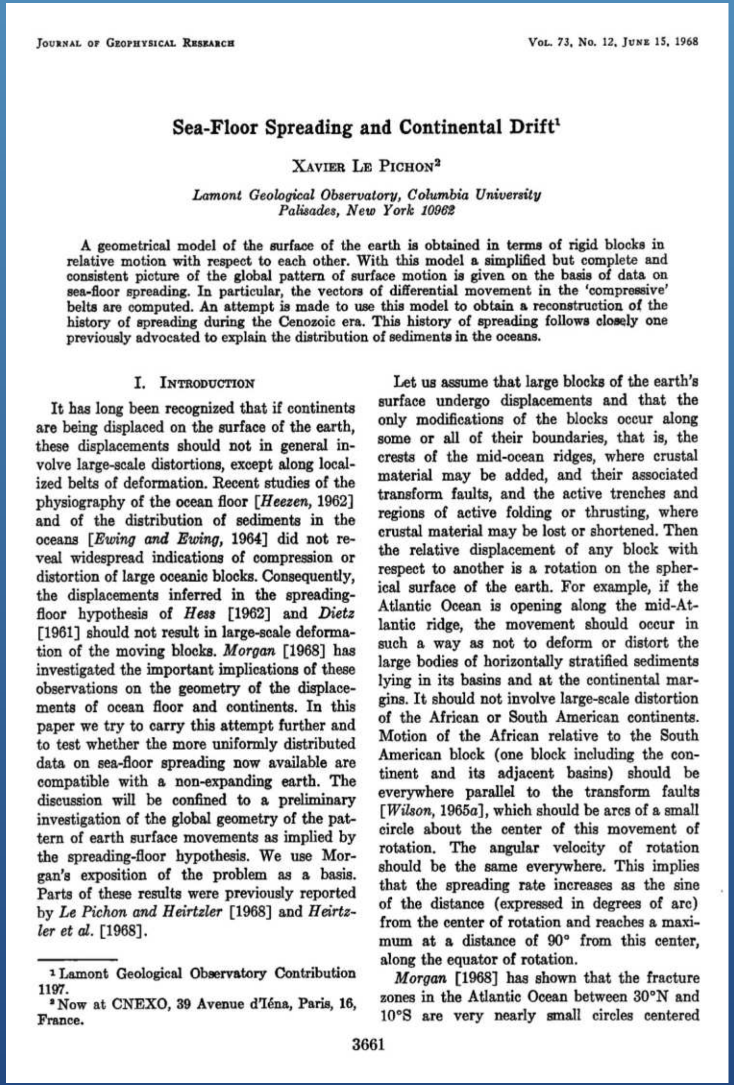
MAGNETIC ANOMALIES OVER OCEANIC RIDGES

By F. J. VINE and Dr. D. H. MATTHEWS

Department of Geodesy and Geophysics, University of Cambridge

LAMONT-DOHERTY EARTH OBSERVATORY
COLUMBIA CLIMATE SCHOOL

and Carlo Laj, GIFT Workshop 2019



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

A geometrical model of the surface of the earth is obtained in terms of rigid blocks in relative motion with respect to each other. With this model a simplified but complete and consistent picture of the global pattern of surface motion is given on the basis of data on sea-floor spreading. In particular, the vectors of differential movement in the 'compressive' belts are computed. An attempt is made to use this model to obtain a reconstruction of the history of spreading during the Cenozoic era. This history of spreading follows closely one previously advocated to explain the distribution of sediments in the oceans.

I. Introduction

It has long been recognized that if continents are being displaced on the surface of the earth, these displacements should not in general involve large-scale distortions, except along localized belts of deformation. Recent studies of the physiography of the ocean floor [*Heezen*, 1962] and of the distribution of sediments in the oceans [*Ewing and Ewing*, 1964] did not reveal widespread indications of compression or distortion of large oceanic blocks. Consequently, the displacements inferred in the spreading-floor hypothesis of *Hess* [1962] and *Dietz* [1961] should not result in large-scale deformation of the moving blocks. *Morgan* [1968] has investigated the important implications of these observations on the geometry of the displacements of ocean floor and continents. In this paper we try to carry this attempt further and to test whether the more uniformly distributed data on sea-floor spreading now available are compatible with a non-expanding earth. The discussion will be confined to a preliminary investigation of the global geometry of the pattern of earth surface movements as implied by the spreading-floor hypothesis. We use Morgan's exposition of the problem as a basis. Parts of these results were previously reported by *Le Pichon and Heirtzler* [1968] and *Heirtzler et al.* [1968].

Let us assume that large blocks of the earth's surface undergo displacements and that the only modifications of the blocks occur along some or all of their boundaries, that is, the crests of the mid-ocean ridges, where crustal material may be added, and their associated transform faults, and the active trenches and regions of active folding or thrusting, where crustal material may be lost or shortened. Then the relative displacement of any block with respect to another is a rotation on the spherical surface of the earth. For example, if the Atlantic Ocean is opening along the mid-Atlantic ridge, the movement should occur in such a way as not to deform or distort the large bodies of horizontally stratified sediments lying in its basins and at the continental margins. It should not involve large-scale distortion of the African or South American continents. Motion of the African relative to the South American block (one block including the continent and its adjacent basins) should be everywhere parallel to the transform faults [*Wilson*, 1965*a*], which should be arcs of a small circle about the center of this movement of rotation. The angular velocity of rotation should be the same everywhere. This implies that the spreading rate increases as the sine of the distance (expressed in degrees of arc) from the center of rotation and reaches a maximum at a distance of 90° from this center, along the equator of rotation.

Morgan [1968] has shown that the fracture zones in the Atlantic Ocean between 30°N and 10°S are very nearly small circles centered

[1] Lamont Geological Observatory Contribution 1197.
[2] Now at CNEXO, 39 Avenue d'Iéna, Paris, 16, France.

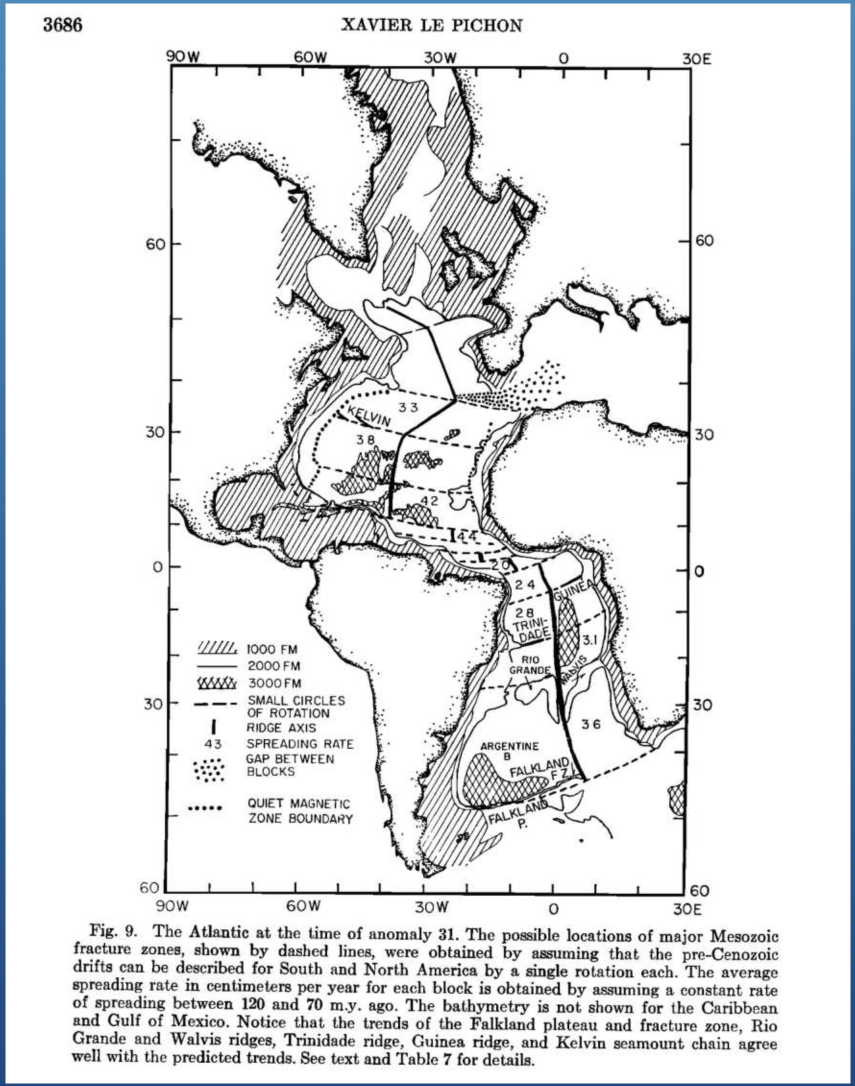
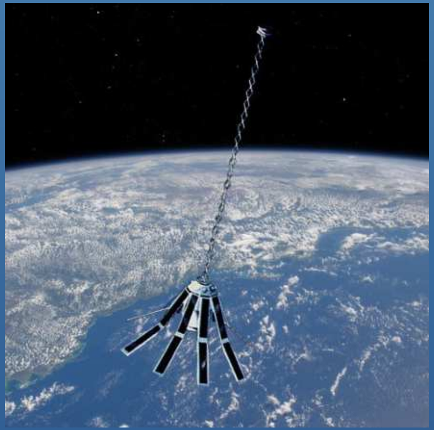


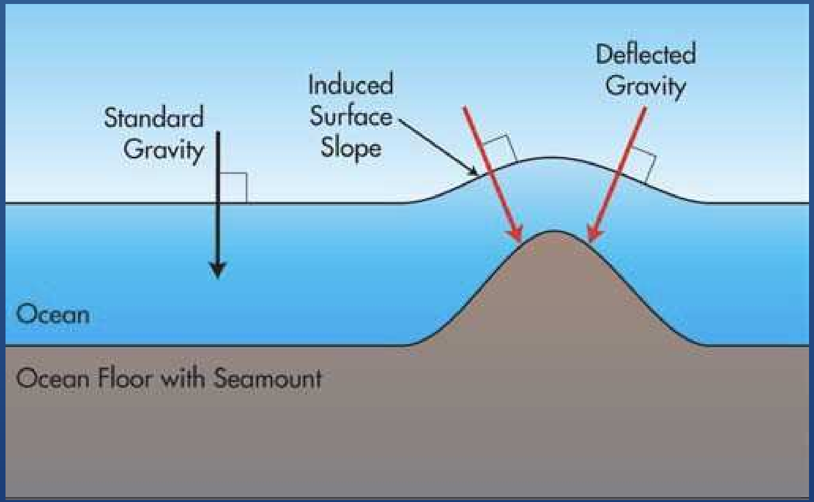
Fig. 9. The Atlantic at the time of anomaly 31. The possible locations of major Mesozoic fracture zones, shown by dashed lines, were obtained by assuming that the pre-Cenozoic drifts can be described for South and North America by a single rotation each. The average spreading rate in centimeters per year for each block is obtained by assuming a constant rate of spreading between 120 and 70 m.y. ago. The bathymetry is not shown for the Caribbean and Gulf of Mexico. Notice that the trends of the Falkland plateau and fracture zone, Rio Grande and Walvis ridges, Trinidade ridge, Guinea ridge, and Kelvin seamount chain agree well with the predicted trends. See text and Table 7 for details.

