UNCOVERING THE MEDITERRANEAN SALT GIANT

Angelo Camerlenghi

OGS - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

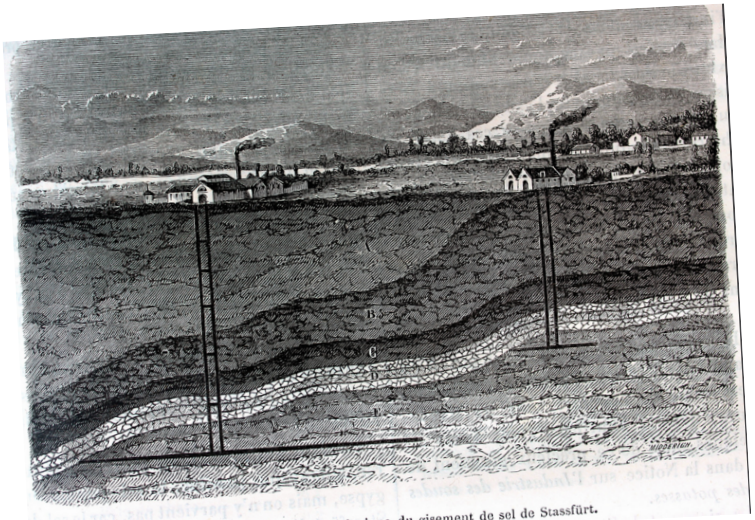
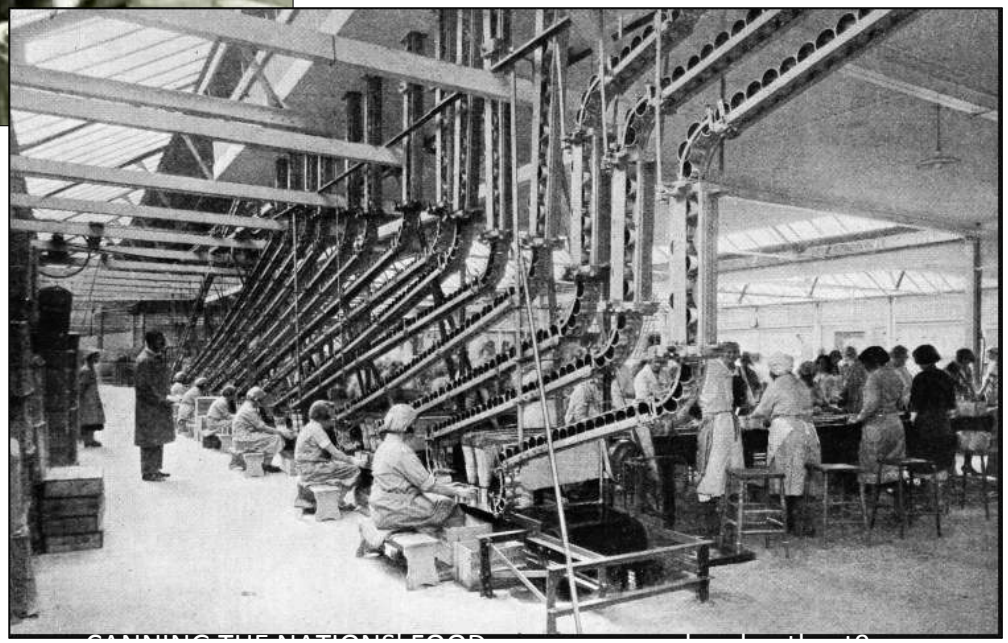


Fig. 319. — Coupe géologique du gisement de sel de Stassfürt.

INAIL **Mostra fotografica itinerante sulle donne tra antichi mestieri e nuovi rischi – Liguria**



Anik Messier

Ettore and Infersa Salt Museum, Marsala, Sicily

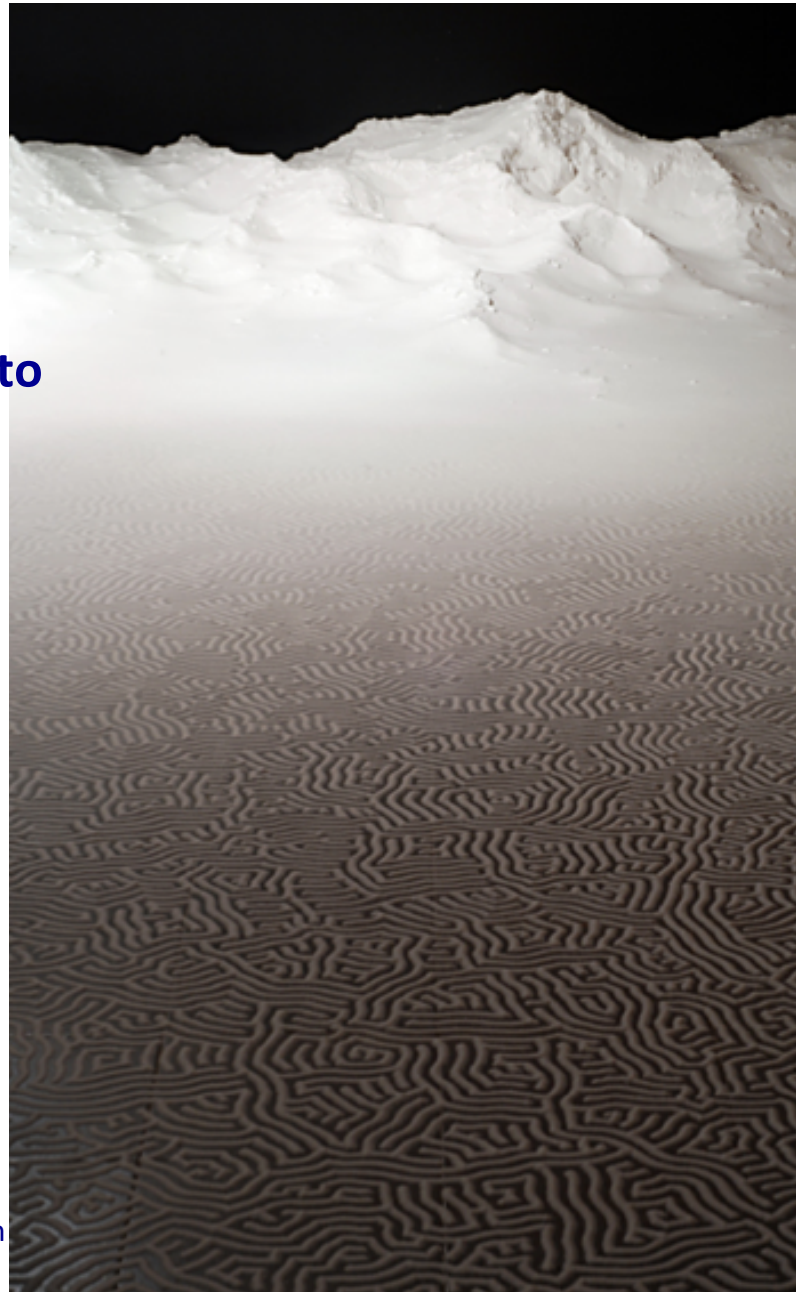
ITALKALI

Distribution of salt to attendees of a funeral, Rima Valsesia, Italy

Motoi Yamamoto

LABYRINTH
salt
3.2 x 11m
Reliefs
Fondation Espace
Ecureuil
Jan - Feb, 2011

LABYRINTH
salt
5 x 14m
Making Mends
Bellevue Arts Museum
March - May, 2012



Salt originates from evaporation of seawater:

1) natural evaporation

>>>>> rock salt

2) artificial evaporation

>>>>>marine salt

Cl^-

Na^+

Mg^{-2}

SO_4^{-2}

Ca^{-2}

K^+

6 major ions in seawater
Their concentration follows the **Marcet's Principle**:
The relative amounts of these ions in seawater is fixed, no matter what the salinity is.

Salinity in the global ocean: 30 – 40 per mil in weight

Sequence of salt precipitation by evaporation of seawater

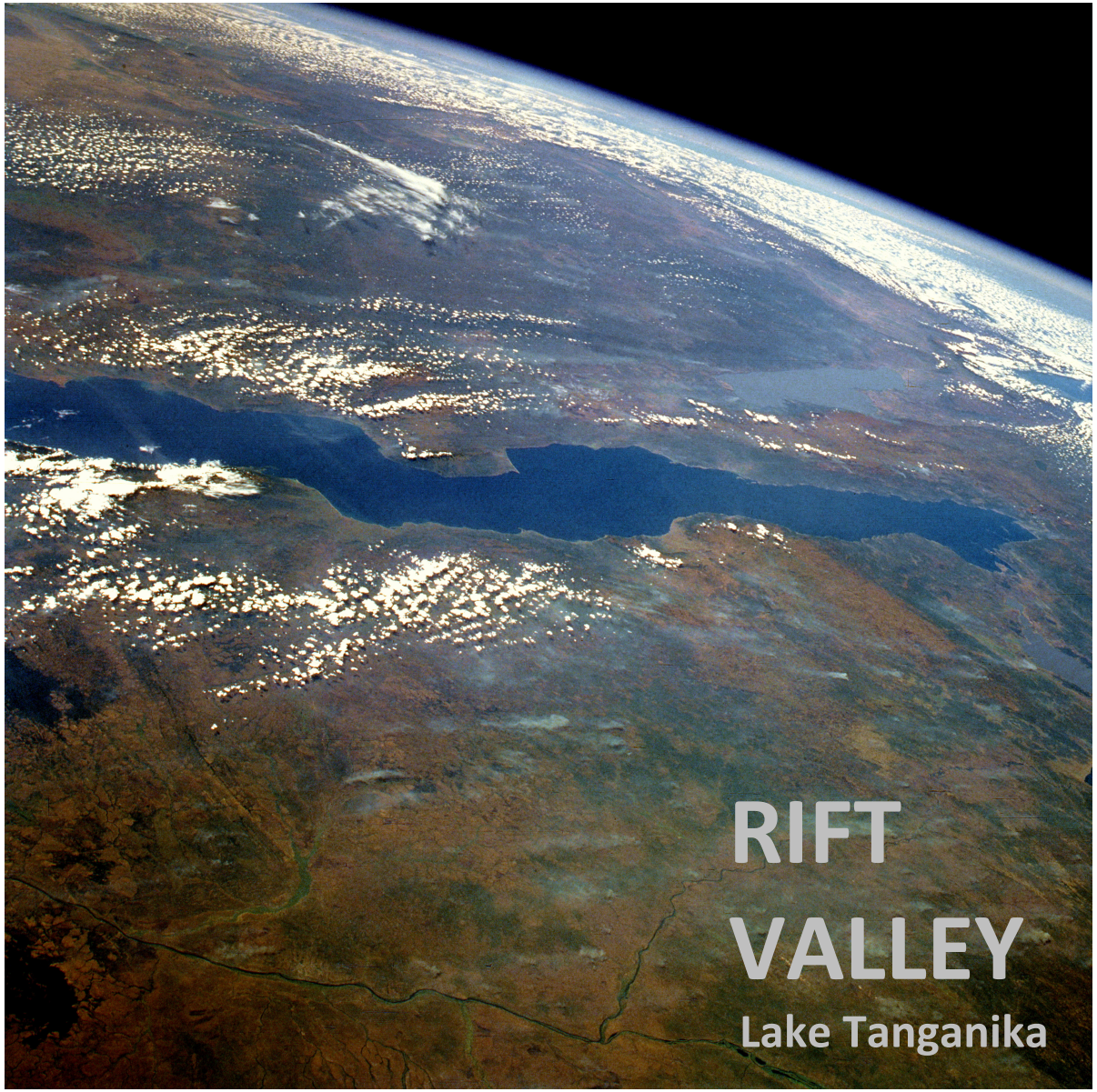
1) $CaCO_3$ & $CaMg(CO_3)_2$ — Calcite and dolomite

