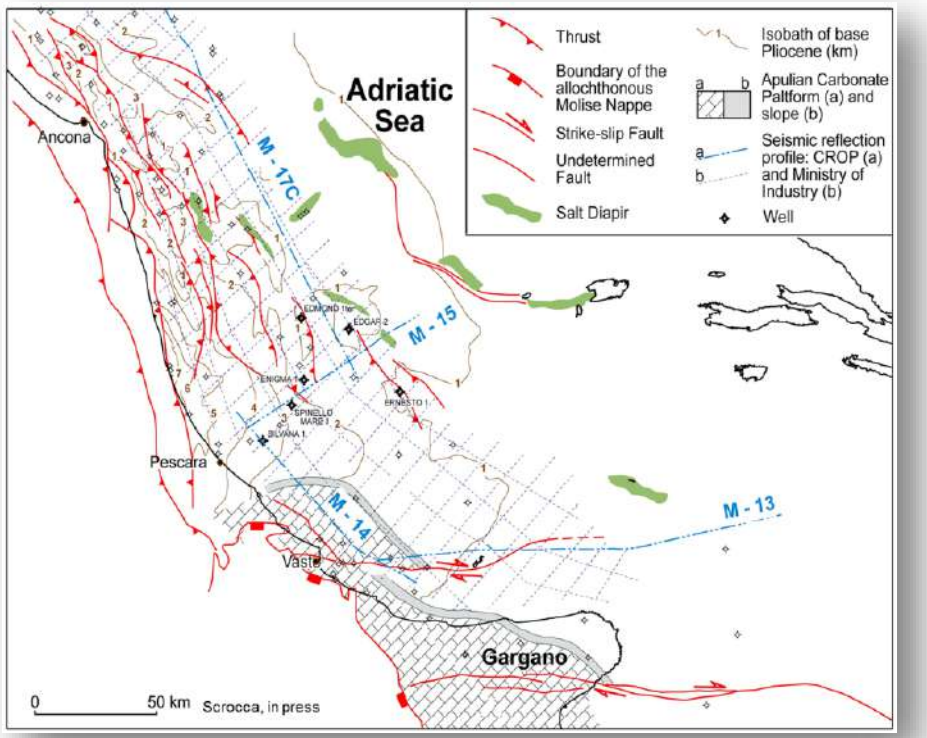
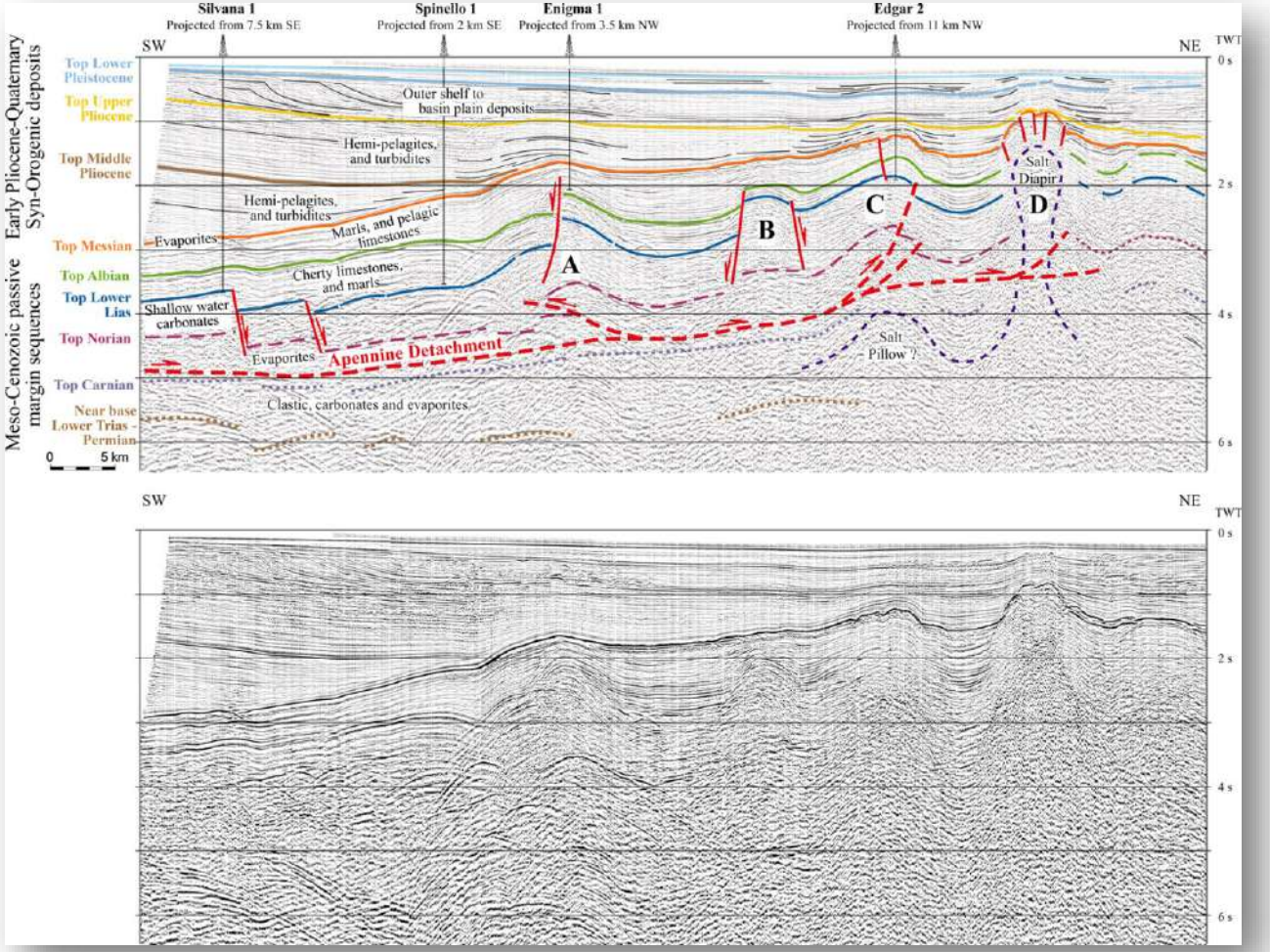