Xavier Le Pichon, Collège de France
June 18, 1937 - March 22, 2025

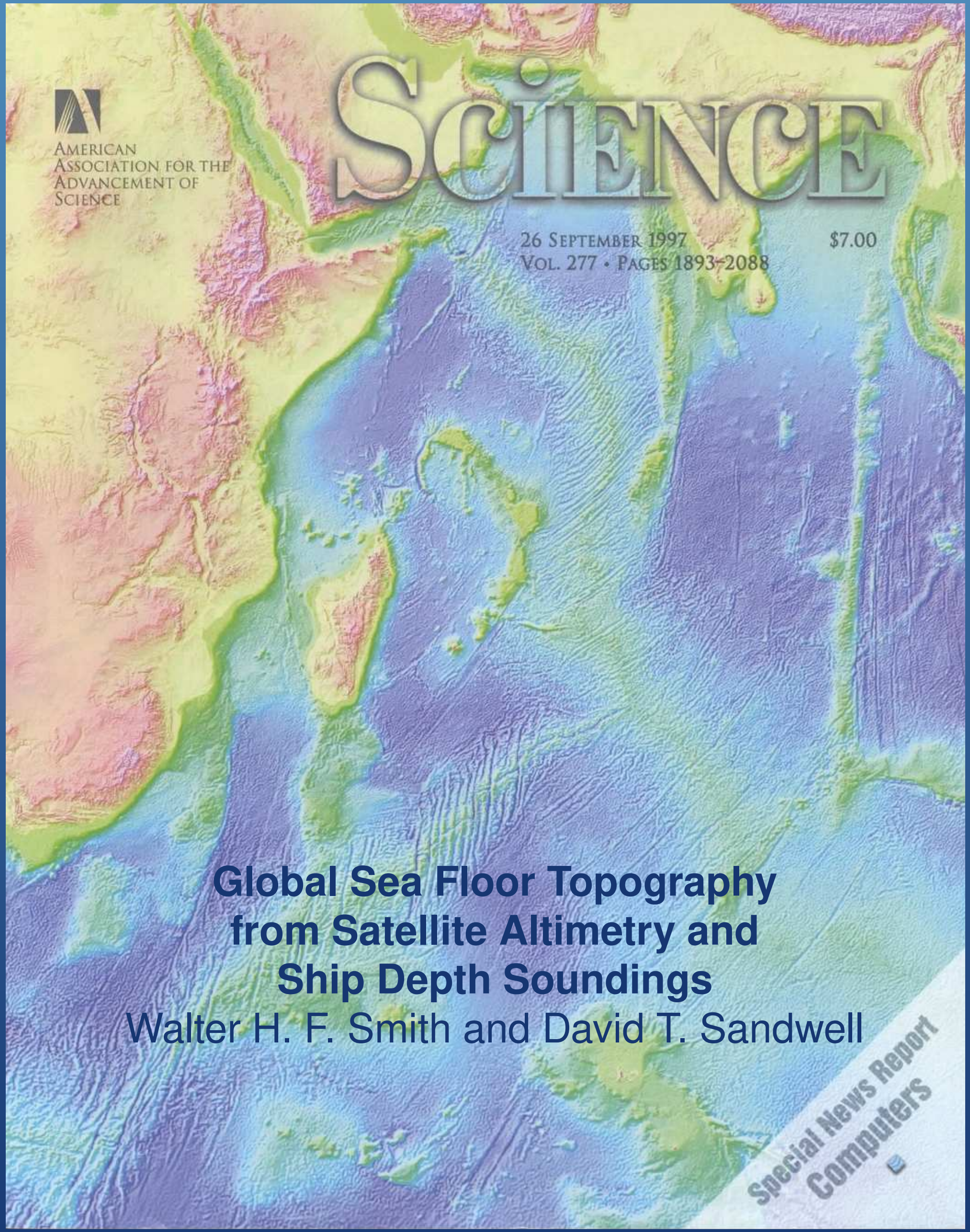
He joined Maurice Ewing's team at the Lamont-Doherty Observatory (USA) in the late 1960s, he followed in the footsteps of Harry Hess, Fred Vine, Drummond Matthews, Tuzo Wilson, Dan McKenzie and Jason Morgan to propose the first global quantitative model describing the relative displacements of the main tectonic plates and reconstructing the evolution of the Atlantic since the Cretaceous

1997 Bathymetry from Space
Smith and Sandwell





Smith and Sandwell, Oceanography • Vol. 17 • No. 1/2004

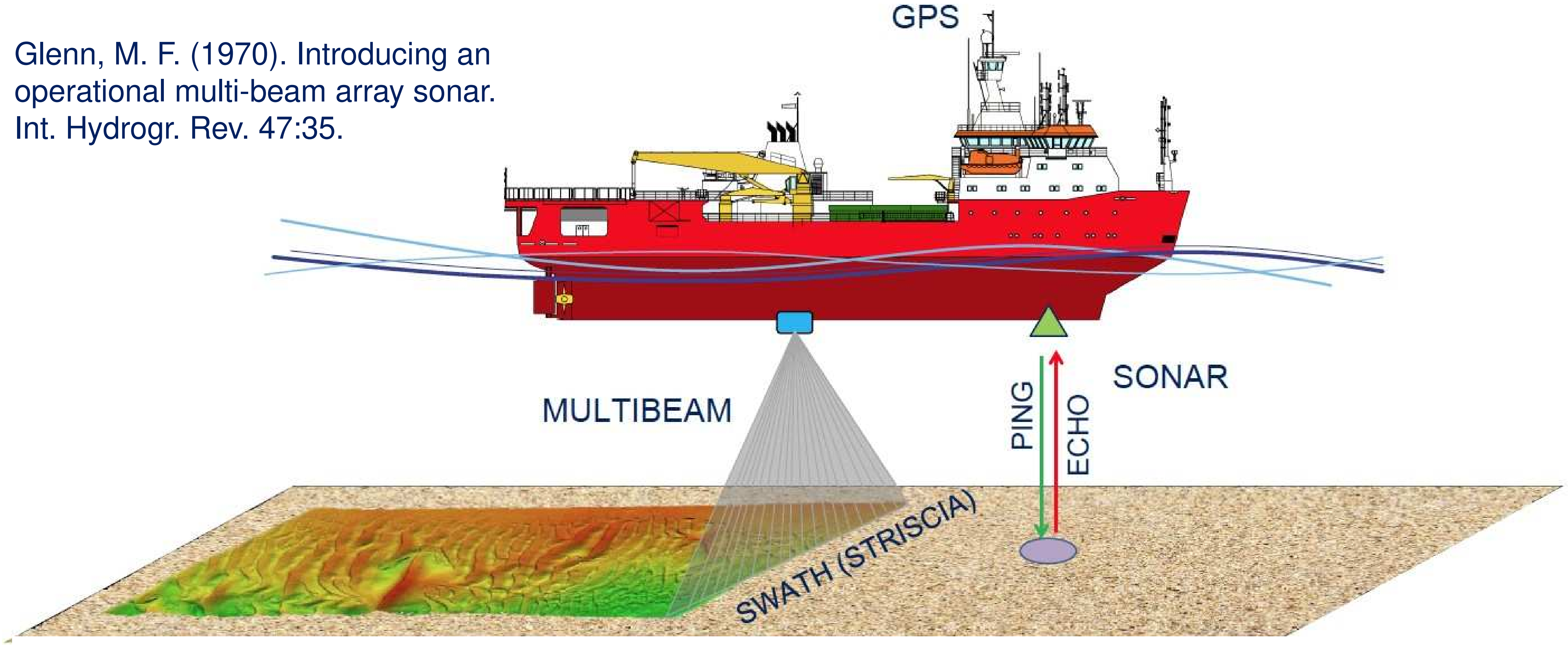


Horizontal resolution of 1 to 12

1970 **Multibeam echo-sounder systems**

Glenn

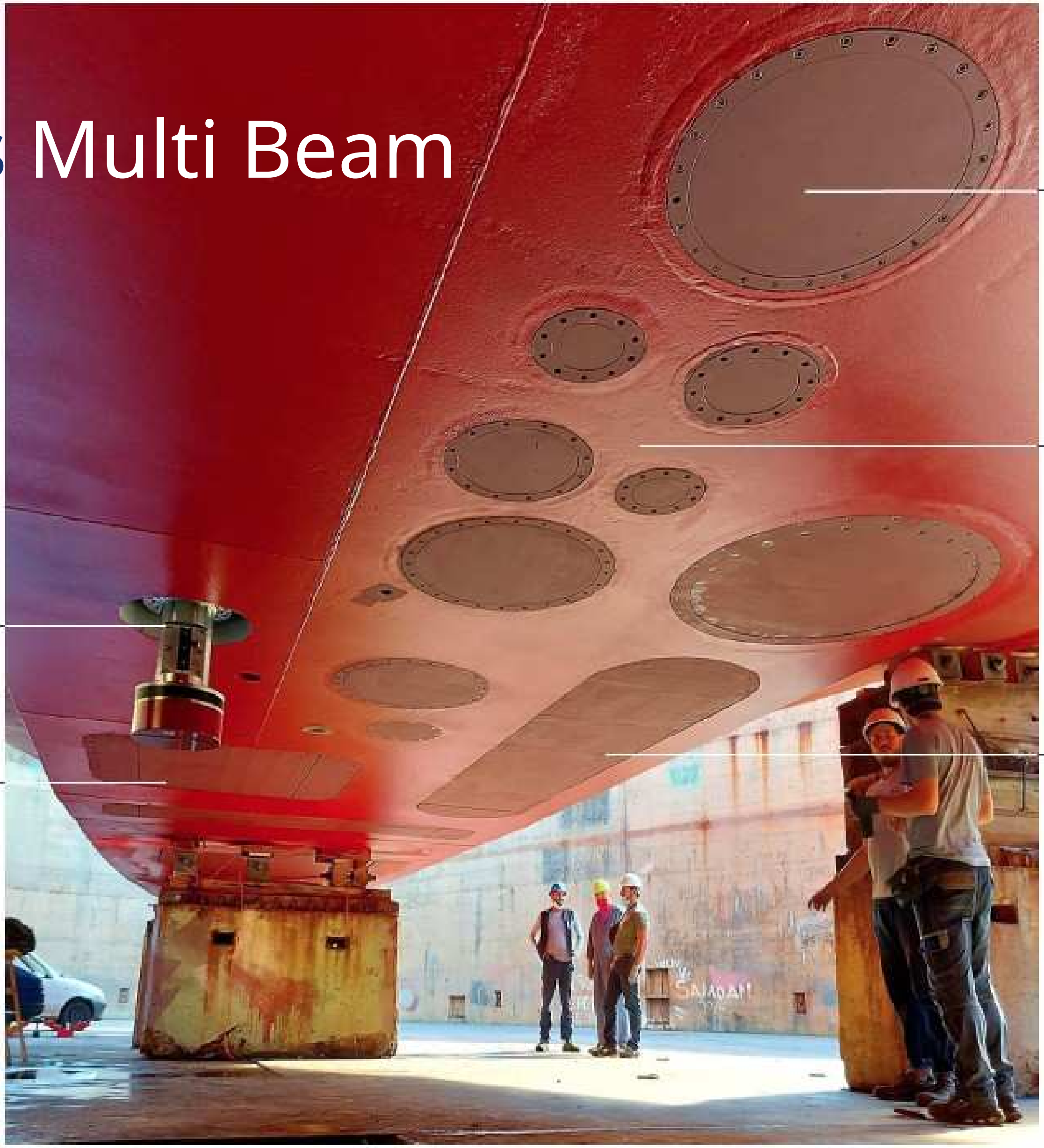
Glenn, M. F. (1970). Introducing an operational multi-beam array sonar. Int. Hydrogr. Rev. 47:35.