2) $CaSO_4$ $2H_20$ — Gypsum

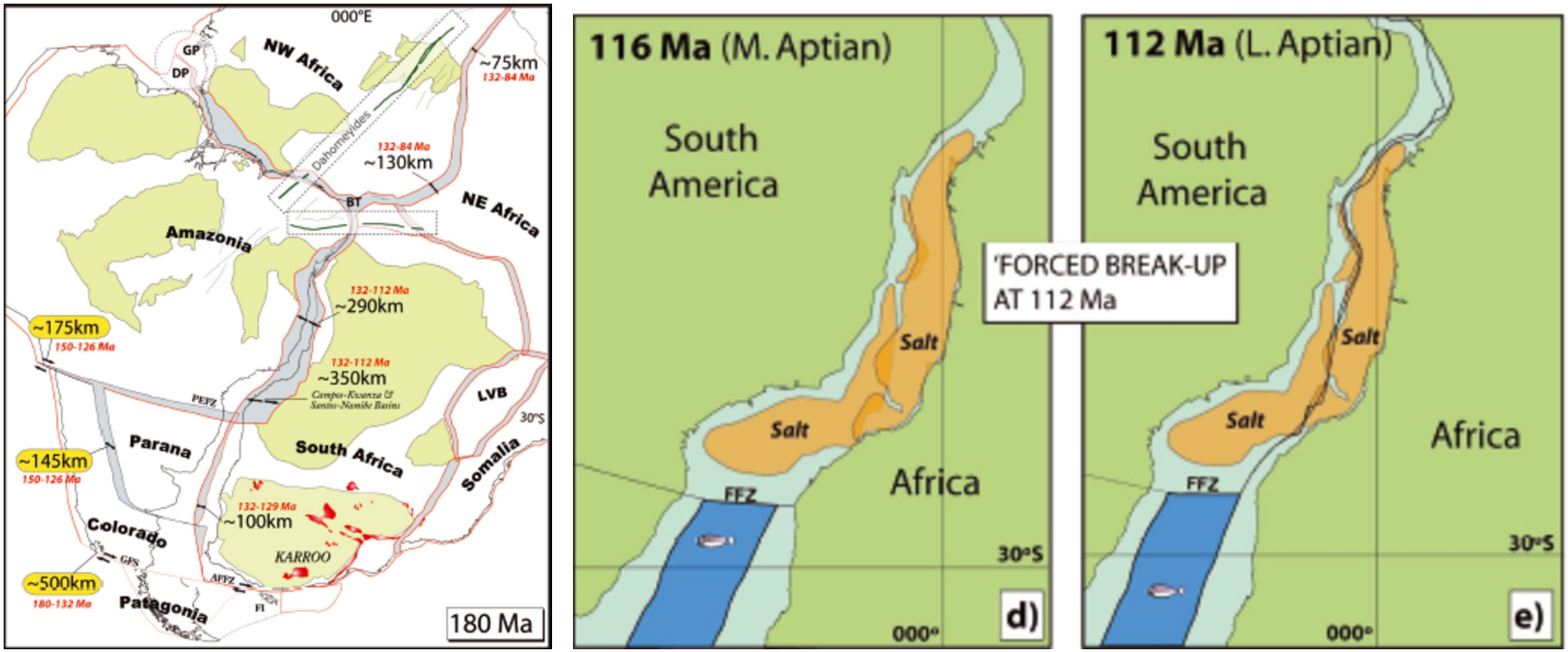
3) $NaCl$ — Halite

4) KCl — Potash -salts

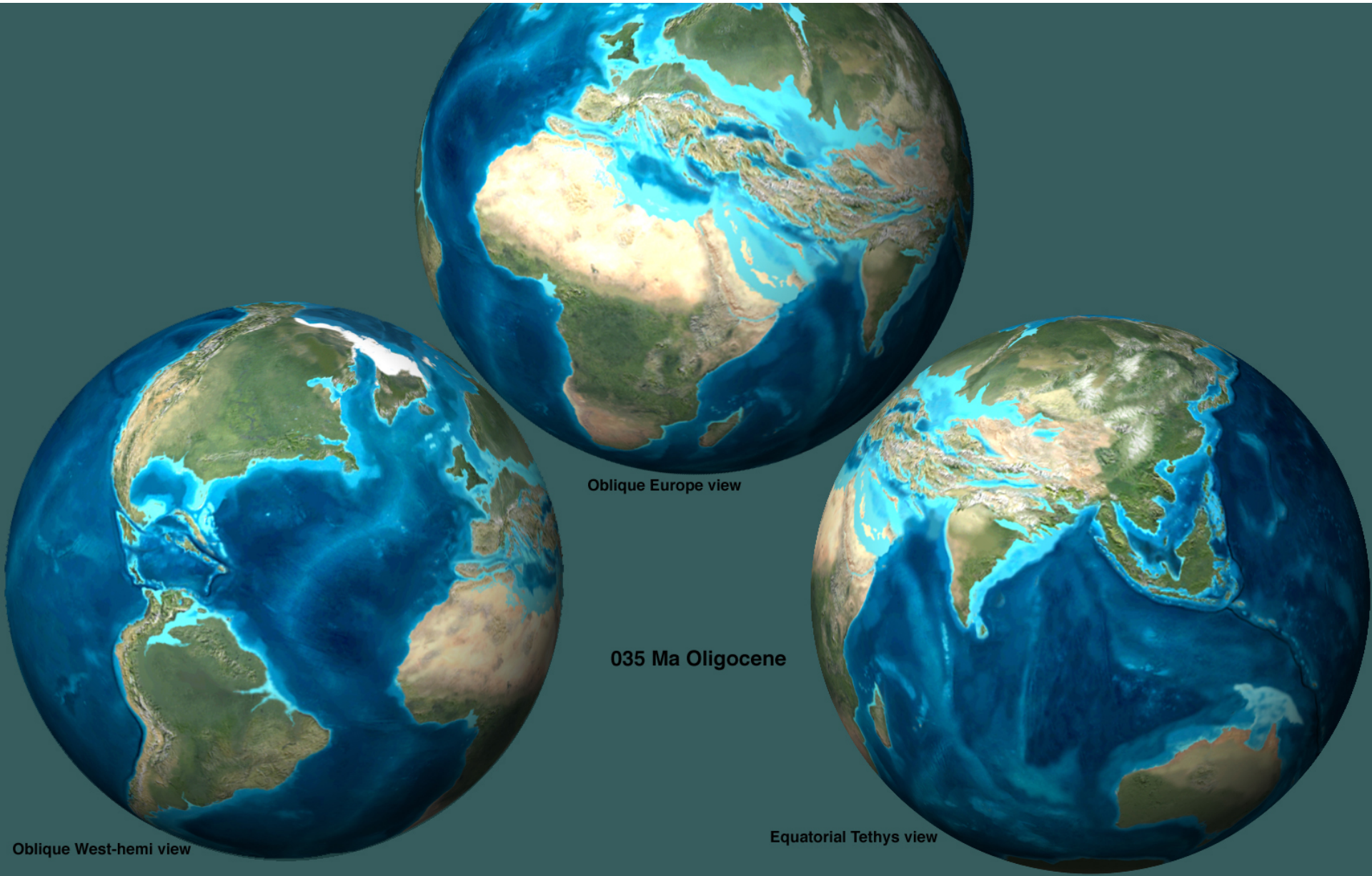
Evaporation of an ocean occurs during the birth and death of oceanic basins

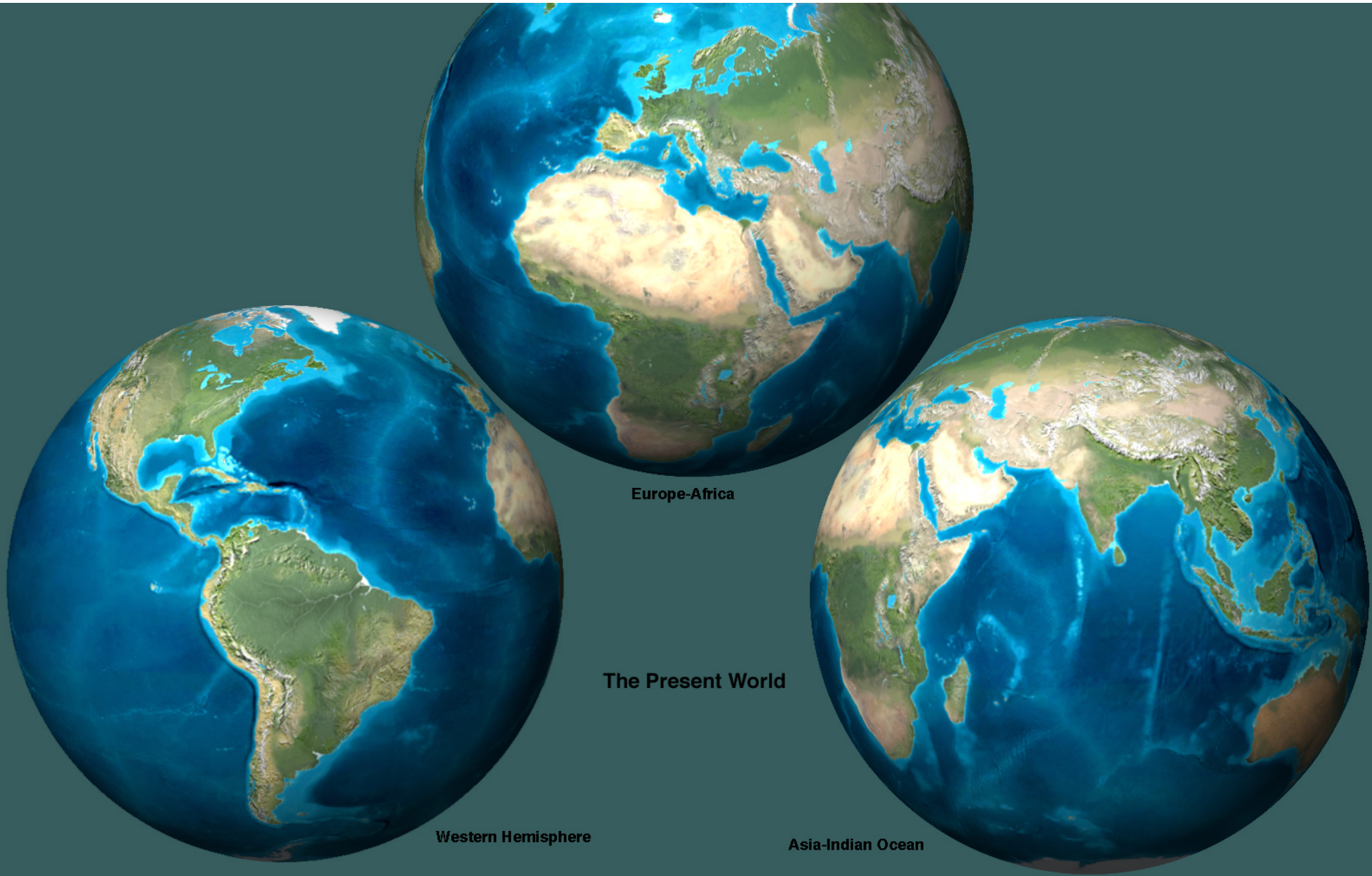


NASA

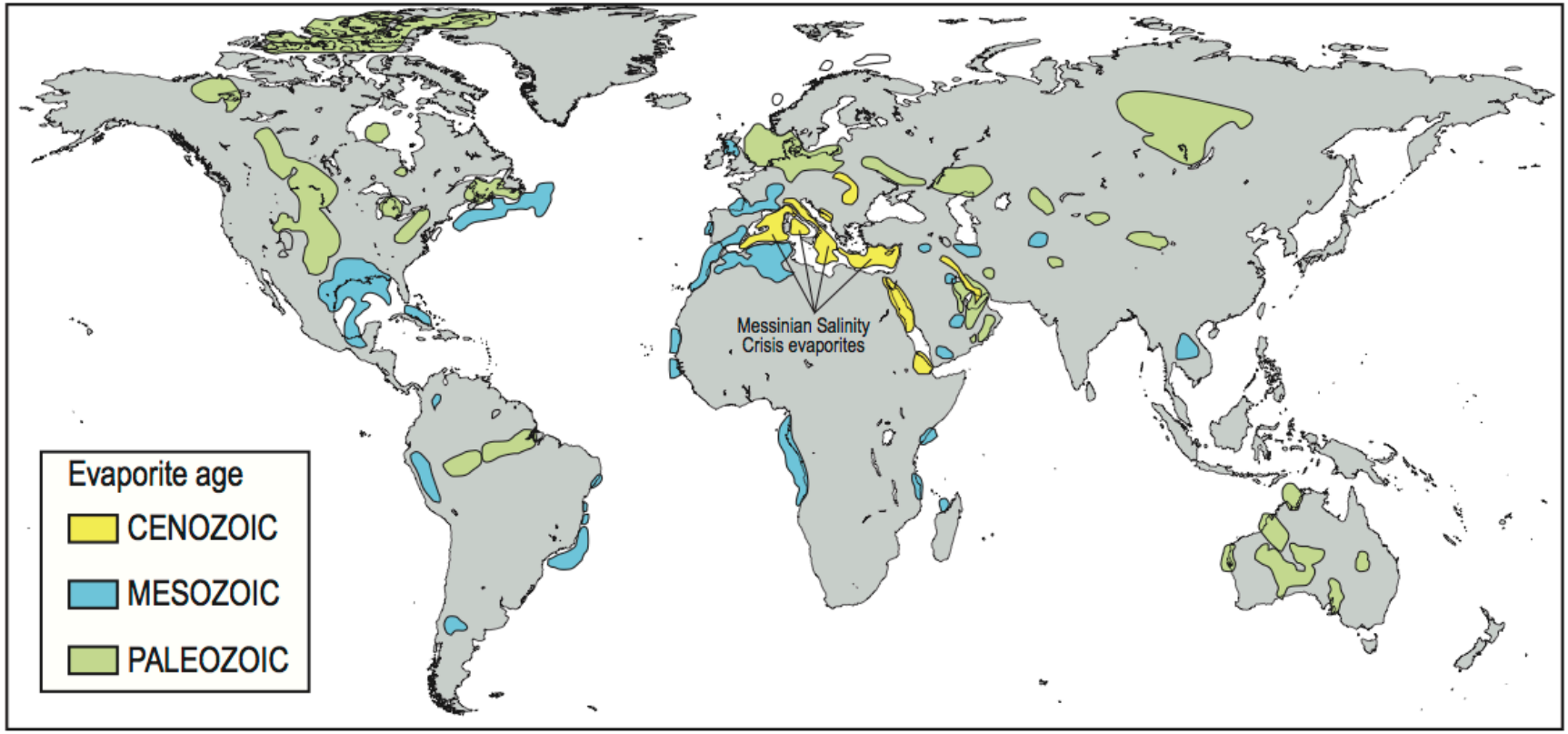


Torsvik T H et al. Geophys. J. Int. 2009;177:1315-1333


Oblique Europe view
035 Ma Oligocene
Oblique West-hemi view
Equatorial Tethys view