Thanks to Roberto Romeo, OGS

OGS Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

SONARS
Single Beam vs Multi Beam



Current meter ACDP

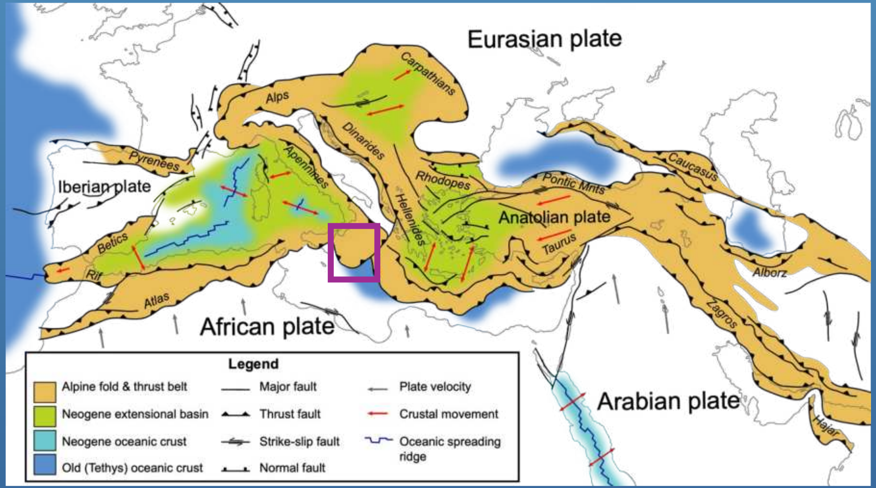
Single-beam Echosounders

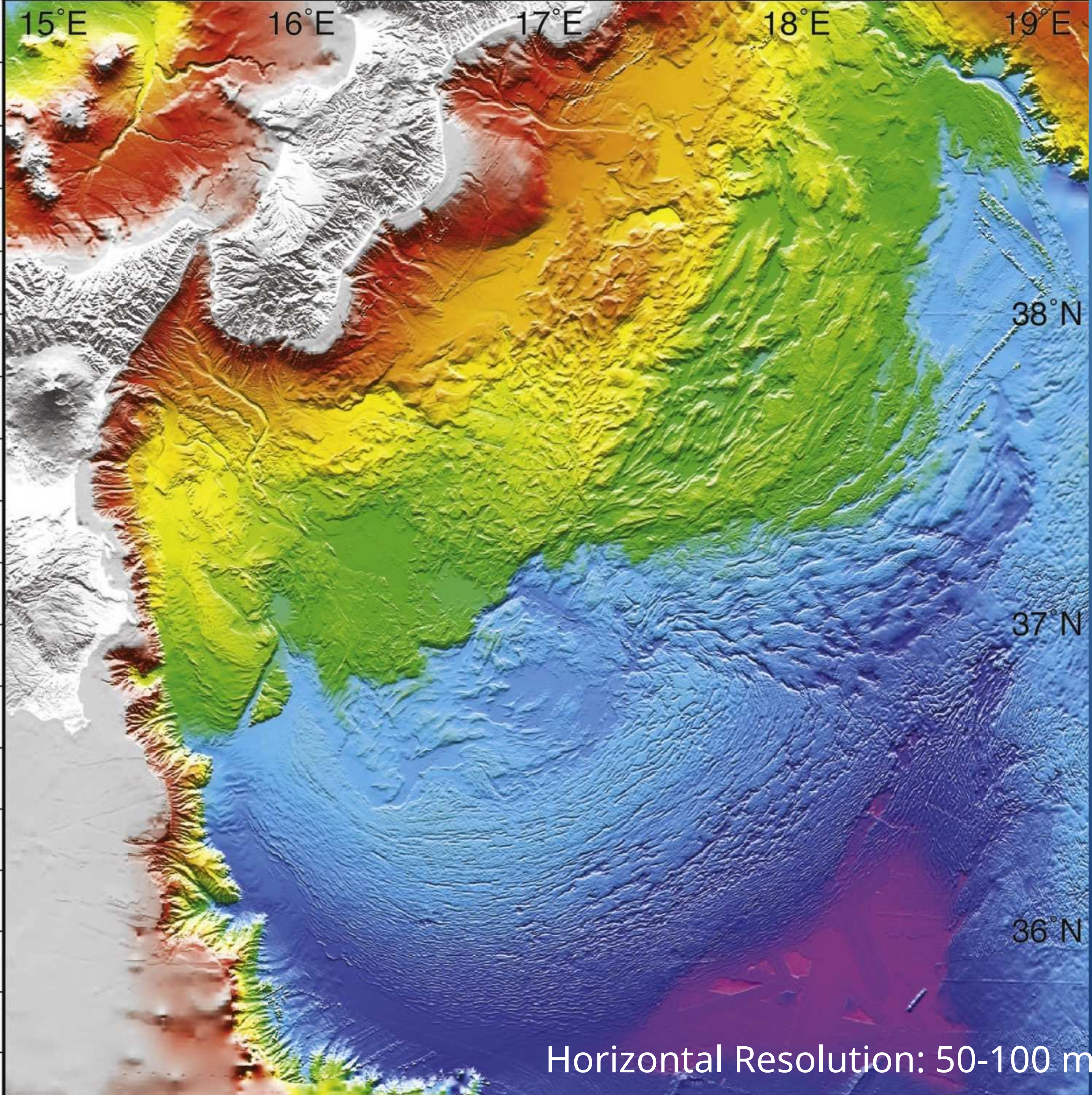
Multibeam Echosounder

Multibeam Echosounder

Subbottom profiler

Thanks to Romeo, OGS





Horizontal Resolution: 50-100 m

Gutscher et al., Earth and Planetary Science Letters

Modern multibeam echo-sounders capable of mapping the deep sea are large and expensive and are typically mounted on large (> 50m) vessels that are in themselves expensive to operate.

It has been estimated that to map the deep (>200 m) portions of the world's ocean seafloor using current day technology would take more than 300 ship years and cost on the order of three to five billion dollars.

Mayer and Roach, 2021
The Quest to Completely Map the World's Oceans in Support of Understanding Marine Biodiversity and the Regulatory Barriers
https://doi.org/10.1163/9789004422438_009

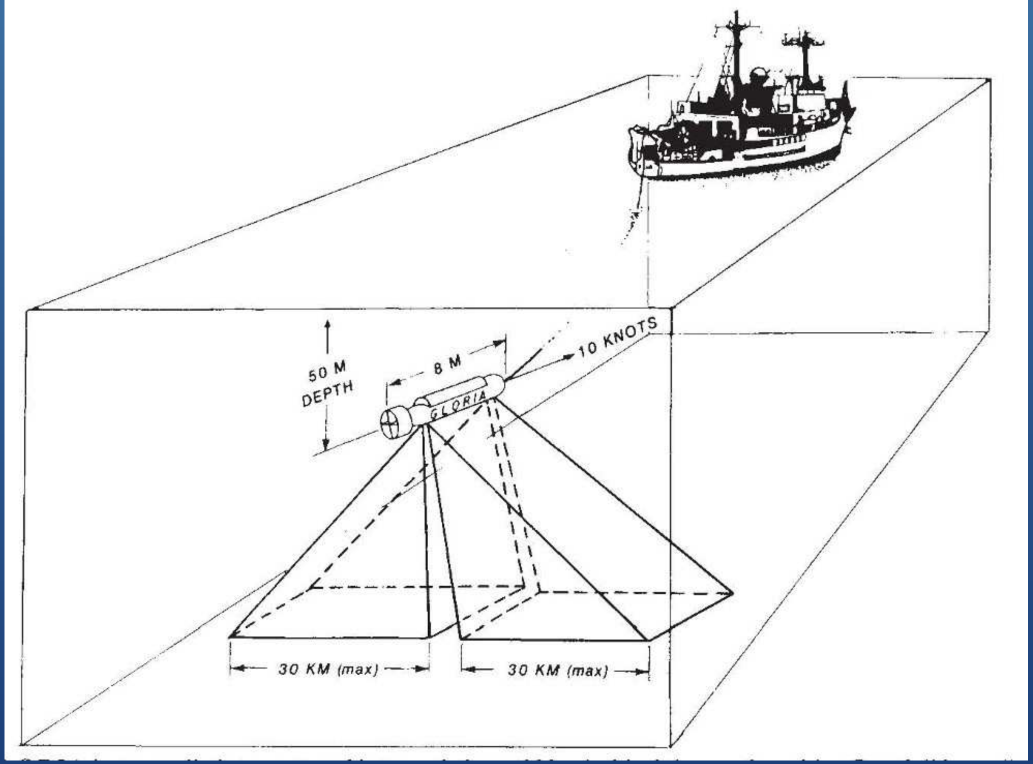
1965 Geological Long-Range Inclined Asdic (GLORIA)

Searle and Hunter

National Institute of Oceanography

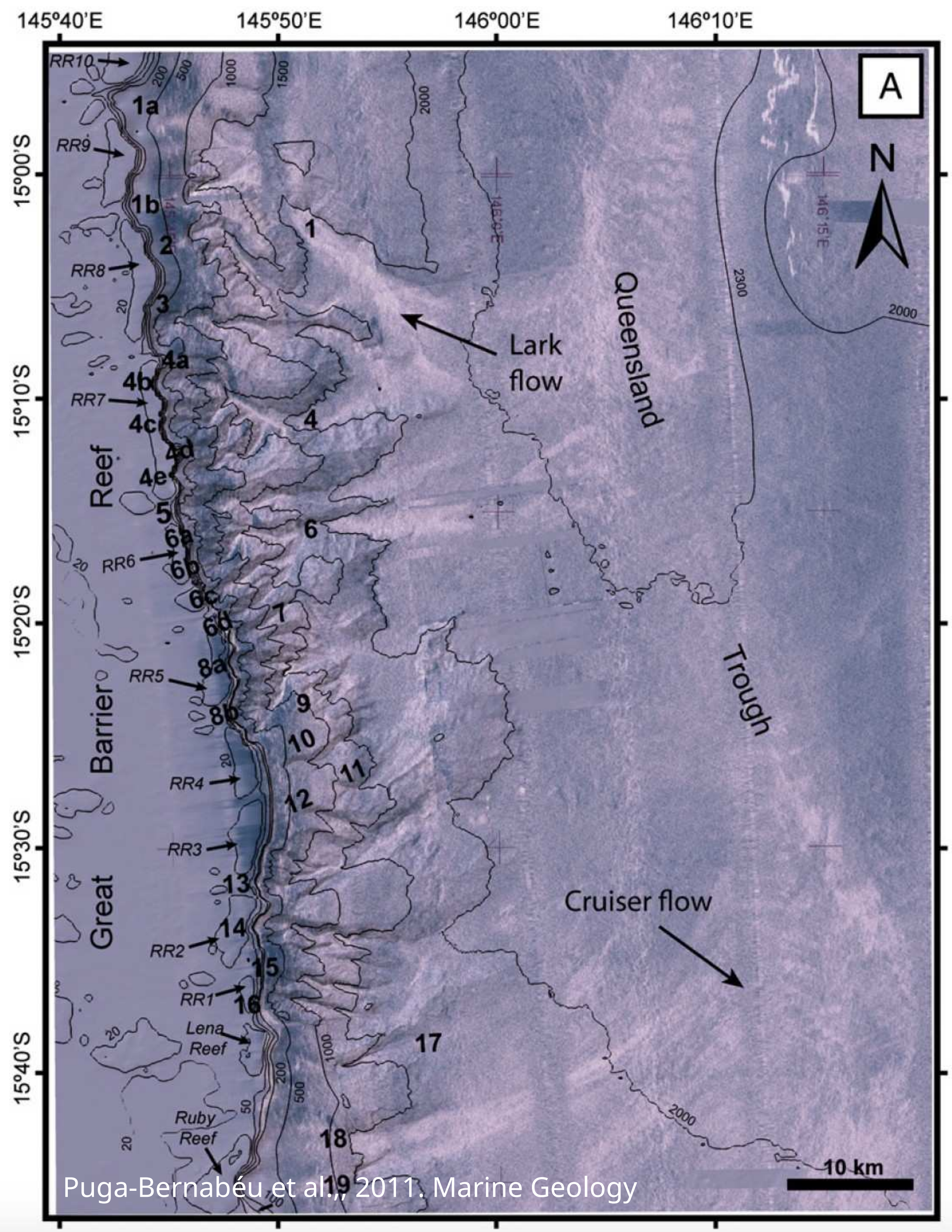
GLORIA is a side-scan sonar device towed behind a research ship.

GLORIA devices enabled oceanographers and geologists to map ocean-floor features, including certain underwater volcanoes, canyons, and tectonic plate boundaries.



GLORIA

https://collection.sciencemuseumgroup.org.uk/



Puga-Bernabéu et al., 2011, Marine Geology

“**Seabed**” seafloor’s surface
“**Seafloor**” surface *and* underground

(Beatriz Martinez-Rius, NEW DEEP TERRITORIES A story of France’s exploration of the seafloor, 2025)

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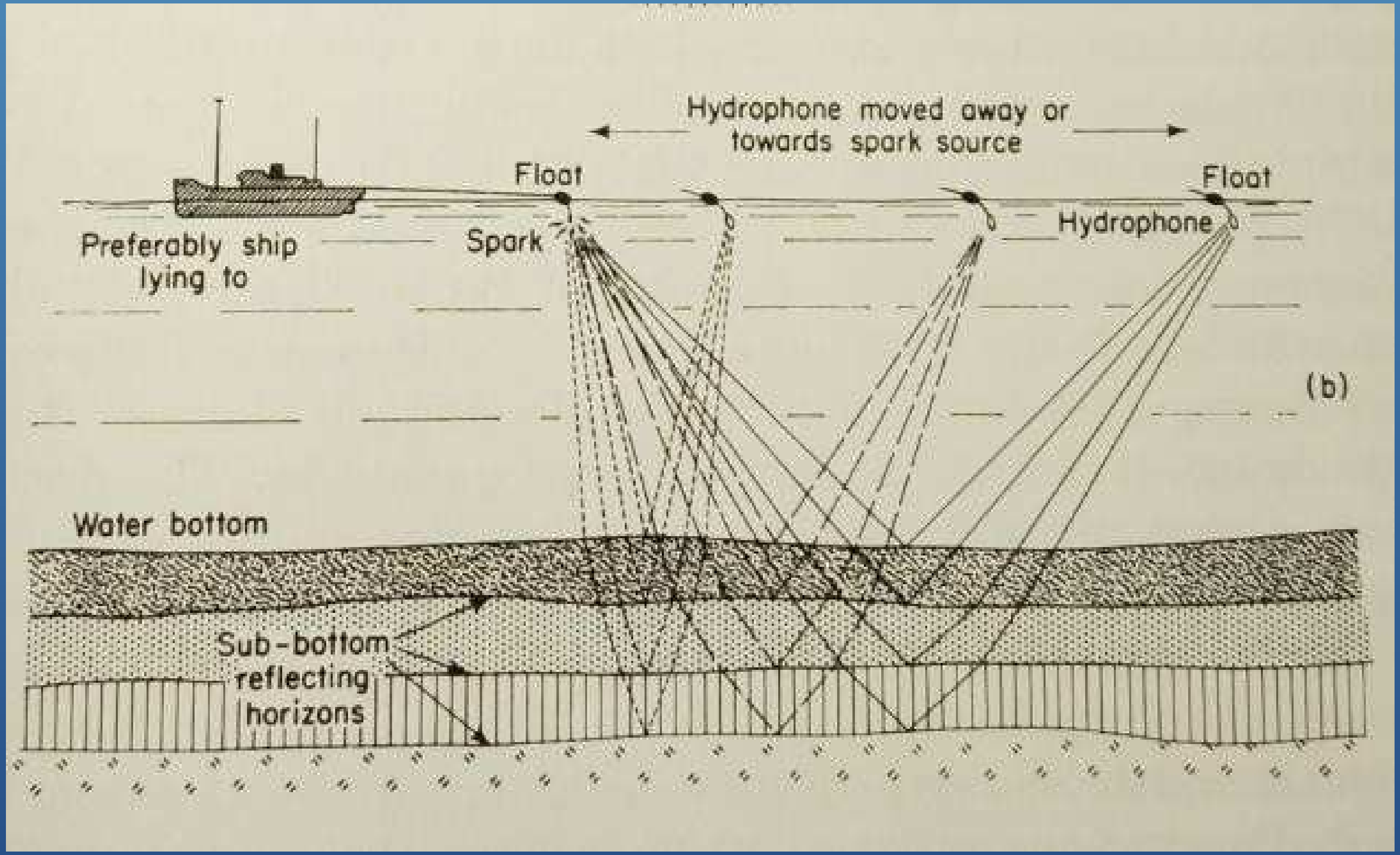

Working schema of reflection seismics (Hersey, “Continuous Reflection Profiling”). Beatriz Martinez-Rius, PhD Thesis, 2022

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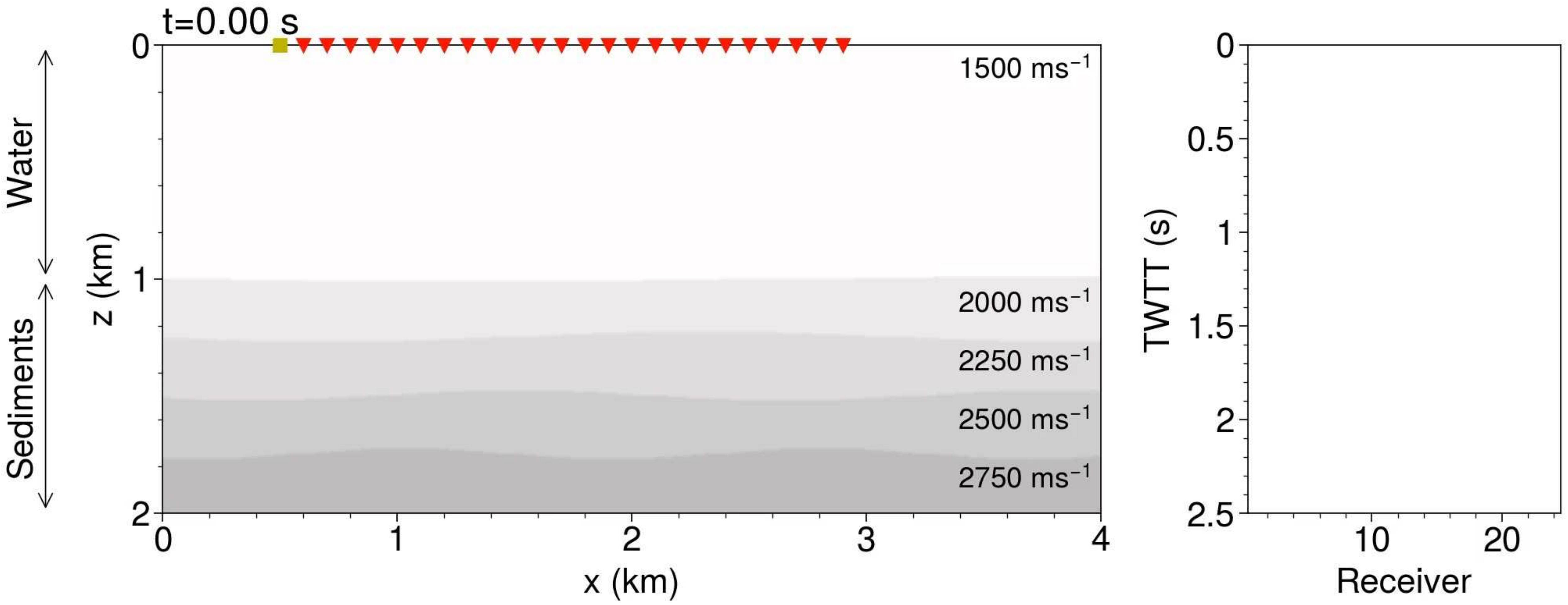
t=0.00 s
1500 ms^{-1}
2000 ms^{-1}
2250 ms^{-1}
2500 ms^{-1}
2750 ms^{-1}
Water
Sediments
z (km)
x (km)
TWTT (s)
Receiver