Europe-Africa
The Present World
Western Hemisphere
Asia-Indian Ocean

SALT GIANTS IN THE WORLD



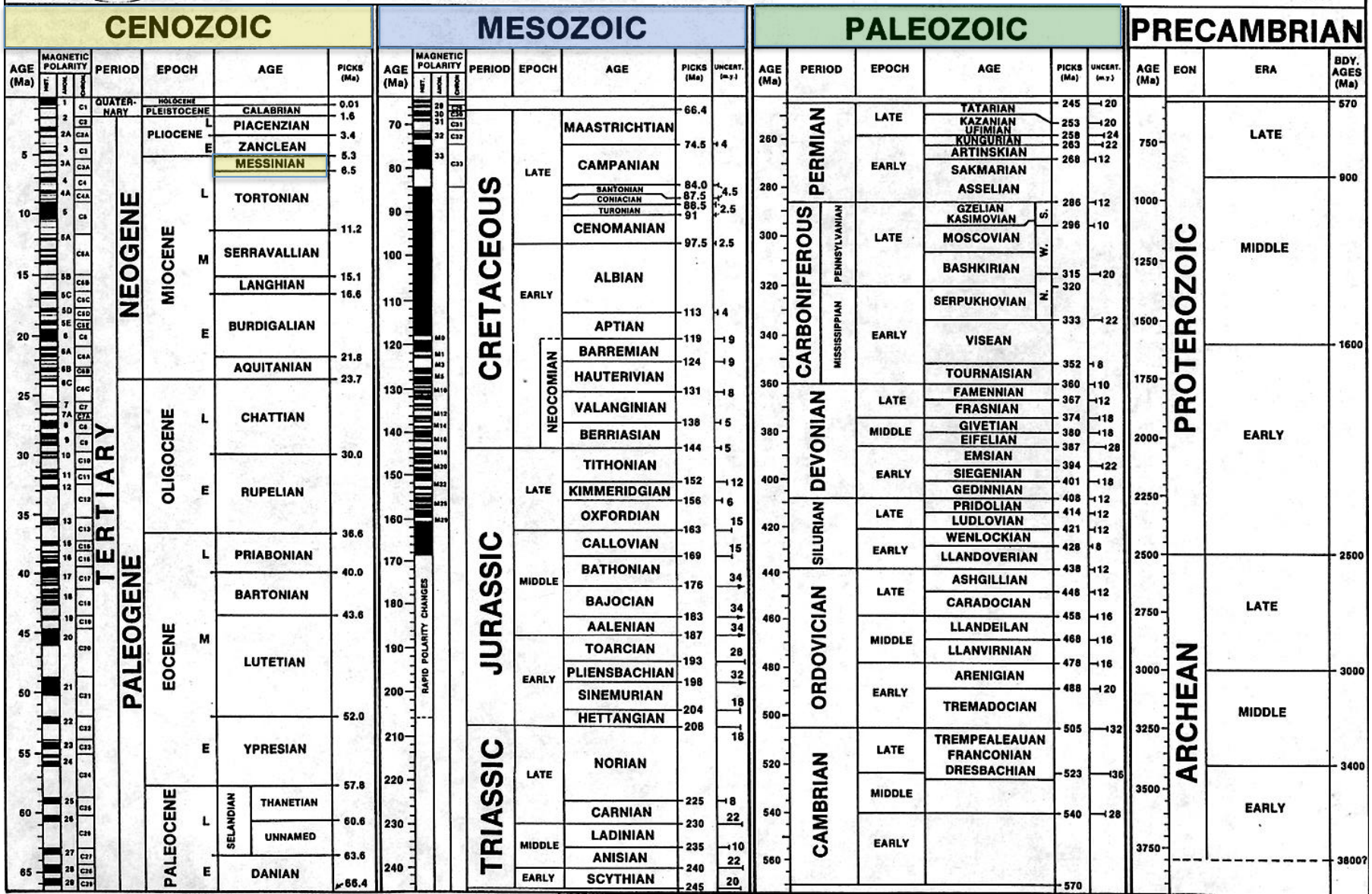
THE GLOBAL IMPORTANCE OF SALT GIANTS

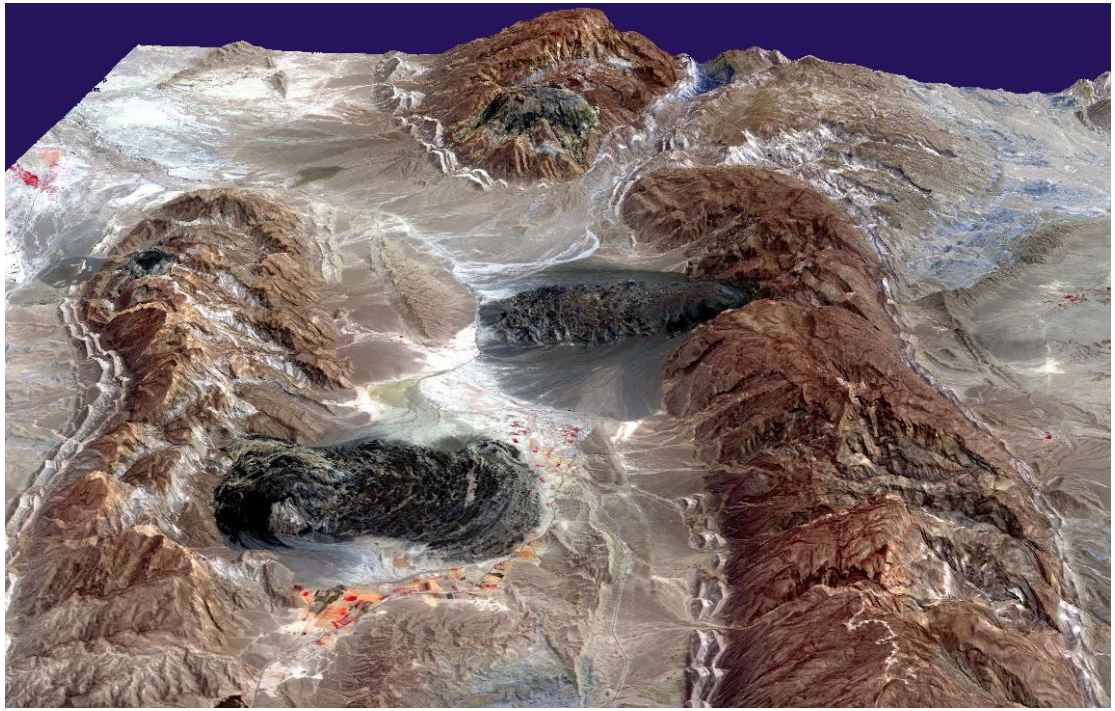
- sedimentary expression of extreme environmental events of global relevance;
- impact the structural, chemical and biological evolution of sedimentary basins;

DECADE OF NORTH AMERICAN GEOLOGY
GEOLOGIC TIME SCALE

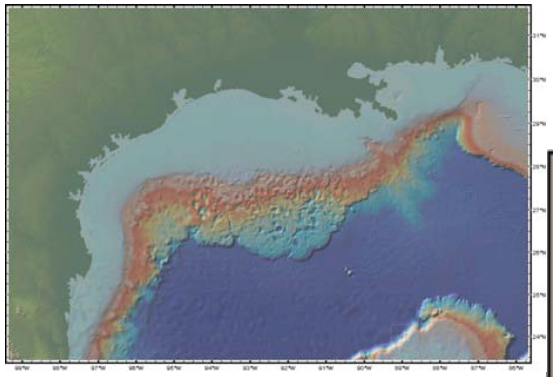
DNAG

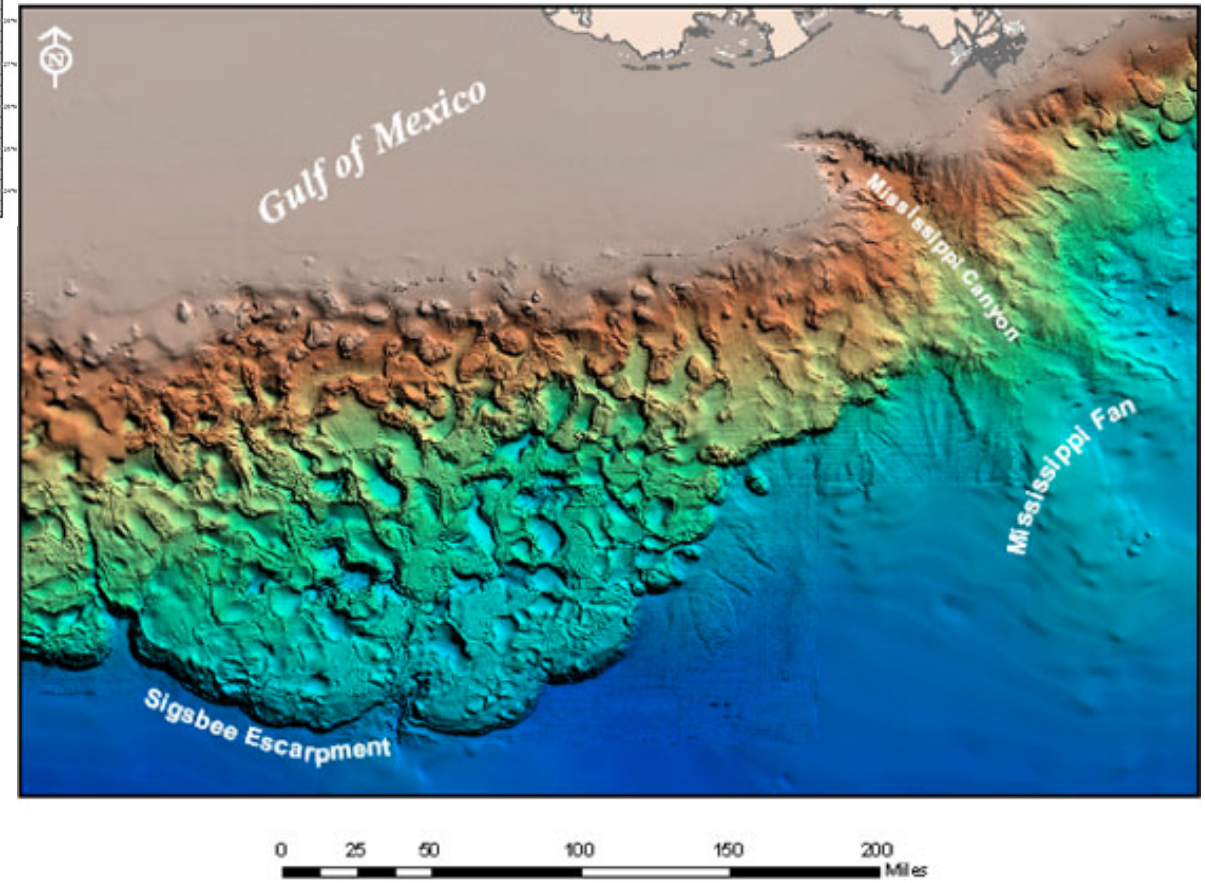
GEOLOGICAL SOCIETY OF AMERICA



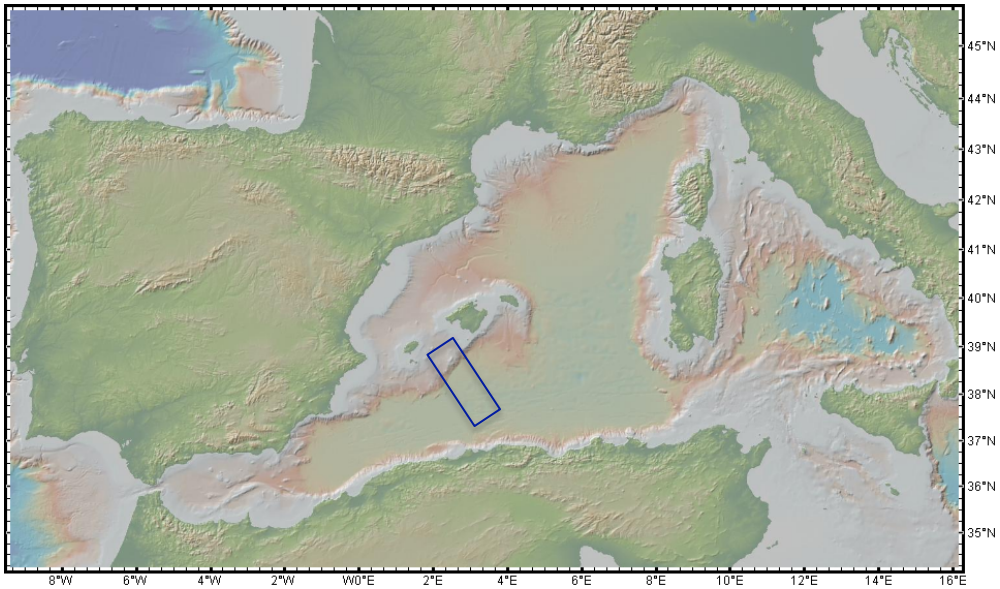


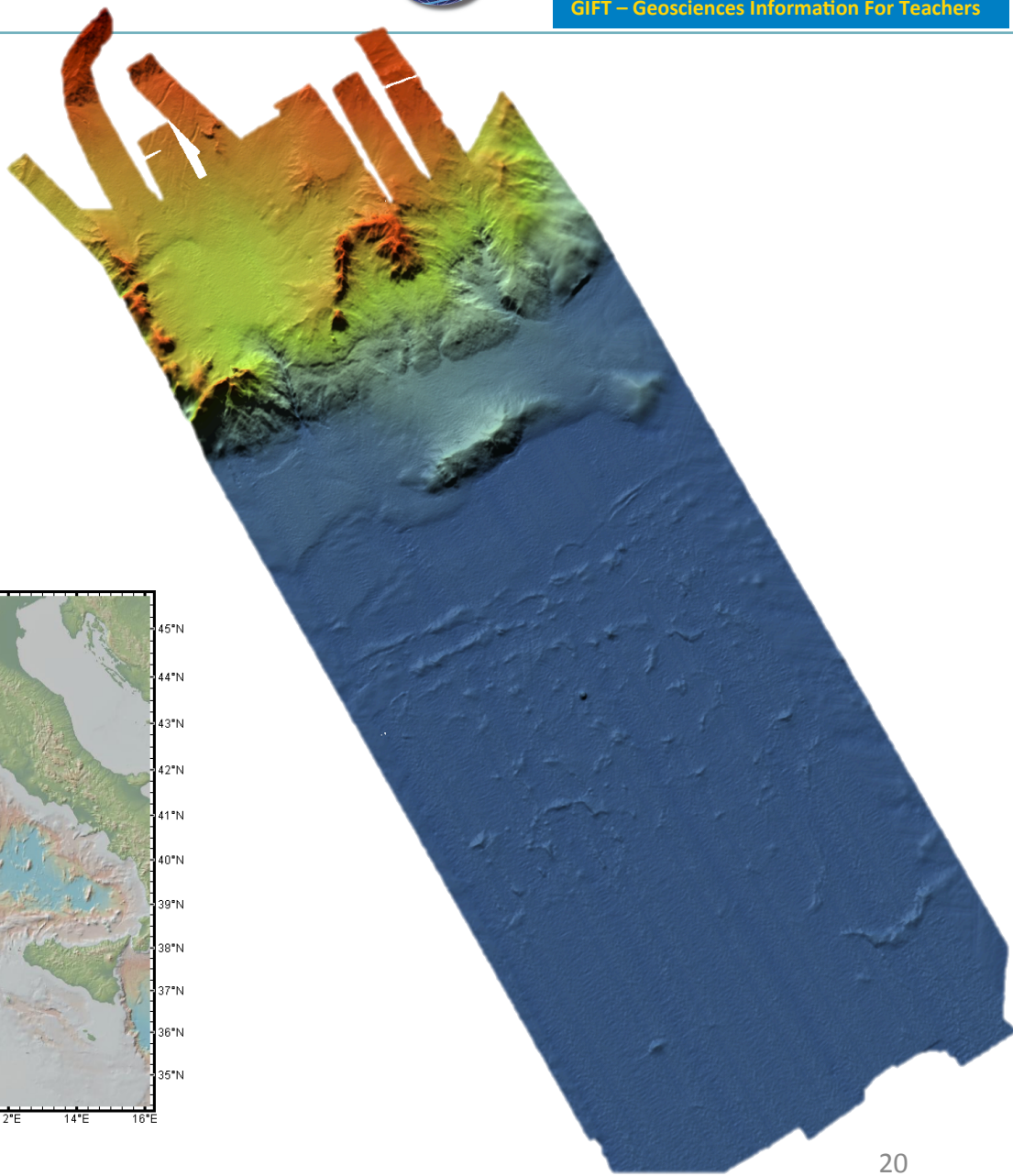
Salt glaciers
http://geology.com/stories/13/salt-glacier/




Gulf of Mexico
Mississippi Canyon
Mississippi Fan
Sigsbee Escarpment
0
25
50
100
150
200
Miles

Algero-Balearic Basin
Mediterranean Sea





Surface	2,500,000 km^2
Average depth	1,500 m
Maximum depth	5,267 m
Volume	3,750,000 km^3
Salinity	38‰

If we evaporate the Mediterranean today:

1500 m^3 ≅ 1500000 kg ≅ 1500 x 38 = 57000 kg of salt per m^2

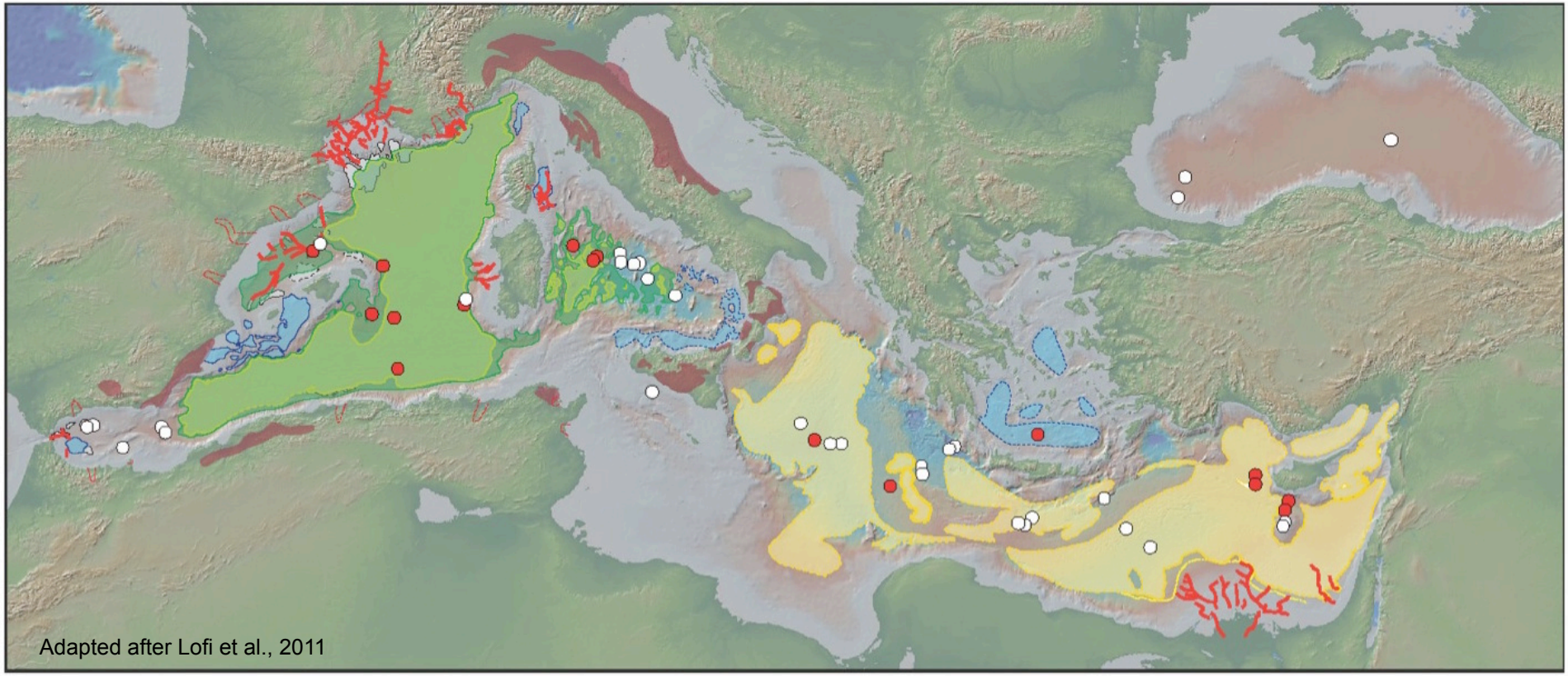
Density of halite: 2200 kg m^{-3}

57000 kg m^{-2} / 2200 kg m^{-3} = **26 m of salt!**

THE MEDITERRANEAN SALT GIANT

Extreme, but geologically brief event (640 ka, 5.97 – 5.33 Ma), that changed the chemistry of the global ocean and impacted both the terrestrial and marine ecosystems;