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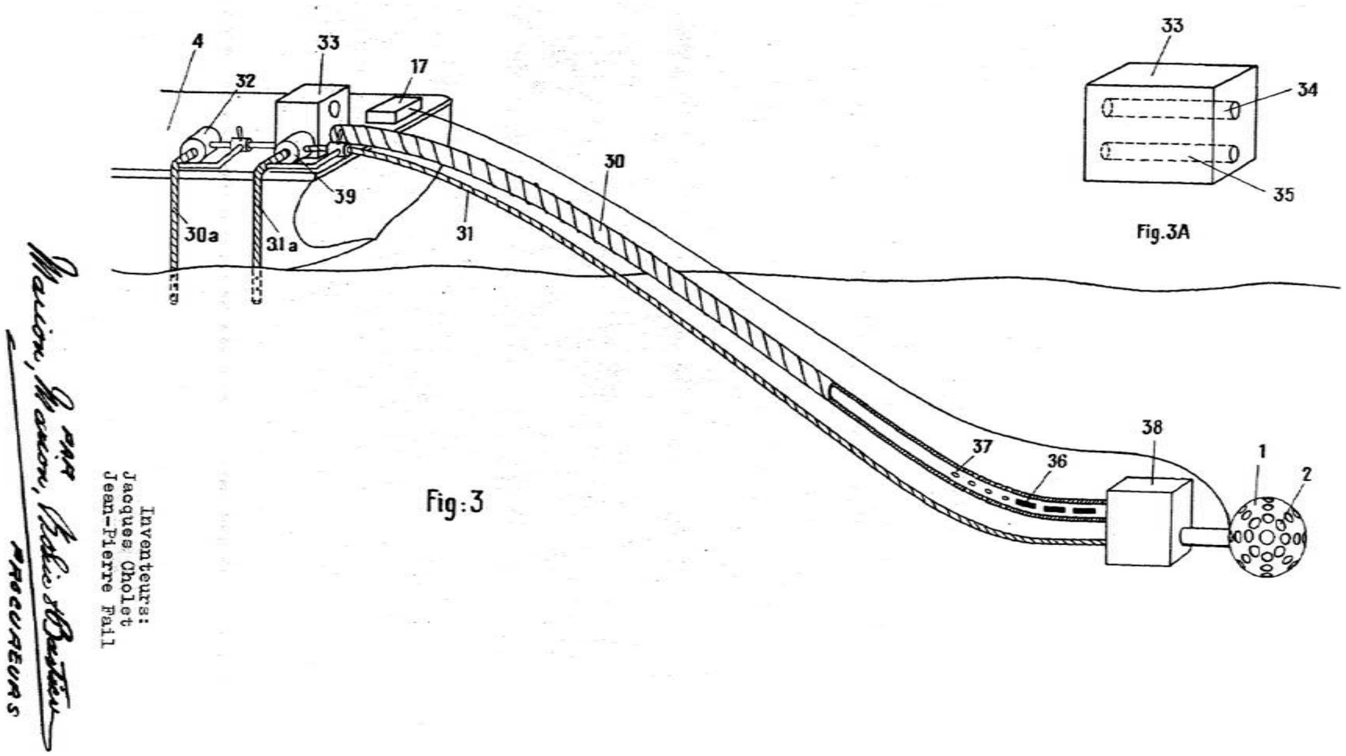
1965 Flexotir seismic source (IFP)
Patented by Fail and Cholet




OGS
OGS EXPLORA - SALTFLU 2012 - Roberto Romeo ©

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Geophysical Surveys - International Association of Geophysical
www.iagc.org

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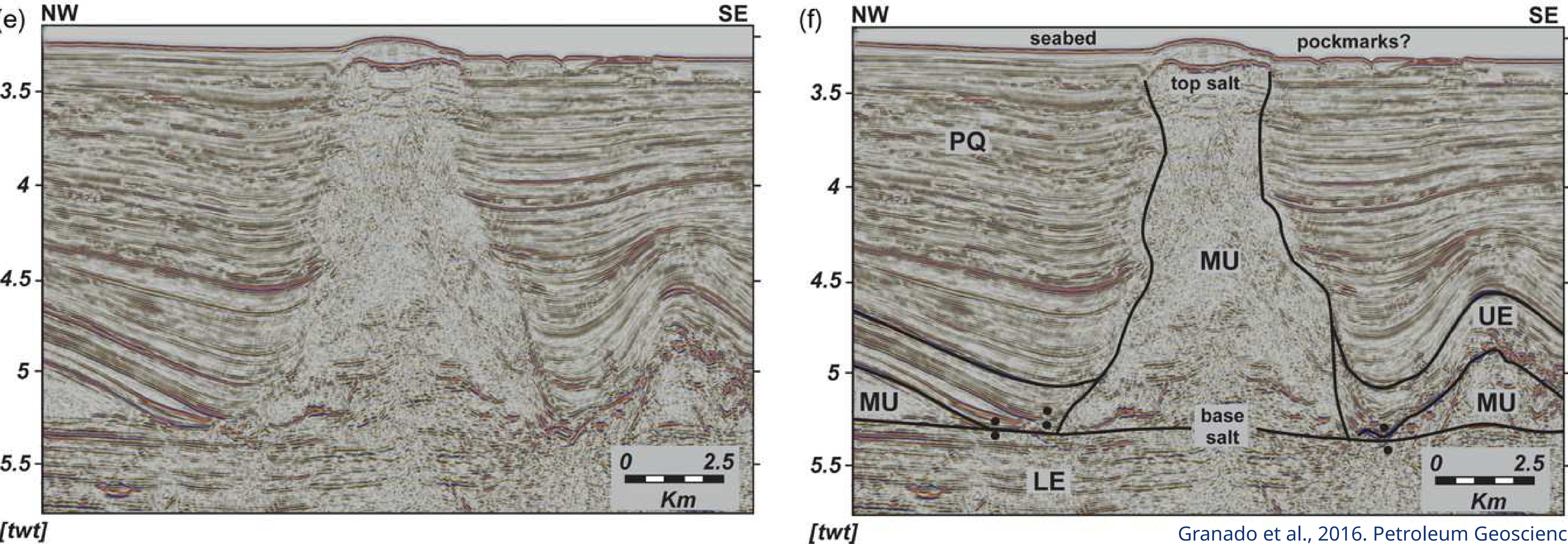
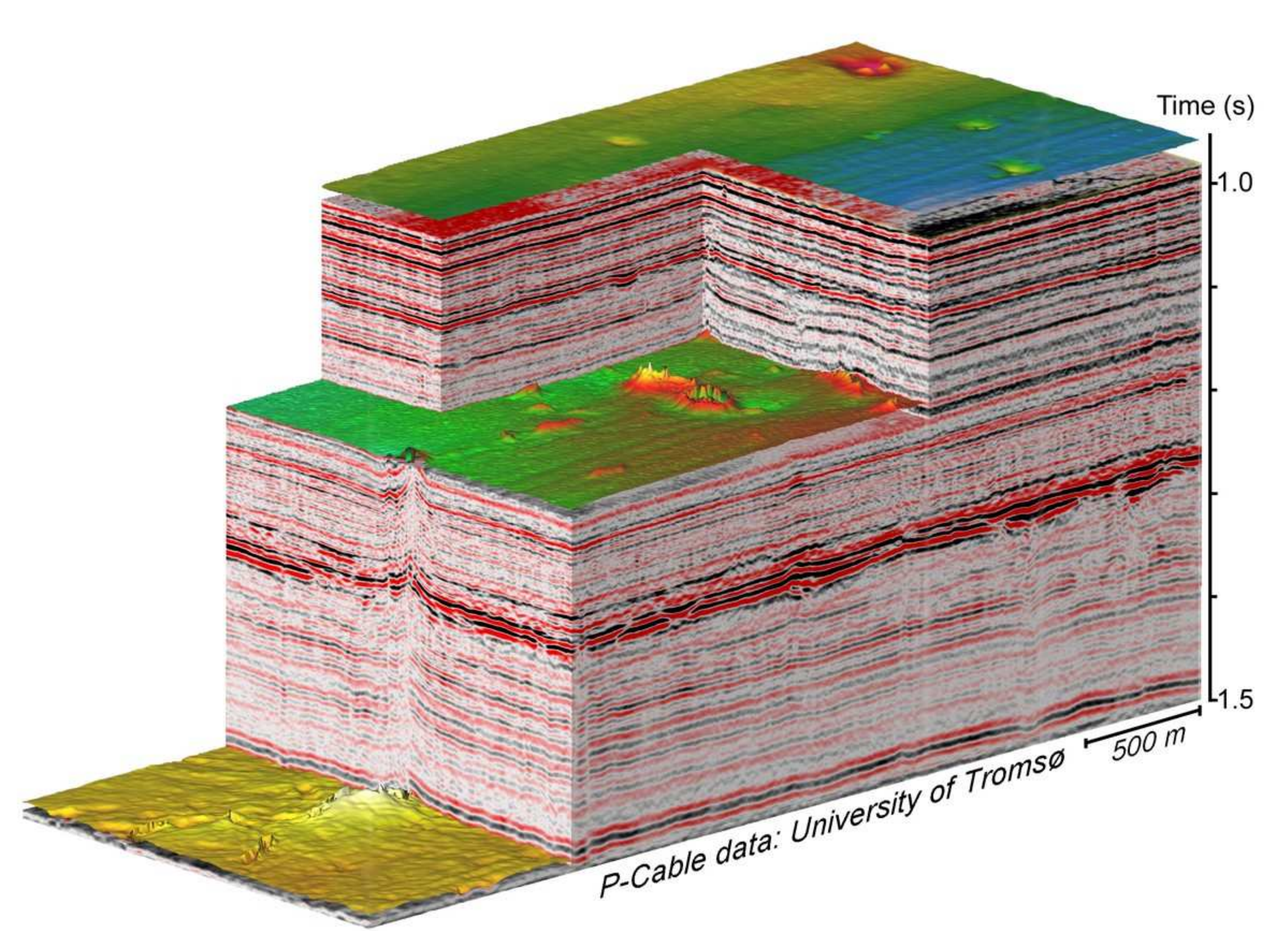
SALT DOMES IN THE WESTERN MEDITERRANEAN



Granado et al., 2016. Petroleum Geoscienc

METHANE GAS CHIMNEYS, SVALBARD MARGIN



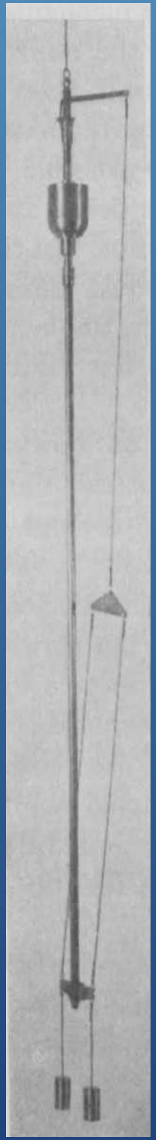
http://www.geometricspcable.com

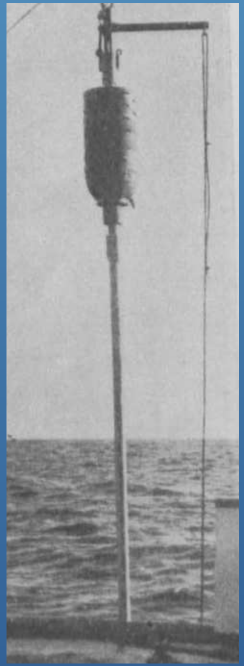
1946 ”Kullenberg” marine piston coring system

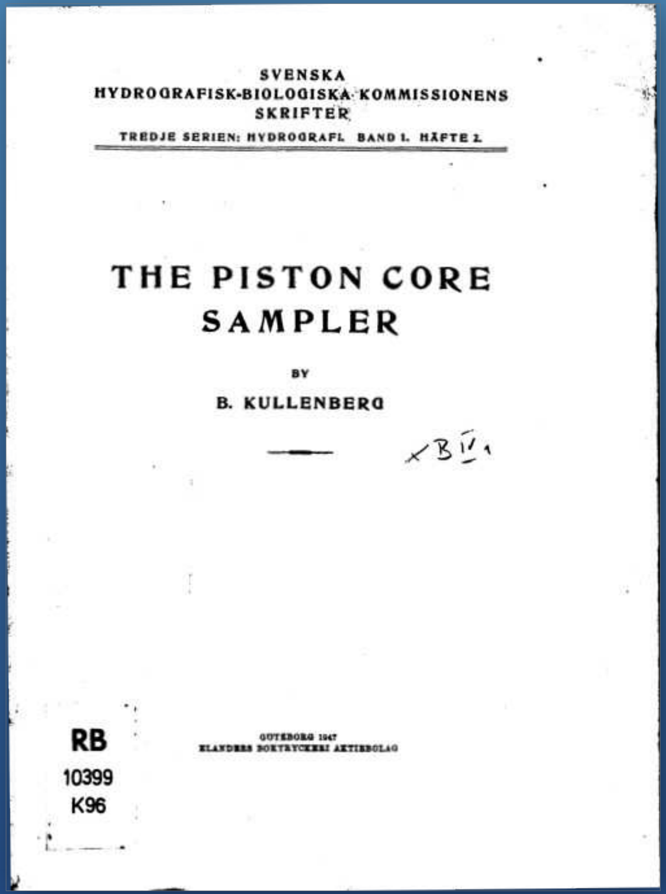
A modifications of the apparatus designed by
F. L. Ekman

The new coring instrument described in this paper was developed during the war years.

…the end of the war made it possible to try it in deep water during a cruise on board the Swedish research ship *‘Skagerak’* in the Mediterranean in the spring of 1946 (Swedish Deep-Sea Expedition in the Western Mediterranean).







SVENSKA
HYDROGRAFISK-BIOLOGISKA KOMMISSIONENS
SKRIFTER

TREDJE SERIEN: HYDROGRAFI. BAND 1. HÄFTE 2.