More than 10^6 km^3 of salt (6% of the dissolved oceanic salt) accumulated;



SALINITY CRISIS IN THE MEDITERRANEAN

Formation **Gessoso-solfifera'** in The Northern Apennines

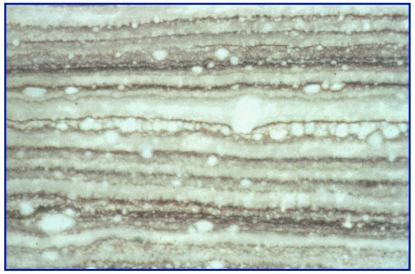
In 1960 Raimondo Selli invented the term Messinian Salinity Crisis to explain the deposition of gypsums of the Messinian Stage of the Miocene.

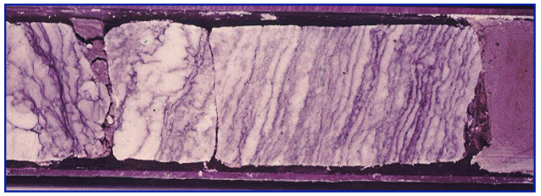
SELLI R. (1960) - Il Messiniano Mayer-Eymar 1867. Proposta di un neostratotipo. **Giornale di Geologia,** 28**, Bologna**

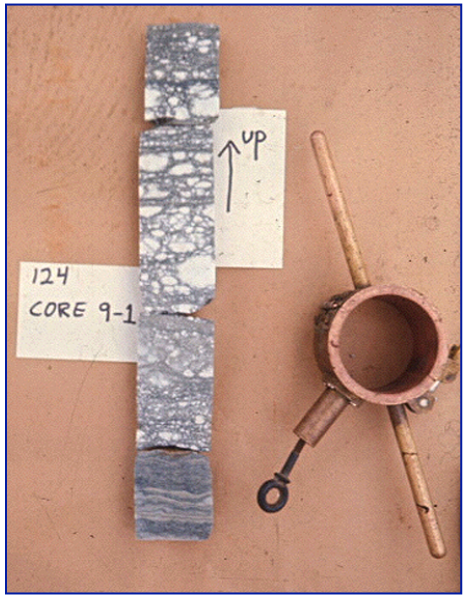
TURNING POINT: THE DEEP SEA DRILLING PROJECT (DSDP) MEDITERRANEAN EXPEDITION IN 1970

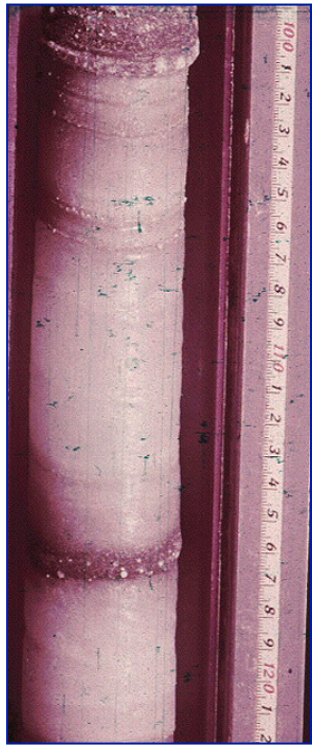
Drilling Ship Glomar Challenger, Deep Sea Drilling Project

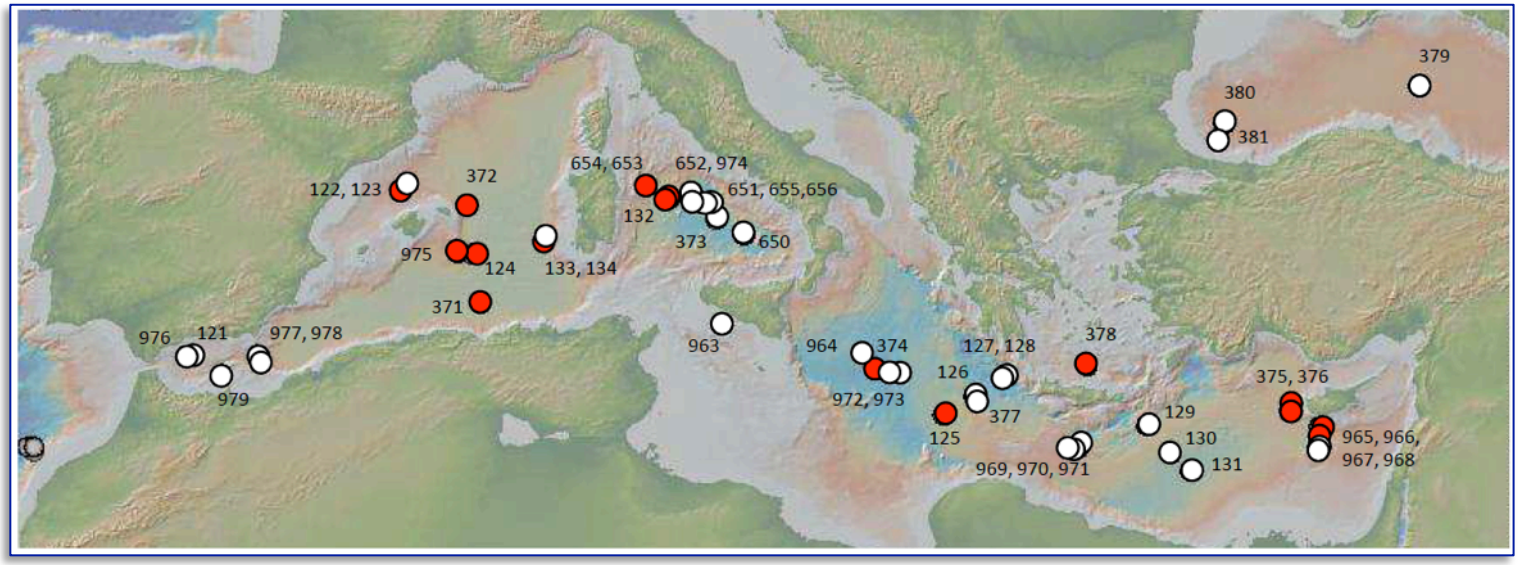
UN COVERING THE MEDITERRANEAN SALT GIANT

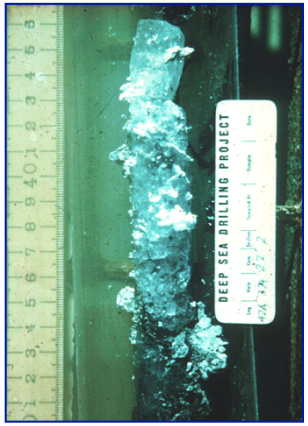


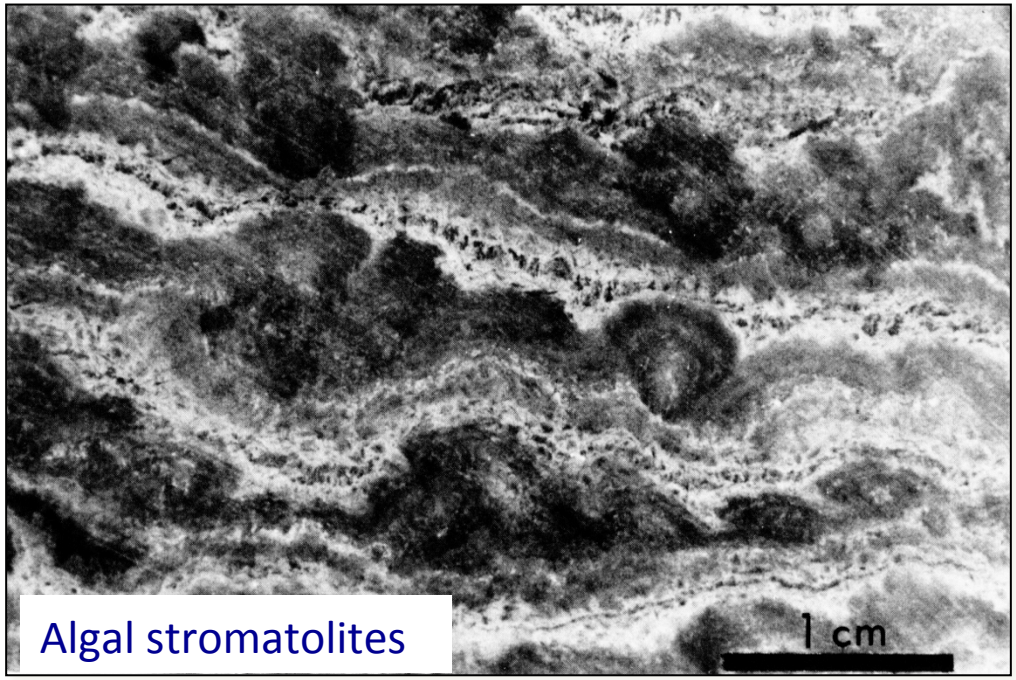












Algal stromatolites

Courtesy: Bill Ryan, presentazione Magellan Workshop 2013, Brisighella

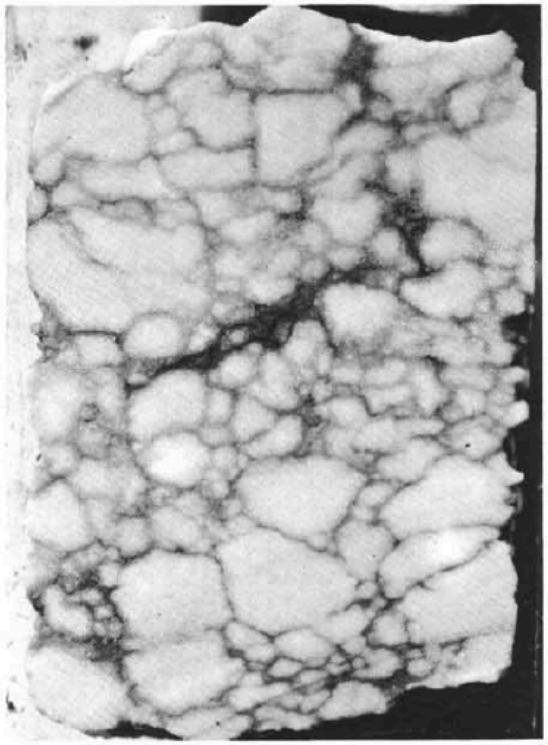


Figure 16. *Messinian evaporitic series. Massive gypsum with undulated laminations suggesting stromatolites. Tyrrhenian Sea (132-27-2, 105 cm on scale).*

Nesterof, Wetzel, Pautot, DSDP Leg 13 Scientific Report, 1973

THE OBSERVATION:

Shallow water deposition of teh Messinain evaporites: nodular shape of anhydrite and "chicken-wire" stromatolitic laminatioin

A petrographic study of the evaporite rocks in cores obtained from Sites 124, 132, and 134 suggests that these rocks originated in a subaerial sabkha environment (Friedman, DSDP Leg 13 Initial Reports, 22, 1973)

From salinity crisis to desiccation theory for the Mediterranean Sea, 1973

240 NATURE VOL. 242 MARCH 23 1973

Late Miocene Desiccation of the Mediterranean

K. J. HSÜ
Geologisches Institut, ETH, Zürich
W. B. F. RYAN
Lamont-Doherty Geological Laboratory, Palisades, New York
M. B. CITA
Università degli Studi, Milano

This article presents evidence that the Mediterranean Sea was a desiccated deep basin some 6 million years ago.

THE presence of an evaporite deposit of Late Miocene Messinian age under the Mediterranean Sea was discovered two years ago by the Deep Sea Drilling Project (DSDP) Cruise Leg XIII (refs. 1–4). To start with, our postulates were greeted with disbelief, but detailed analyses of samples and syntheses of regional geology during the past two years have led to a confirmation of this apparently preposterous idea. We shall present in this article our principal conclusions and some of the critical evidence. Detailed documentation will be published in due course[5].

Three Models

The origin of the Mediterranean evaporites could be accounted for by three different models. In the first, there was evaporation of a deep water Mediterranean basin, which received constant inflow from the Atlantic so that its brine level was maintained at or slightly below the world wide sea level. The second involves evaporation of a shallow water Mediterranean basin, which, similarly, received constant inflow from the Atlantic so that its brine level was maintained at or slightly below the world wide sea level. According to the third, desiccation of a deep Mediterranean basin, isolated from the Atlantic, took place, so that evaporites were precipitated from playas or salt lakes whose brine levels were dropped down to thousands of metres below the Atlantic sea level.

The first may be called the "deep water, deep basin model"[6] and the second the "shallow water, shallow basin model"[7]. The third, namely the desiccated deep basin model, is, however, the one we prefer.

Late Miocene Basin Geometry

Geophysical evidence—chiefly the basin-wide distribution of an acoustic reflector[8] (Fig. 1) which has been identified by drilling as the top of the Mediterranean evaporites[5] clearly indicates that the Late Miocene Mediterranean had a configuration not greatly different from that of today. The surface of the reflector conforms more or less to the contours of the intricate submarine topography, indicating that the Mediterranean basin had already been created when the evaporite was being deposited.

More convincing evidence is provided by stratigraphical and palaeontological studies. The strata underlying the evaporites are deep marine pelagic sediments. During the DSDP Leg XIII, Middle Miocene pelagic marls were cored from sites 126 and 129 (see Fig. 2) in the Ionian Basin[1,2], and lower Upper Miocene (Tortonian) marls were sampled from site 121 in the Alboran Basin[3]. The correlative Tortonian marl underlying the Upper Miocene evaporites (Messinian) of Sicily has been proved to be a deep water deposit by a study of its benthonic foraminiferal faunas[9]. Deep marine pelagic marls of Lower Miocene age are also known on the island of Pianosa in the Tyrrhenian Sea[10]. These facts clearly indicate that the Mediterranean basins were already deep before the salinity crisis.

The strata directly overlying the Messinian evaporites are also deep marine pelagic sediments. These earliest Pliocene strata contain a benthonic ostracod fauna, which could only live in ocean bottom below 1,000 m (ref. 11). The associated benthonic Foraminifera are likewise indicative of a deep marine environment of deposition[5]. The fact that of the deep-swimming planktonic genus *Sphaeroidinellopsis* is the dominant (up to 90%) microfauna lends further credence to the concept of a deep Mediterranean in the earliest Pliocene[2]. Additional data in support of deep marine sedimentation immediately after the salinity crisis have been provided by the oxygen isotope measurements[5]. As geophysical considerations exclude the possibility of a catastrophic subsidence[2], the only alternative is the sudden drowning of a desiccated deep basin.

Pelagic oozes are, in fact, intercalated in the Messinian evaporites. At site 134, to the west of Sardinia, we cored a

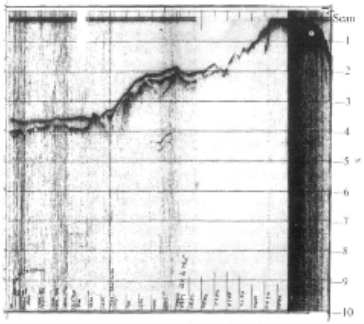
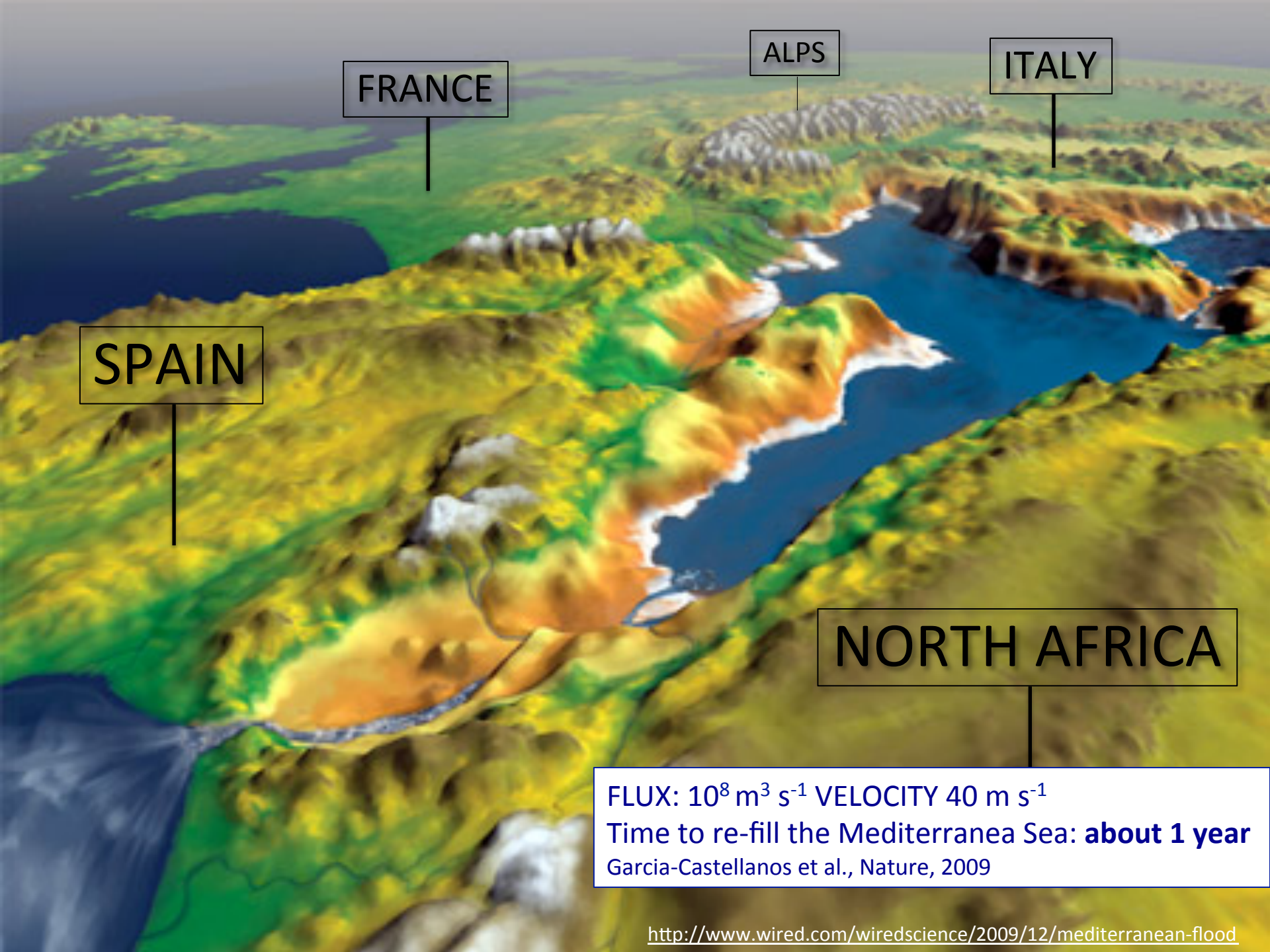


Fig. 1 The Mediterranean reflector. This strong reflector corresponds to the top of the Upper Miocene evaporite formation. The relief of the reflector conforms the bottom topography, suggesting that the evaporites were deposited in a basin similar in topography to that of the present Mediterranean.

© 1973 Nature Publishing Group

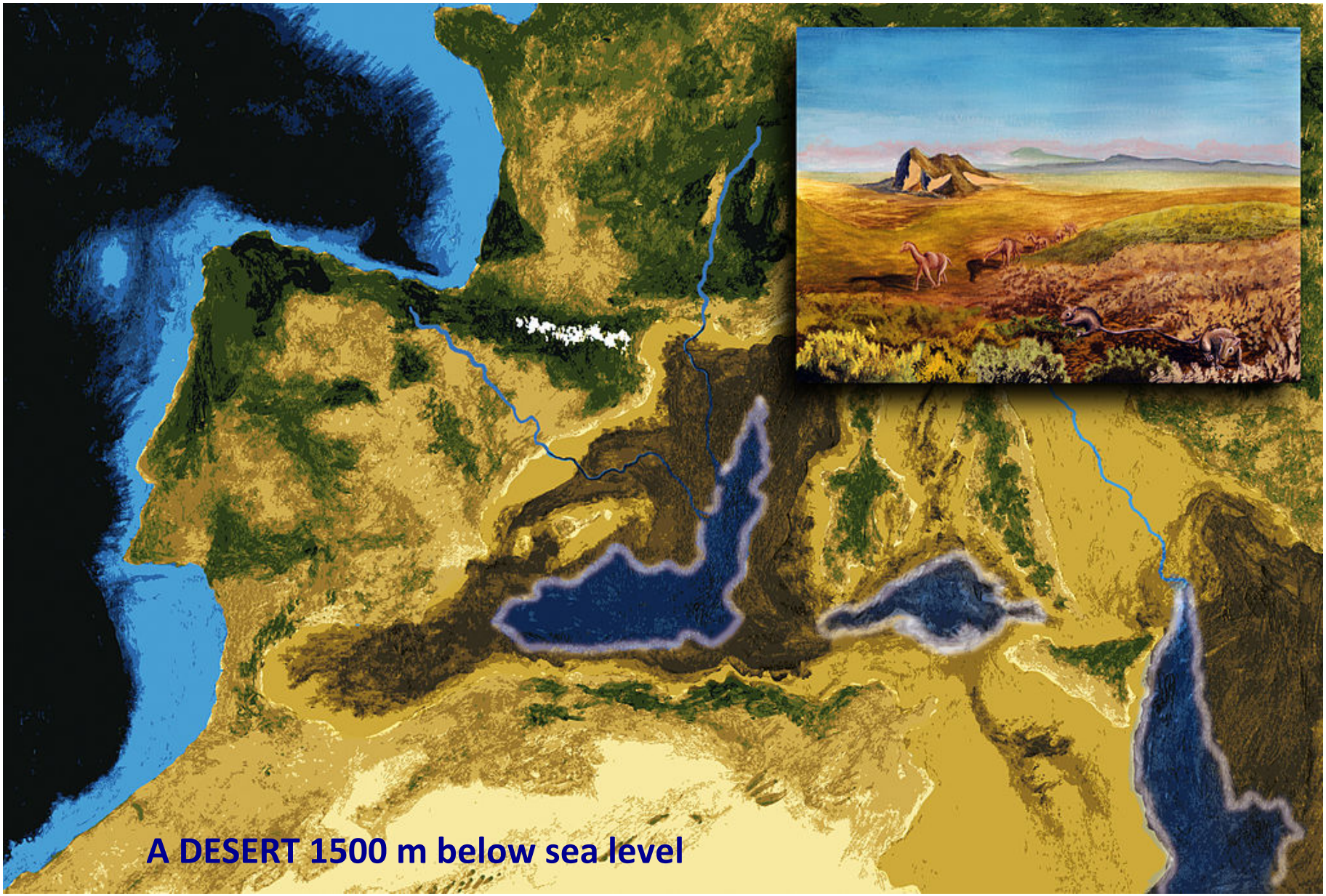


FLUX: 10^8 m^3 s^{-1} VELOCITY 40 m s^{-1}

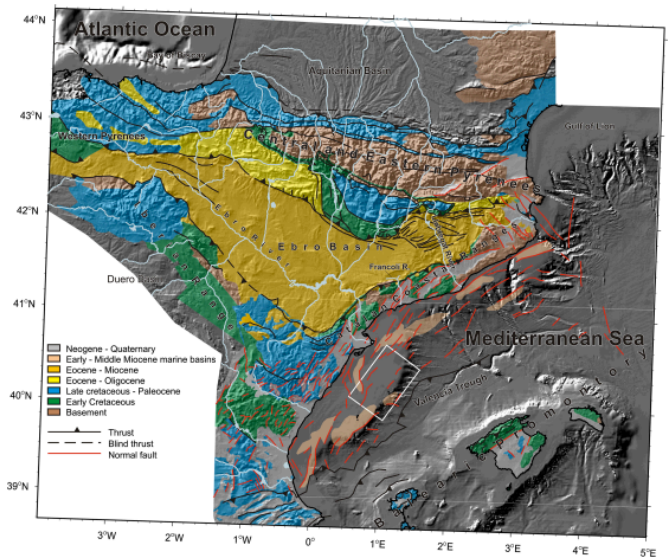
Time to re-fill the Mediterranea Sea: **about 1 year**

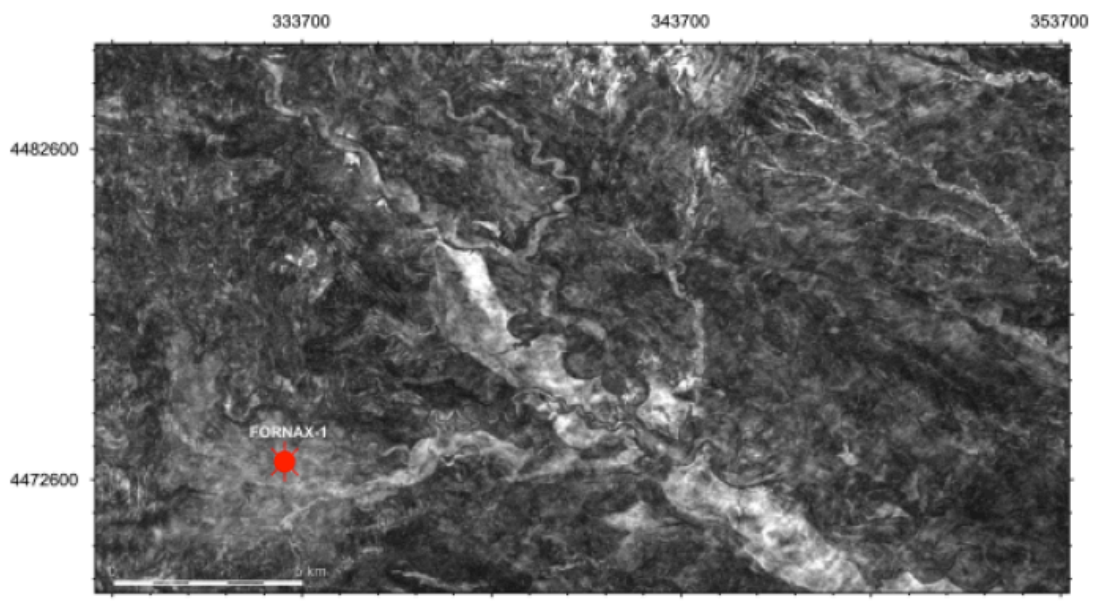
Garcia-Castellanos et al., Nature, 2009

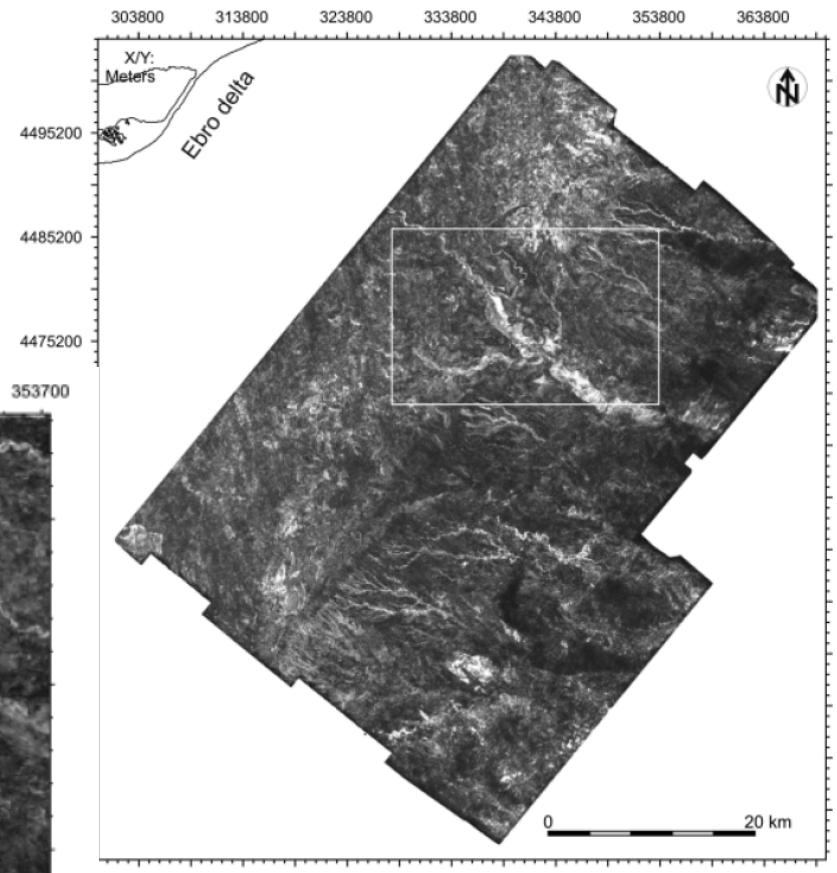
http://www.wired.com/wiredscience/2009/12/mediterranean-flood