THE PISTON CORE
SAMPLER

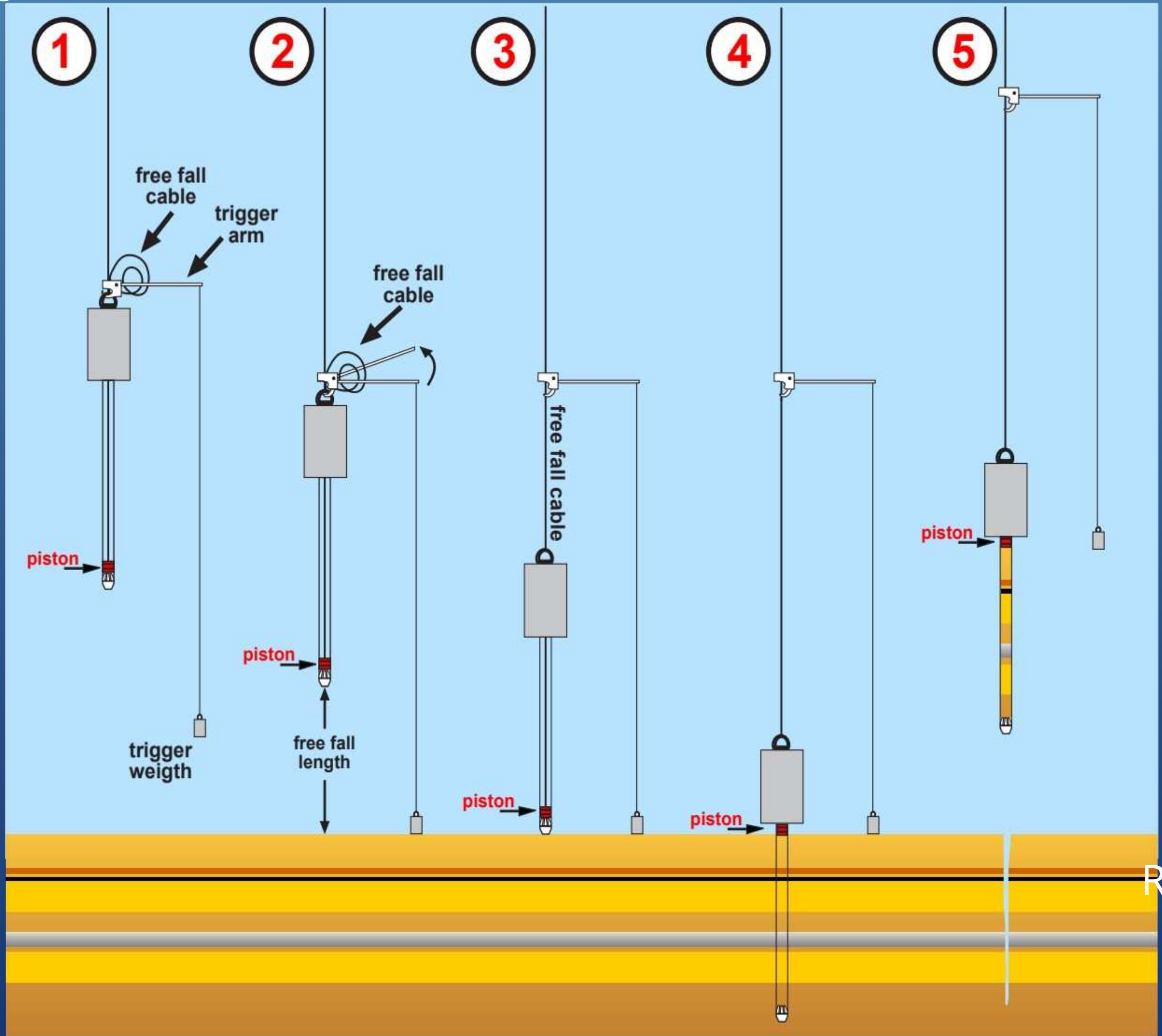
BY

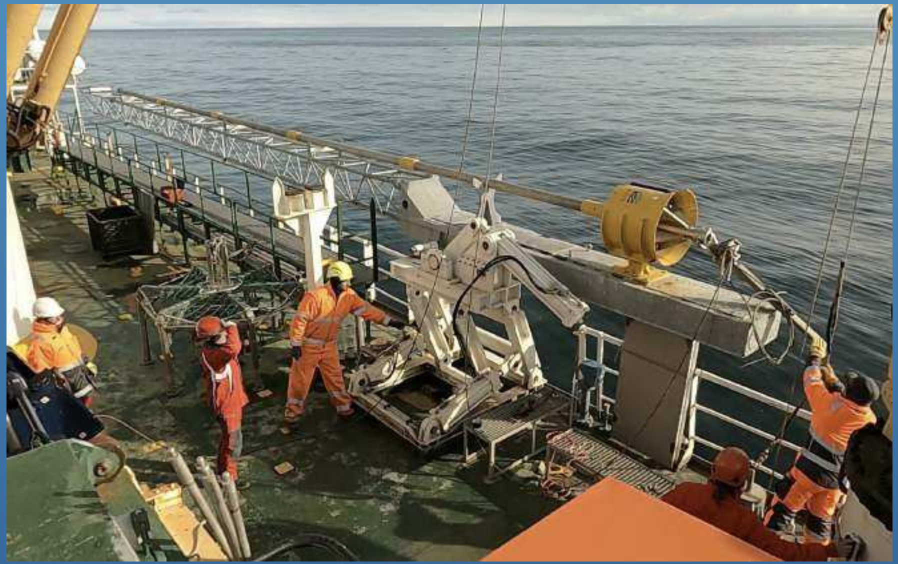
B. KULLENBERG

GÖTEBORG 1947
ELANDERS BOKTRYCKERI AKTIEBOLAG

RB
10399
K96

”Kullenberg” marine piston coring system



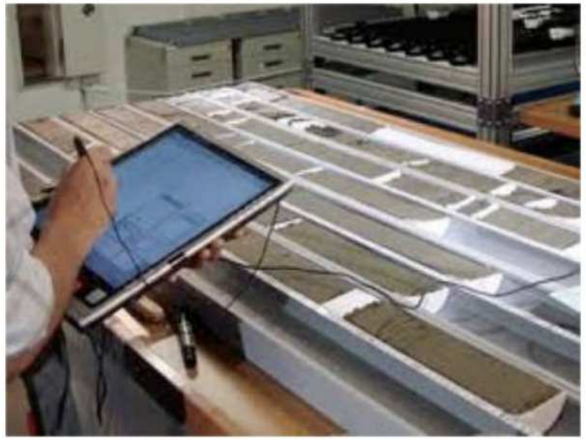


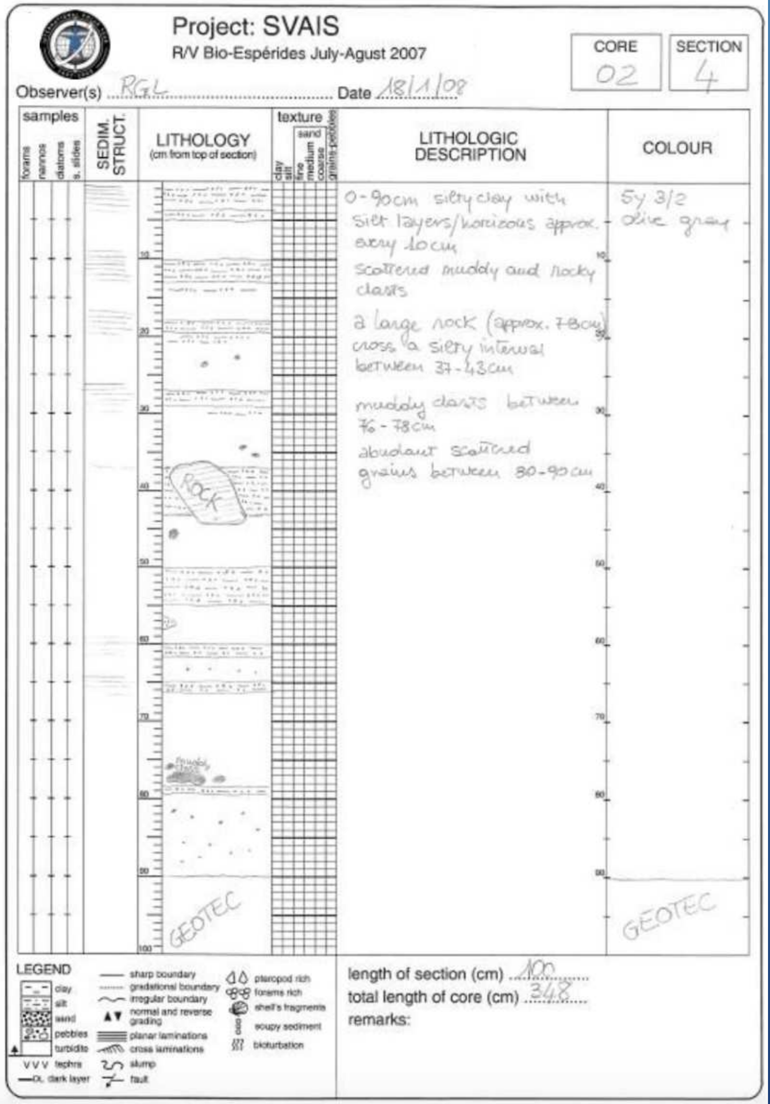
R/V Laura Bassi

Record penetration in sediments: about 60 m

Thanks to Renata G. Lucchi, OGS

”Kullenberg” marine piston coring system





Project: SVAIS

R/V Bio-Espérides July-Agust 2007

Observer(s) RGL .... Date 18/1/08

CORE 02 | SECTION 4

samples (forams, nannos, diatoms, s. slides)	SEDIM. STRUCT.	LITHOLOGY (cm from top of section)	texture (clay, silt, sand: fine, medium, coarse, grains-pebbles)	LITHOLOGIC DESCRIPTION	COLOUR
		ROCK		0-90cm silty clay with silt layers/horizons approx. every 10cm scattered muddy and rocky clasts a large rock (approx. 7-8cm) cross a silty interval between 37-43cm muddy clasts between 76-78cm abundant scattered grains between 80-90cm	5y 3/2 olive gray
		GEOTEC			GEOTEC

LEGEND: clay, silt, sand, pebbles, turbidite, tephra, DL dark layer; sharp boundary, gradational boundary, irregular boundary, normal and reverse grading, planar laminations, cross laminations, slump, fault; pteropod rich, forams rich, shell's fragments, soupy sediment, bioturbation

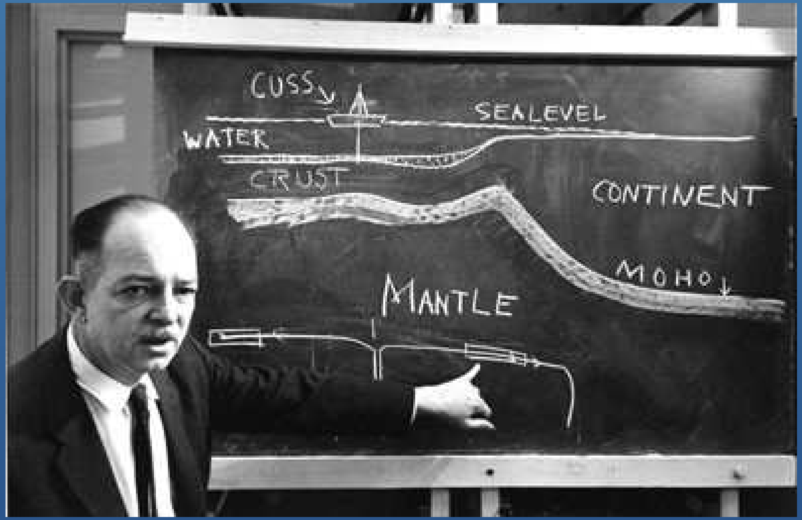
length of section (cm) 100

total length of core (cm) 348

remarks:

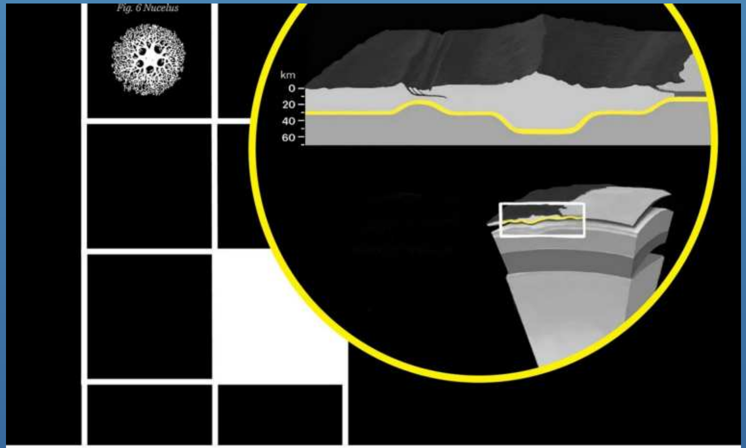
Thanks to Renata G. Lucchi, OGS

PROJECT MOHOLE (1958–1964)
proposed by Walter Munk and Harry Hess



Harry Hess discovered the Mid-oceanic ridges and the guyots, and in the ’62 he published the Sea floor Spreading theory, fundamental for the Plate Tectonic theory.

From left facing camera: Roger Revelle, Walter Munk, and Gustaf Arrhenius aboard the oil drillship, CUSS I, during Project Mohole, 1961.


How an ill-fated undersea adventure in the 1960s changed the way scientists see the Earth

Sometimes there's success in failure.

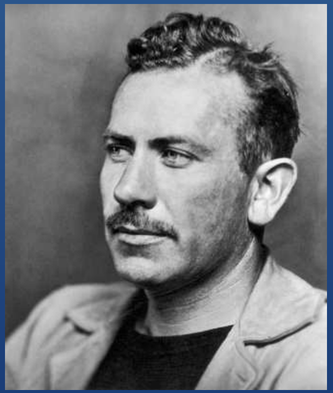
By Byrd Pinkerton | Mar 17, 2021, 9:00am EDT

https://www.vox.com/unexplainable/22276597/project-mohole-deep-ocean-drilling-unexplainable-podcast

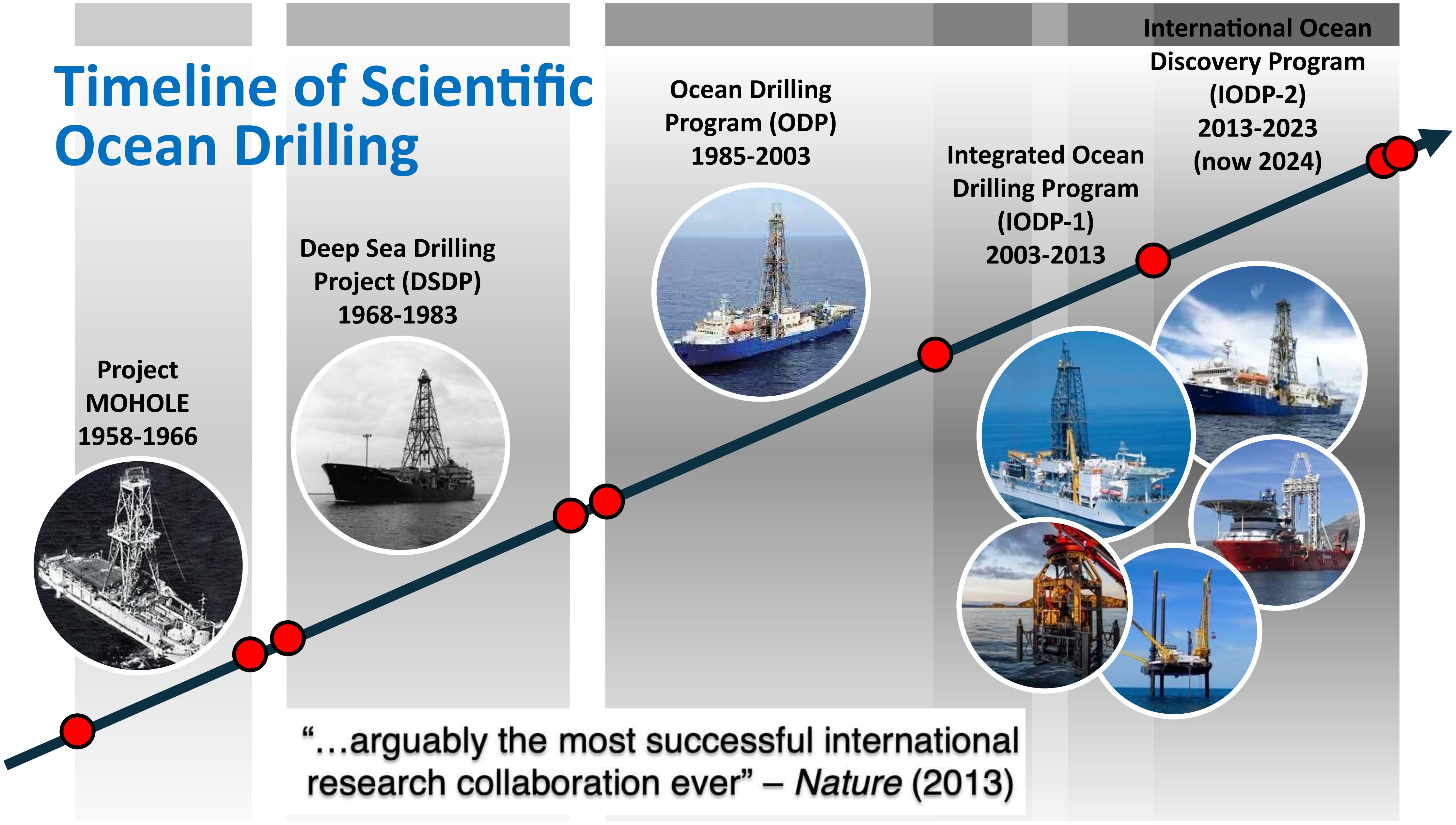
The drilling vessel CUSS I as used during phase 1 of Project Mohole.

Huge public interest developed, thanks to a prominent article by the famous novelist John Steinbeck in Life magazine (Steinbeck, 1961).

Steinbeck, J. 1961. High drama of bold thrust through ocean floor: Earth's second layer is tapped in prelude to Mohole. Life, April 14, 1961, 110–121.