A DESERT 1500 m below sea level

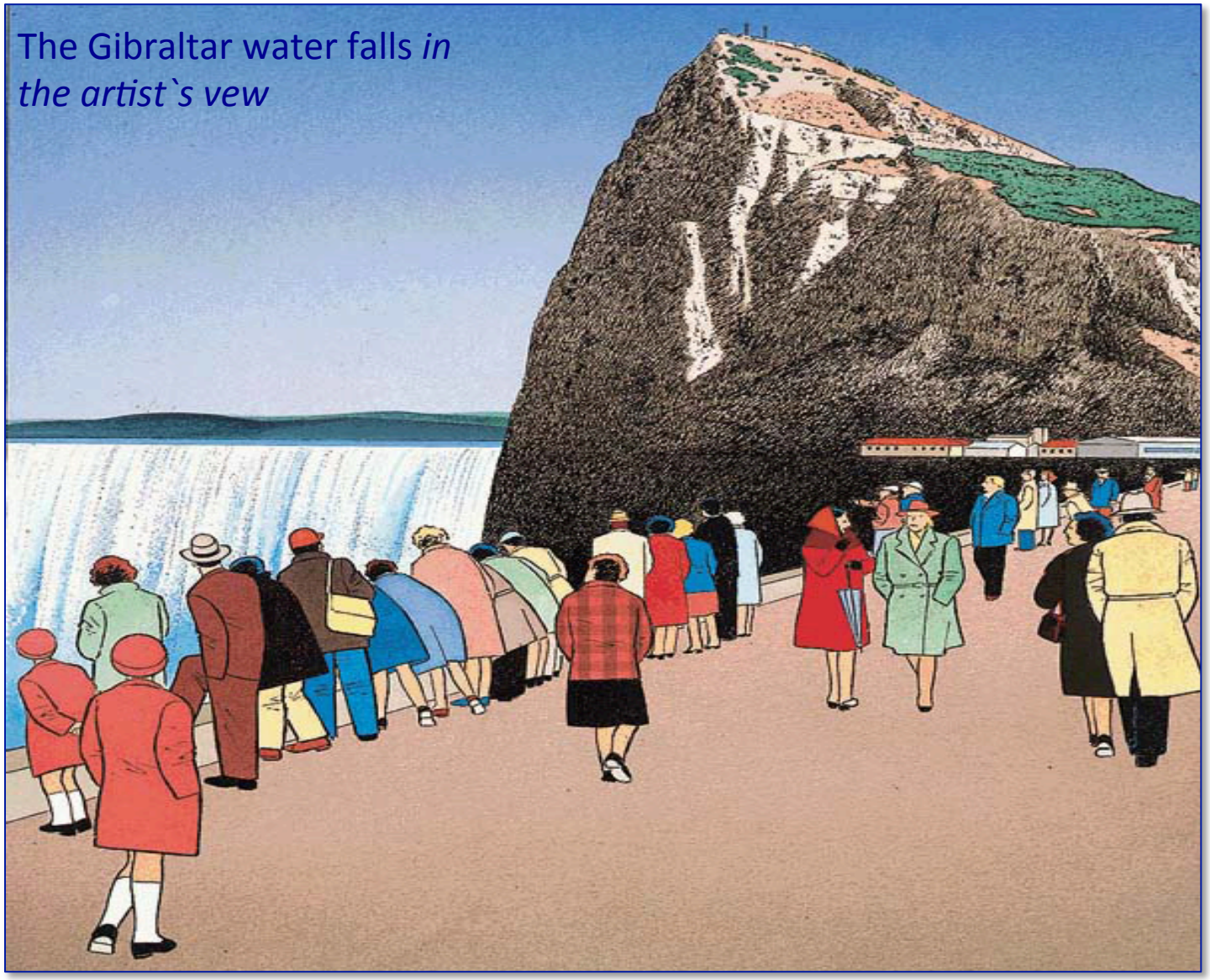
DEEP SUBAERIAL EROSIONAL CANYONS







Urgeles et al., 2010



©1986 Guy Billout, first published in The Atlantic Monthly

Thanks to: Daniel Garcia Catellanos, CSIC Barcelona

The enduring controversy:

Did the Mediterranean dry-out or not during the Messinian Salinity Crisis?

- Some scientists believe the Mediterranean sea level decreased by 1500-2000 m (note: his would leave a salty pond possibly 1000 m deep or more
- Others think the decrease was nearly negligible
- Disagreement is on when how long the sea level draw down lasted
- Disagreement is also on the way the Mediterranean returned to normal conditions

COST Action CA15103
UNCOVERING THE MEDITERRANEAN SALT GIANT (MEDSALT)

Chair: Angelo Camerlenghi, OGS, Trieste
Co-Chair: Johanna Lofi, University of Montpellier

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COST has been supporting networking of research activities across all 36 Member Countries and beyond for more than **40 years**.

COST is open to all disciplines, to all novel and ground-breaking S&T ideas, to all categories of partners where mutual benefit is real.

206 participations in running COST Actions accros 16 countries

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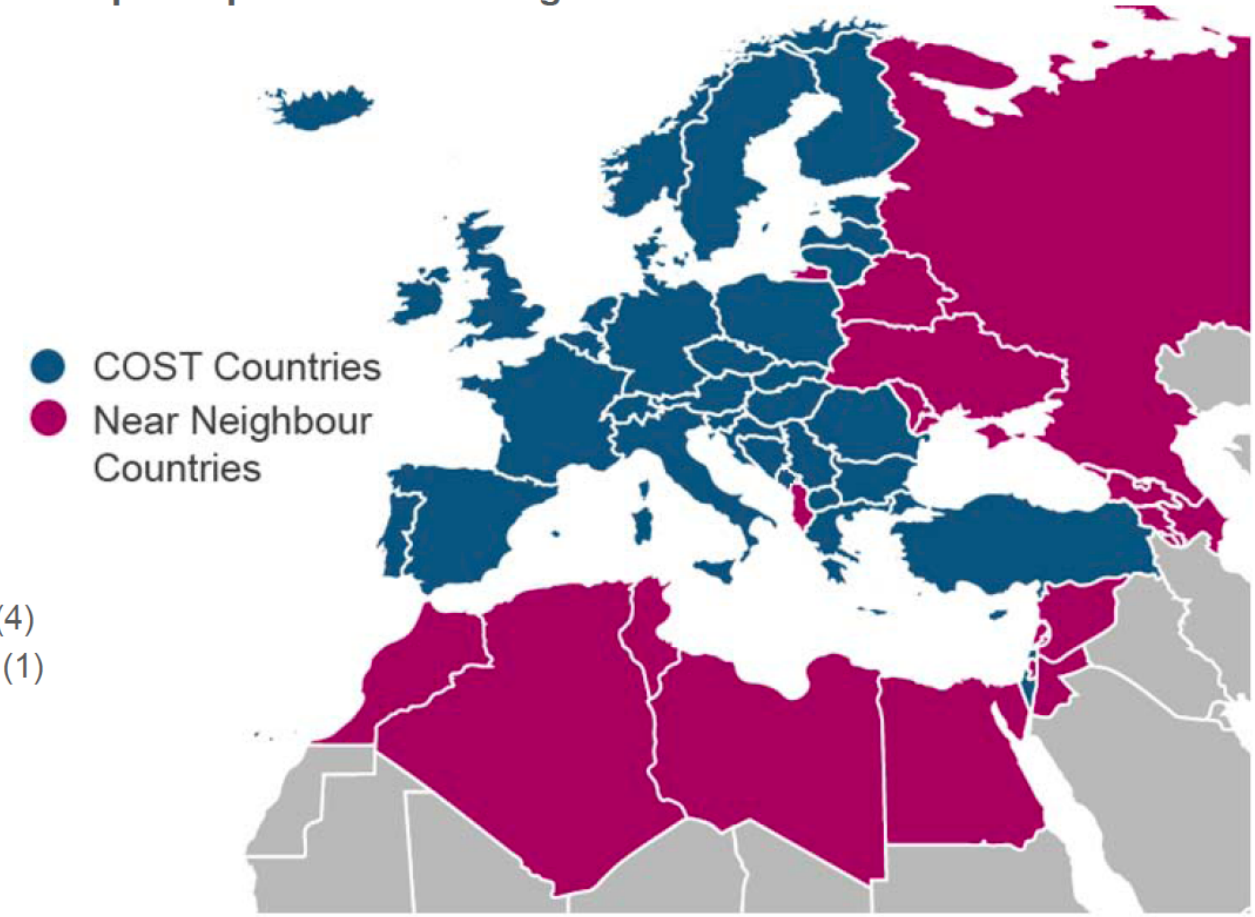
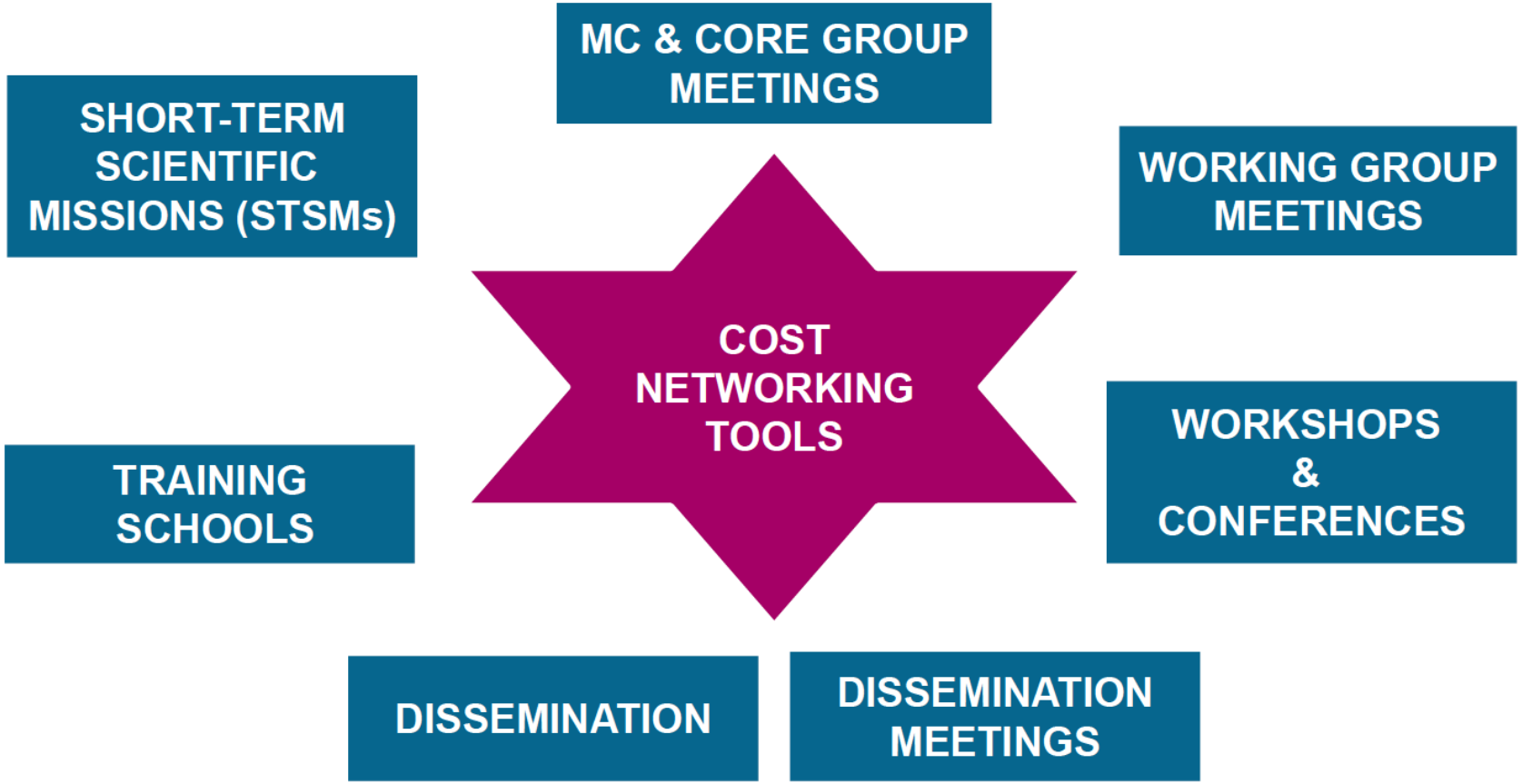
- Lebanon (2)
- Moldova (4)
- Morocco (17)
- Palestinian Authority (4)
- Syrian Arab Republic (1)
- Russia (54)
- Tunisia (14)
- Ukraine (52)

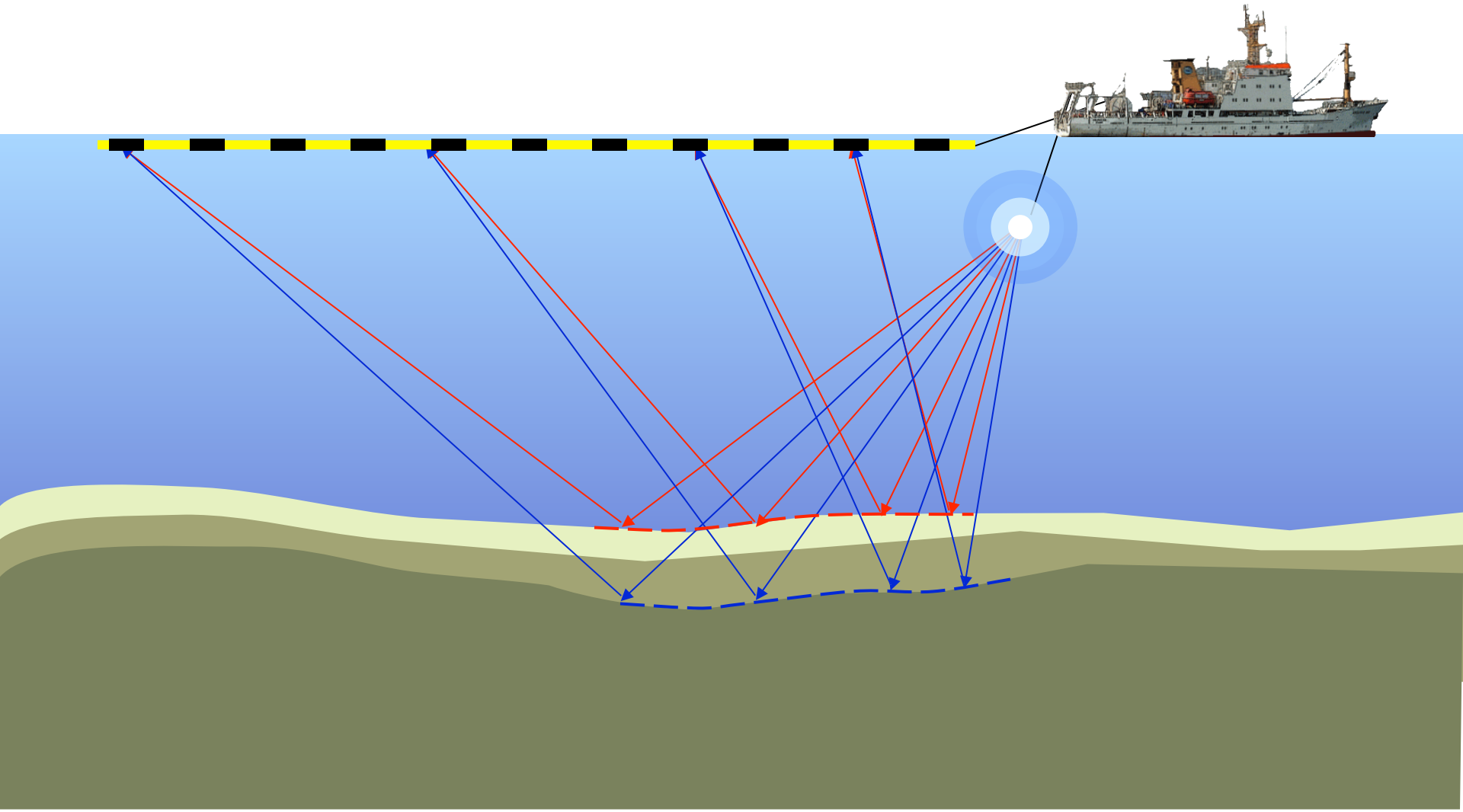


20 May 2015 data

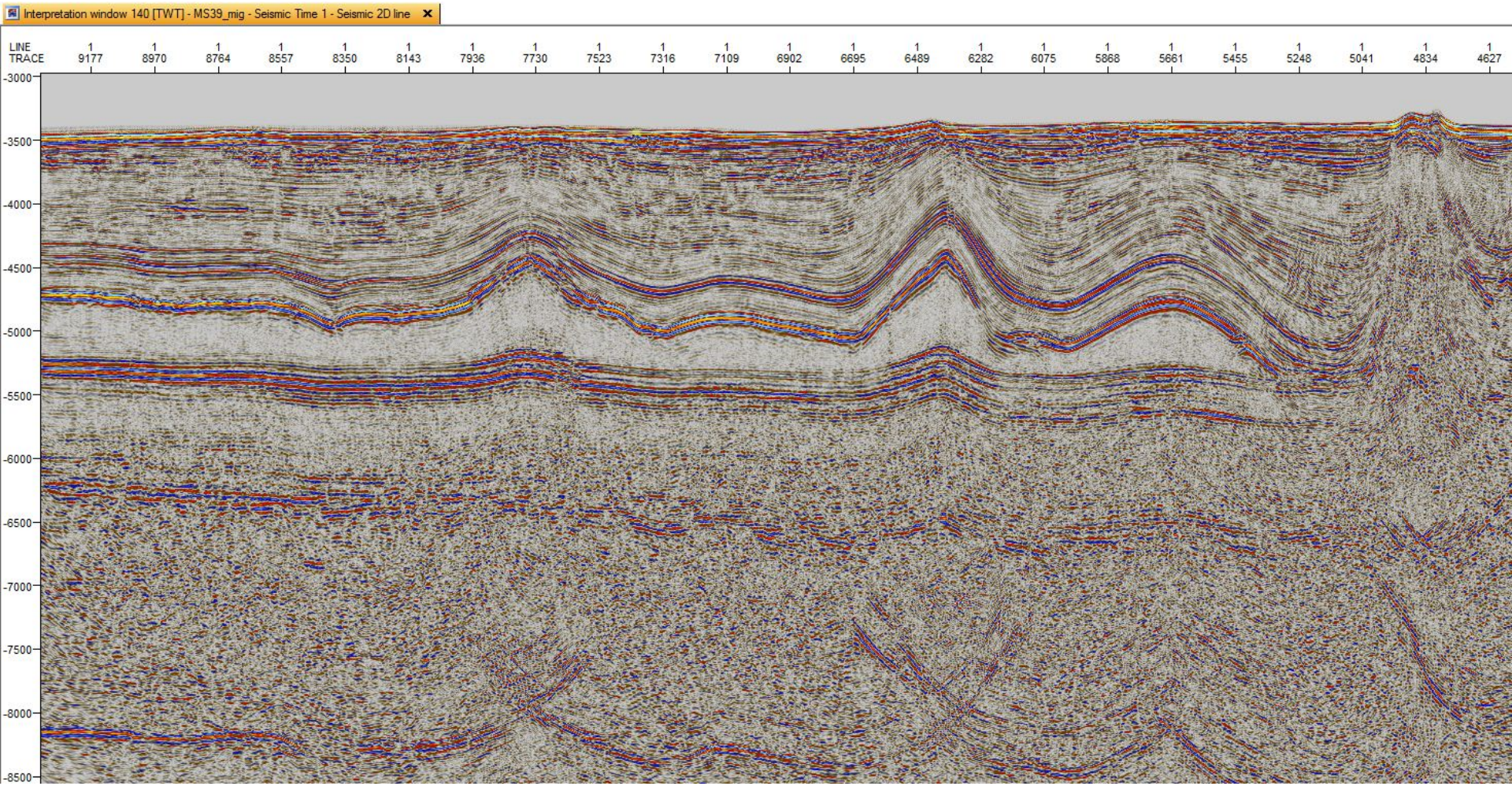
COST Actions tools

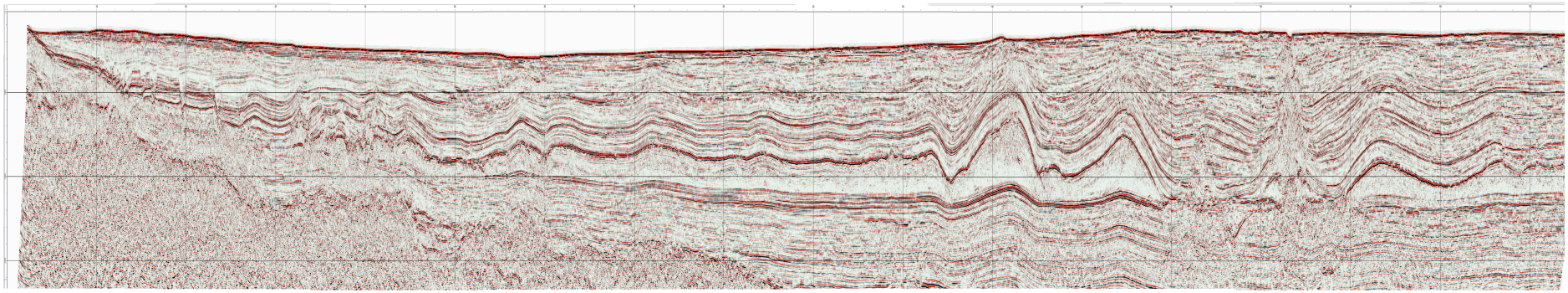


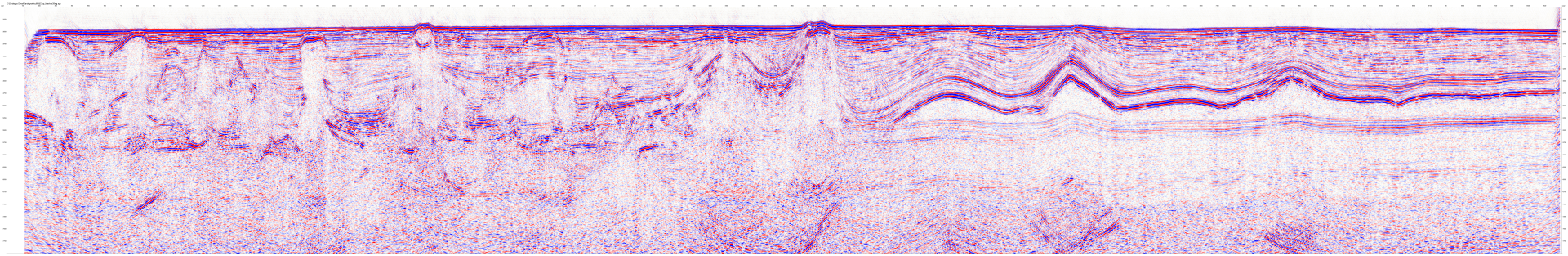
Research Vessel OGS Explora

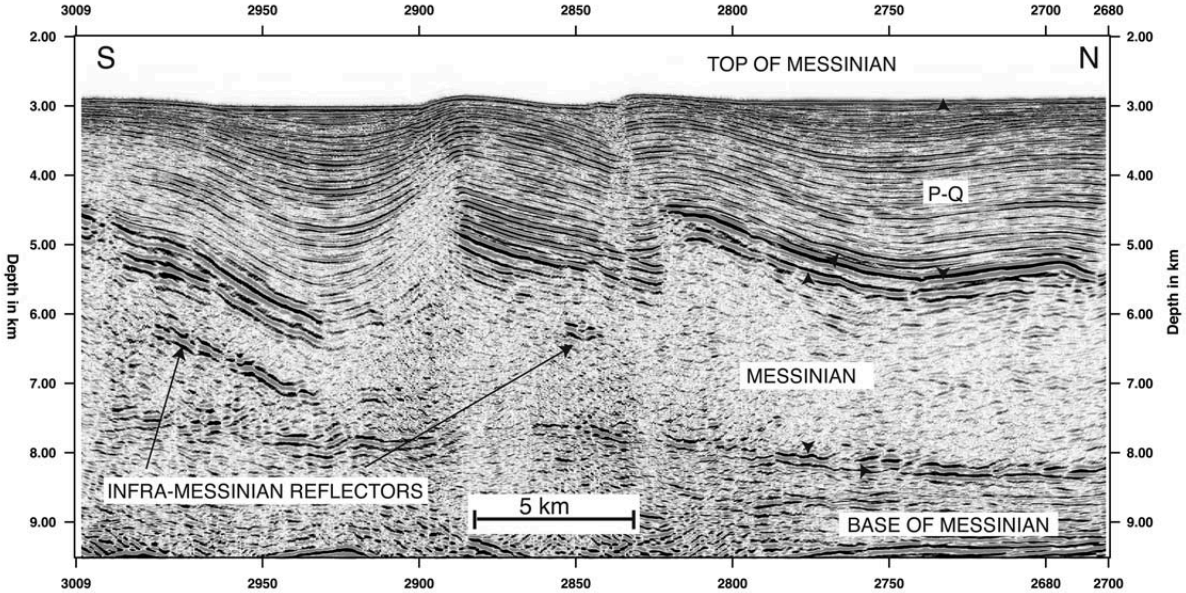


Profili sismici



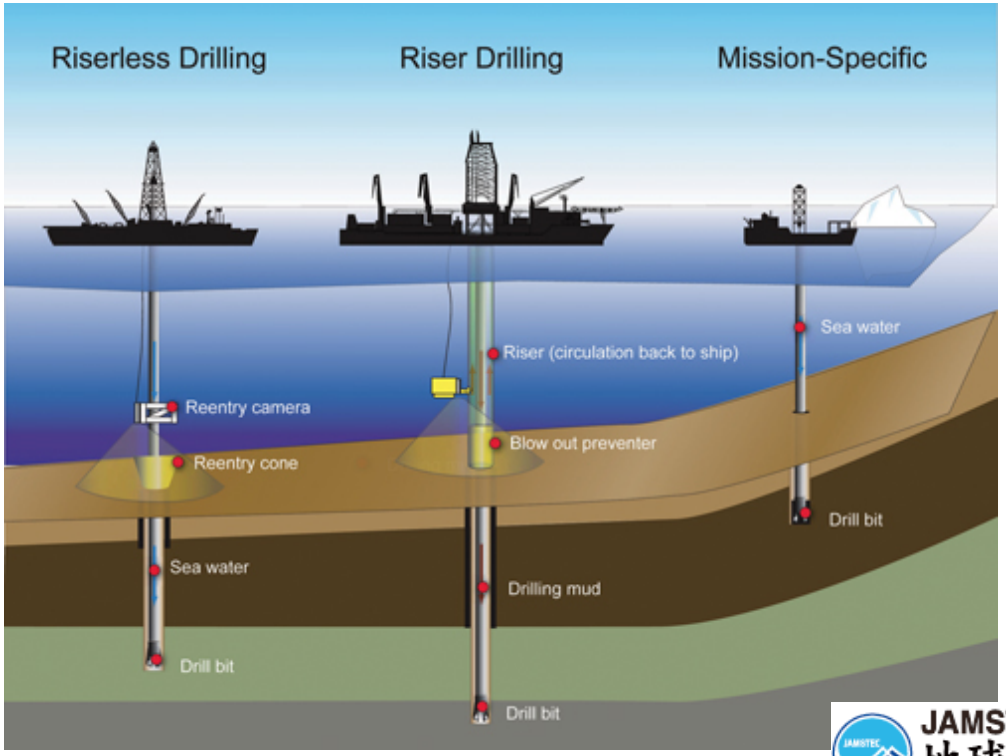






Lo spessore dei sali Messiniani sul fondo del Mediterraneo supera 3 km

Il volume è circa 1 milione di km^3



ECORD European Consortium for Ocean Research Drilling

icdp

JAMSTEC 地球深部探査センター CENTER FOR DEEP EARTH EXPLORATION

IODP INTEGRATED OCEAN DRILLING PROGRAM

COMMON BELIEF:

DRILLING THE MEDITERRANEAN SALT GIANT REPRESENTS A UNIQUE OPPORTUNITY

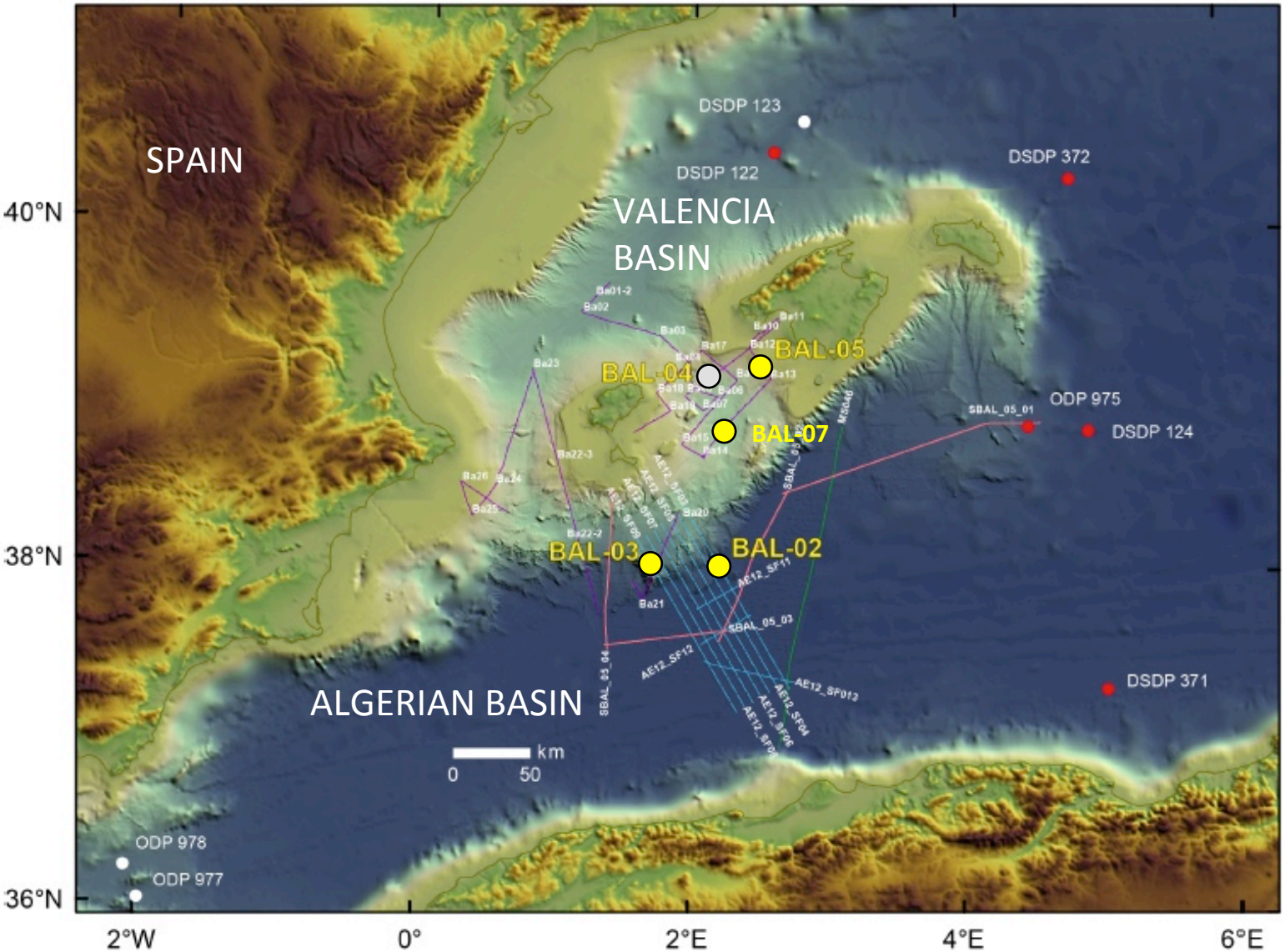
- To understand the **genesis, sedimentary and structural evolution, the biosphere and fluid dynamics** of a salt giant in a state close to its original depositional configuration, and
- to understand the **responsiveness of a land-locked oceanic basin to planetary dynamics**.