Timeline of Scientific Ocean Drilling



"…arguably the most successful international research collaboration ever" – *Nature* (2013)

IODP³

INTERNATIONAL OCEAN DRILLING PROGRAMME

\+ **China** and **US** programs

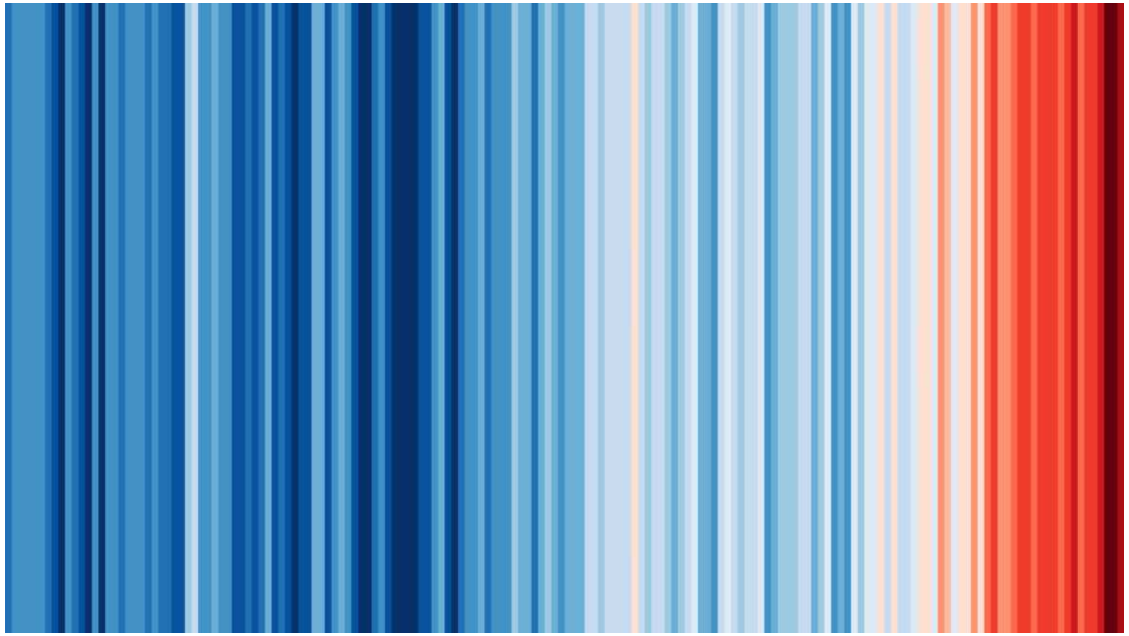
Penetration to about 2 km in sediments and rocks

IODP³ and Paleoclimate research

Warming stripes

Climate change is a complex global issue, requiring simple communication about its effects at the local scale. This set of visualisations highlight how we have witnessed temperatures change across the globe over the past century or more. The colour of each stripe represents the temperature of a single year, ordered from the earliest available data at each location to now. All other superfluous information is removed so that the changes in temperature are seen simply and undeniably.

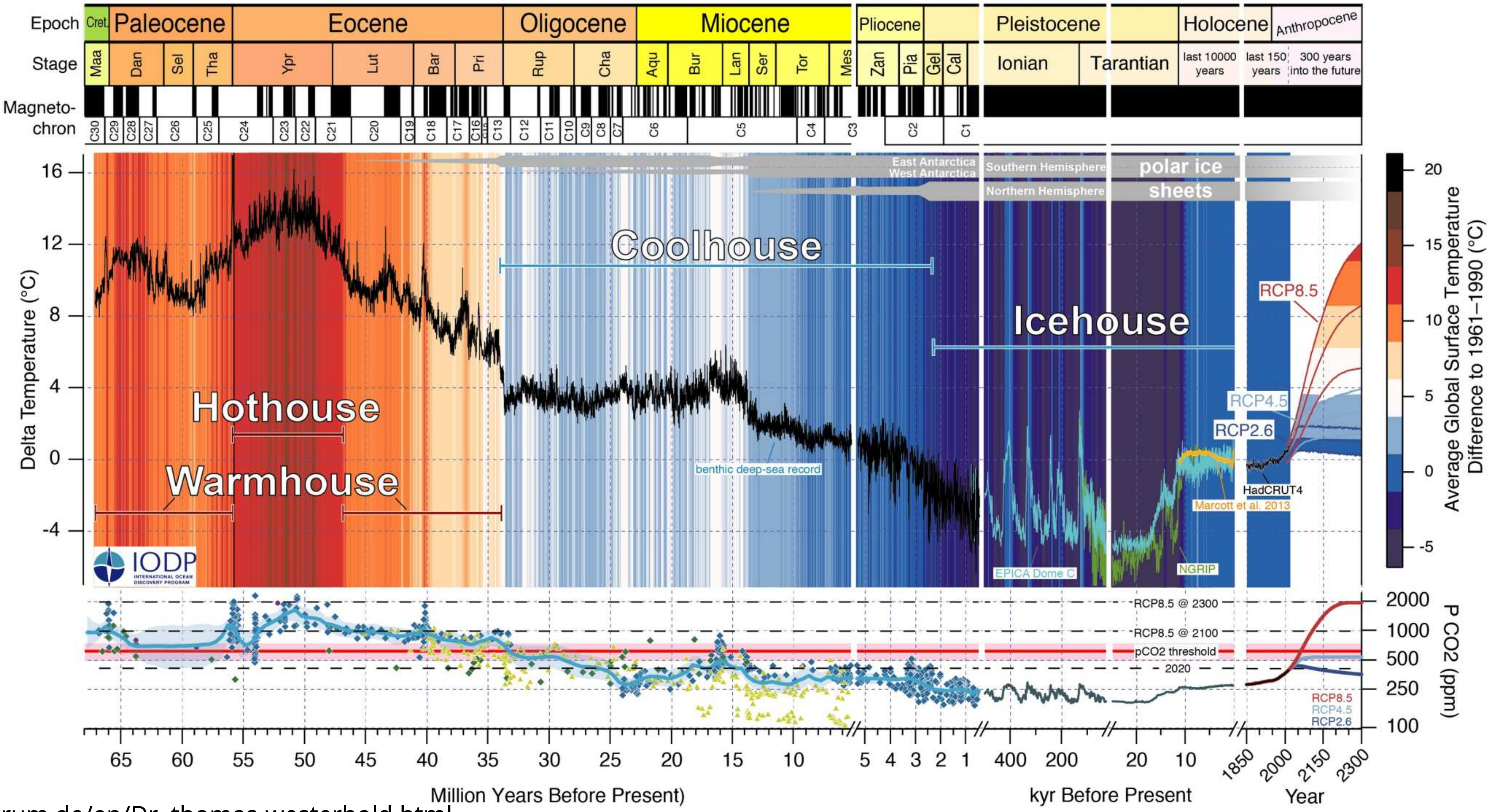
Annual global temperatures from 1850-2017



The colour scale represents the change in global temperatures covering 1.35°C

https://www.climate-lab-book.ac.uk/2018/warming-stripes/

Scientific drilling is the unique tool to understand paleoclimate and test climate model sensitivity

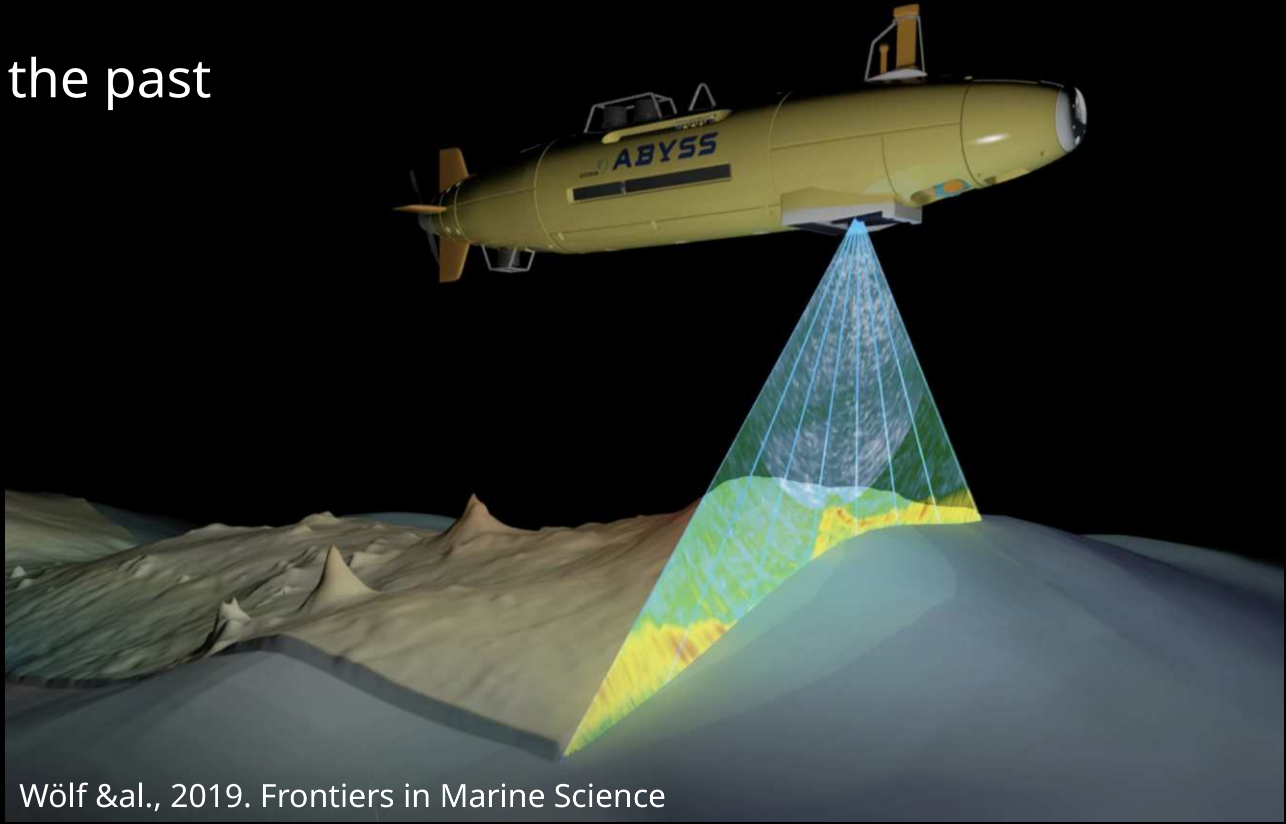


https://www.marum.de/en/Dr.-thomas-westerhold.html

Future

- Explore the hadal zone
- Use of deep sea drones
- New era in scientific drilling
- Enable the safe and sustainable use of the seafloor in the Blue Economy sector (resources, cables, pipelines….)
- Understand submarine geological hazards
- Sample the Earth's mantle
- Improve the understanding of the climate of the past
- …………………

Offshore Energy, Source: Saipem



Wölf &al., 2019. Frontiers in Marine Science

How deep is the ocean

Thank you

Google Earth Pro

The Warship Voyager universe Earth.
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