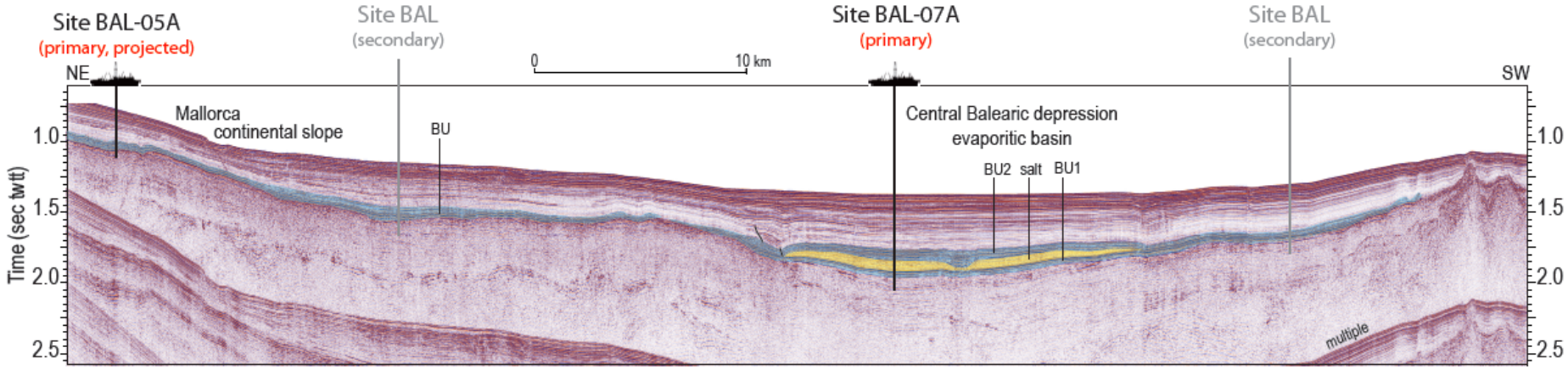
The Mediterranean salt giant will be used as a **reference for older salt giants**.

OVERARCHING SCIENTIFIC QUESTIONS

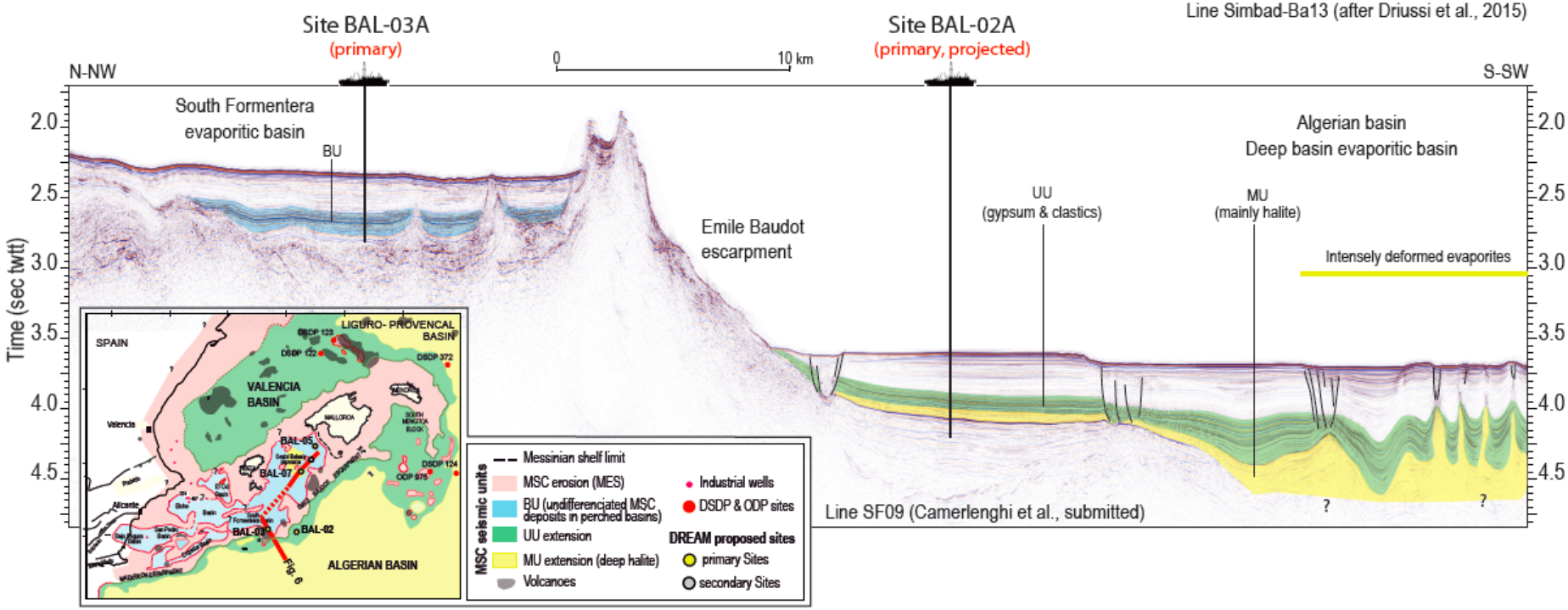
1. What are the causes, timing and emplacement mechanisms of the Mediterranean salt giant?
2. What are the factors responsible for and the socio-economic consequences of early salt deformation and fluid flow across and out of the halite layer?
3. Do salt giants promote the development of a phylogenetically diverse and exceptionally active deep biosphere?
4. What are the mechanisms underlying the spectacular vertical motions inside basins and their margins?

Proposed sites for scientific drilling on the Balearic Promontory

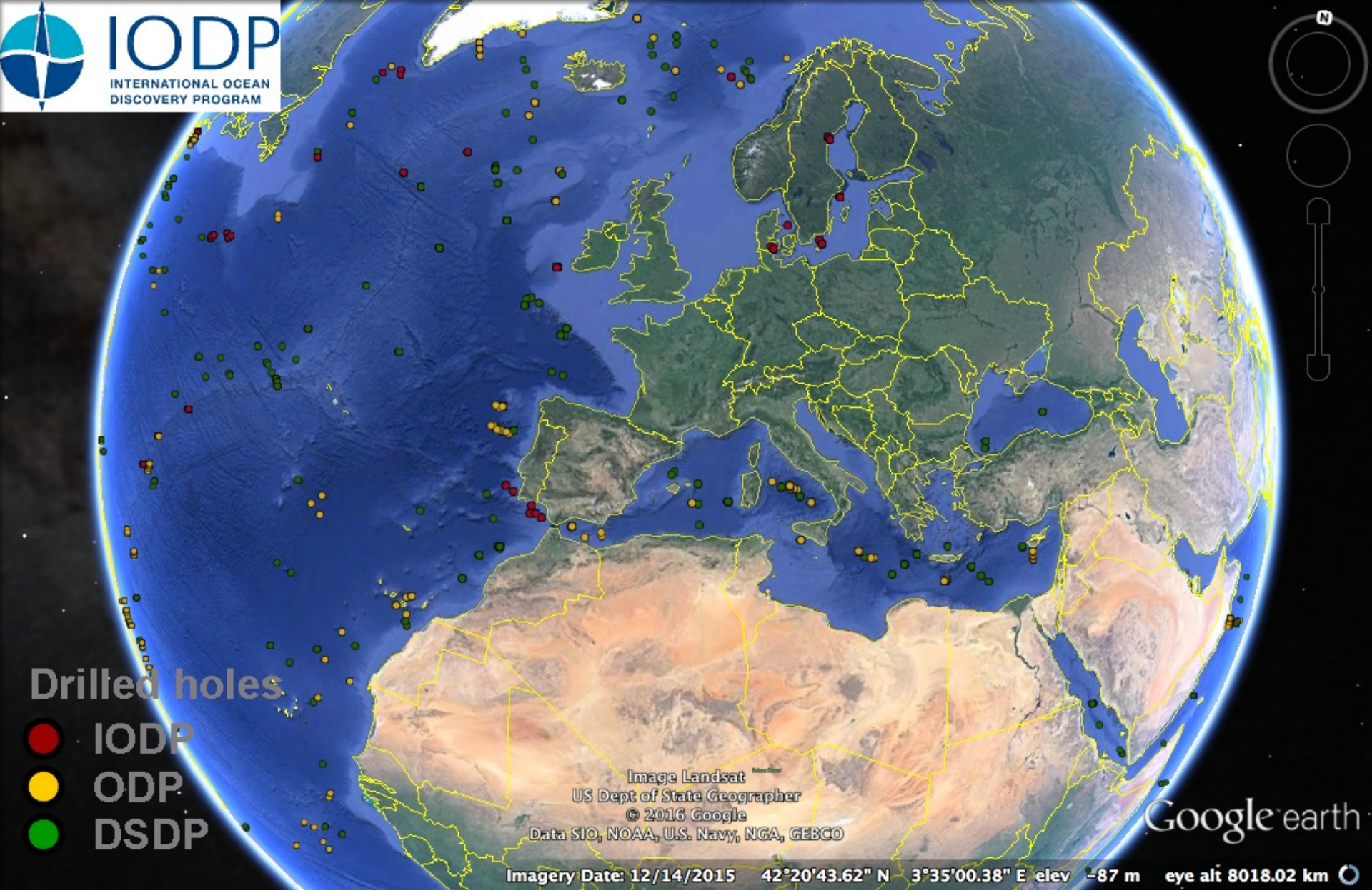




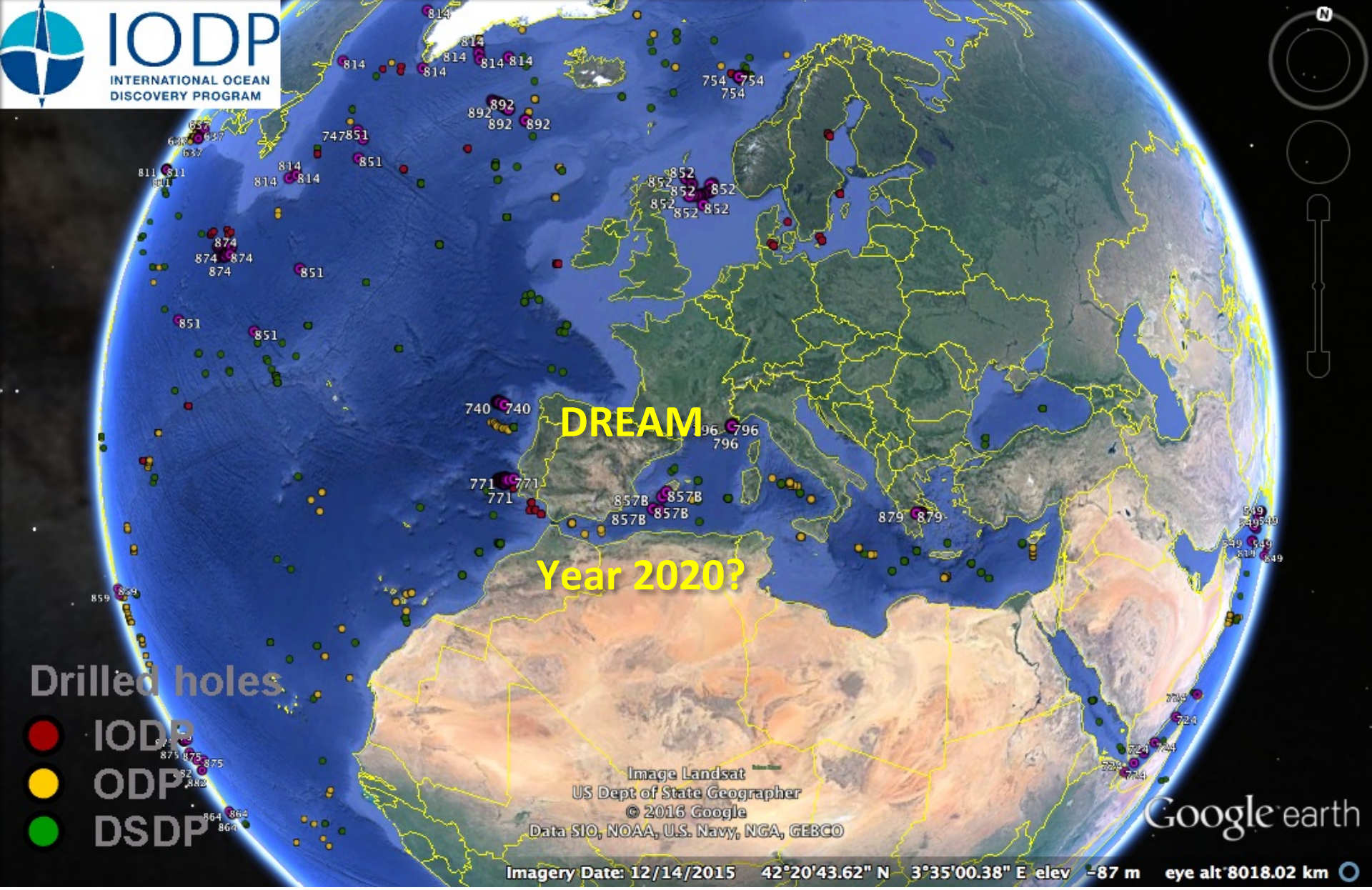
Line Simbad-Ba13 (after Driussi et al., 2015)



Line SF09 (Camerlenghi et al., submitted)



http://www.cost.eu/COST_Actions/ca/CA15103



http://www.cost.eu/COST_Actions/ca/CA15103

1944 Charles Sidney Burwell, cardiologist, Dean of the Harvard Medical School from 1935 to 1949.

In an address to students at the Medical School, he said:

"Half of what we are going to teach you is wrong, and half of it is right. Our problem is that we don't know which half is which."

MedSalt Symposium

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Thank you!

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