# LA CONOSCENZA – assetto strutturale



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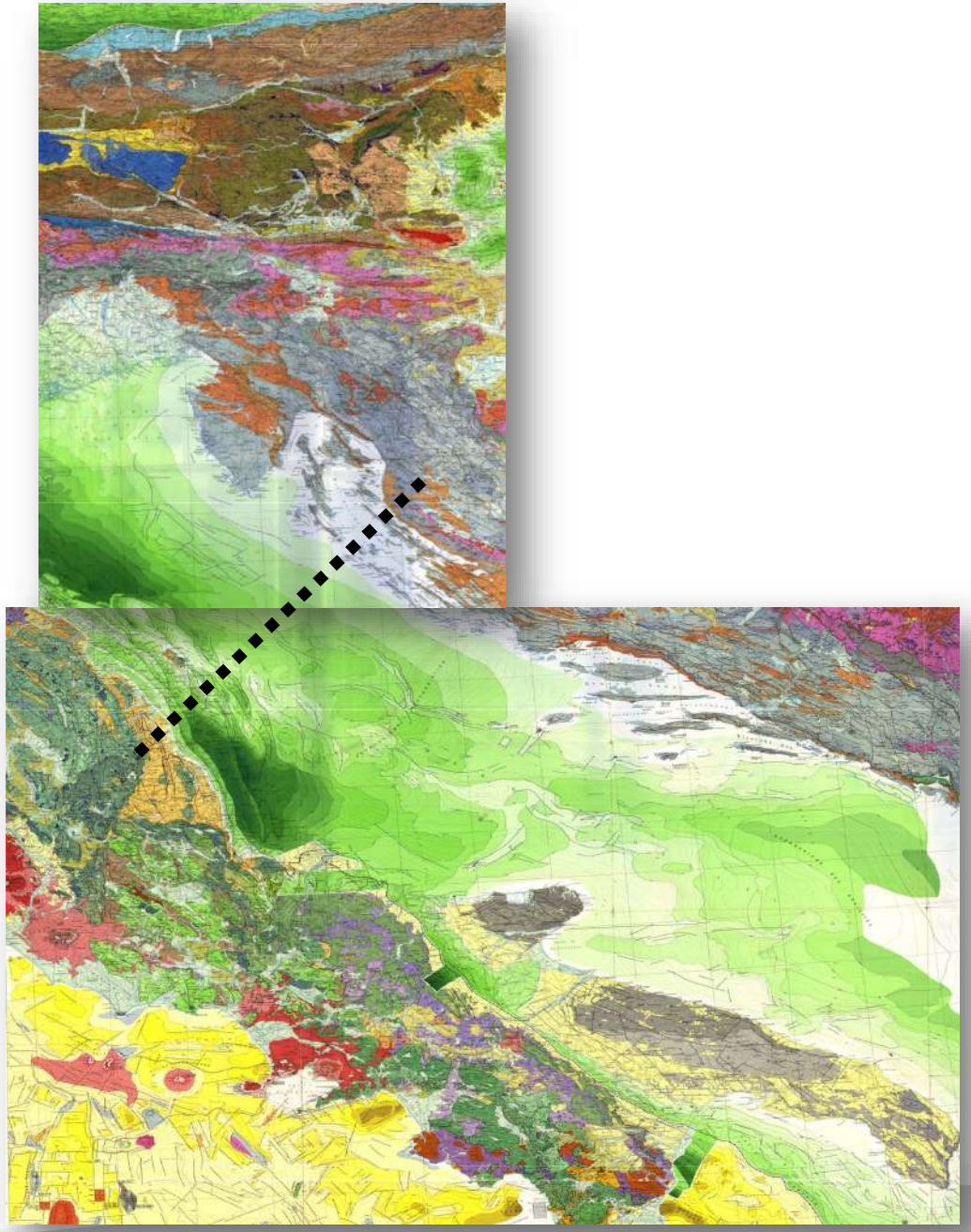
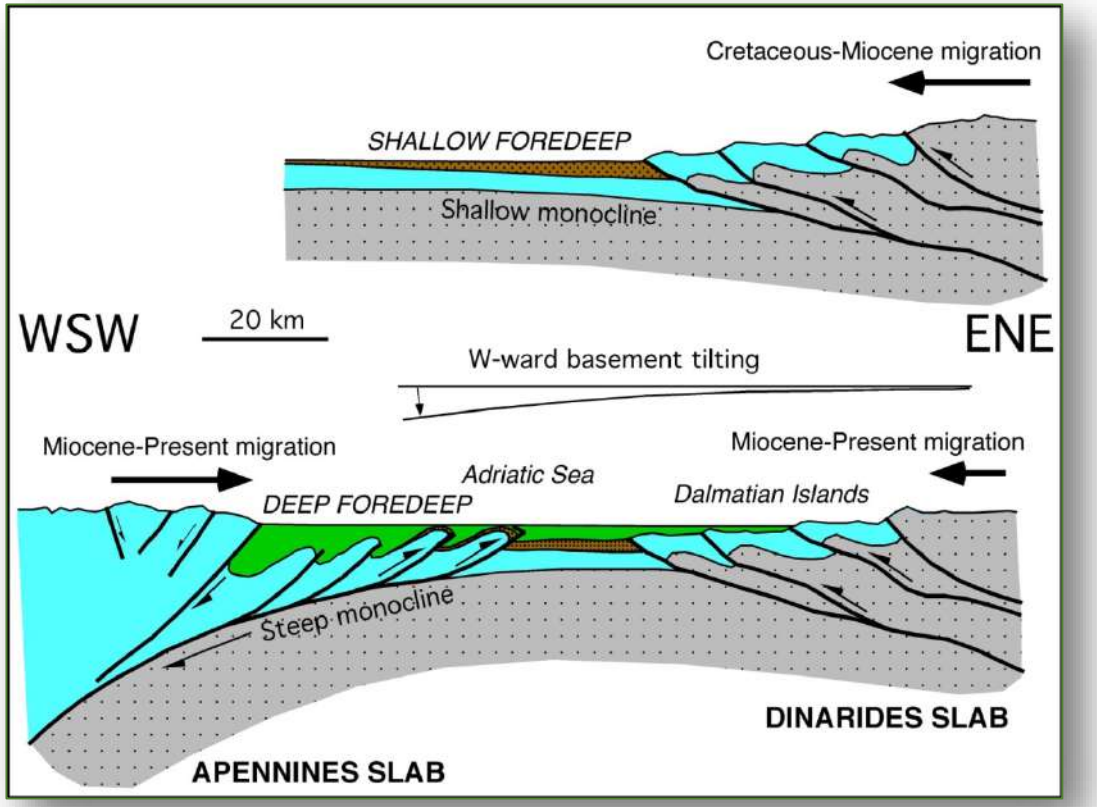
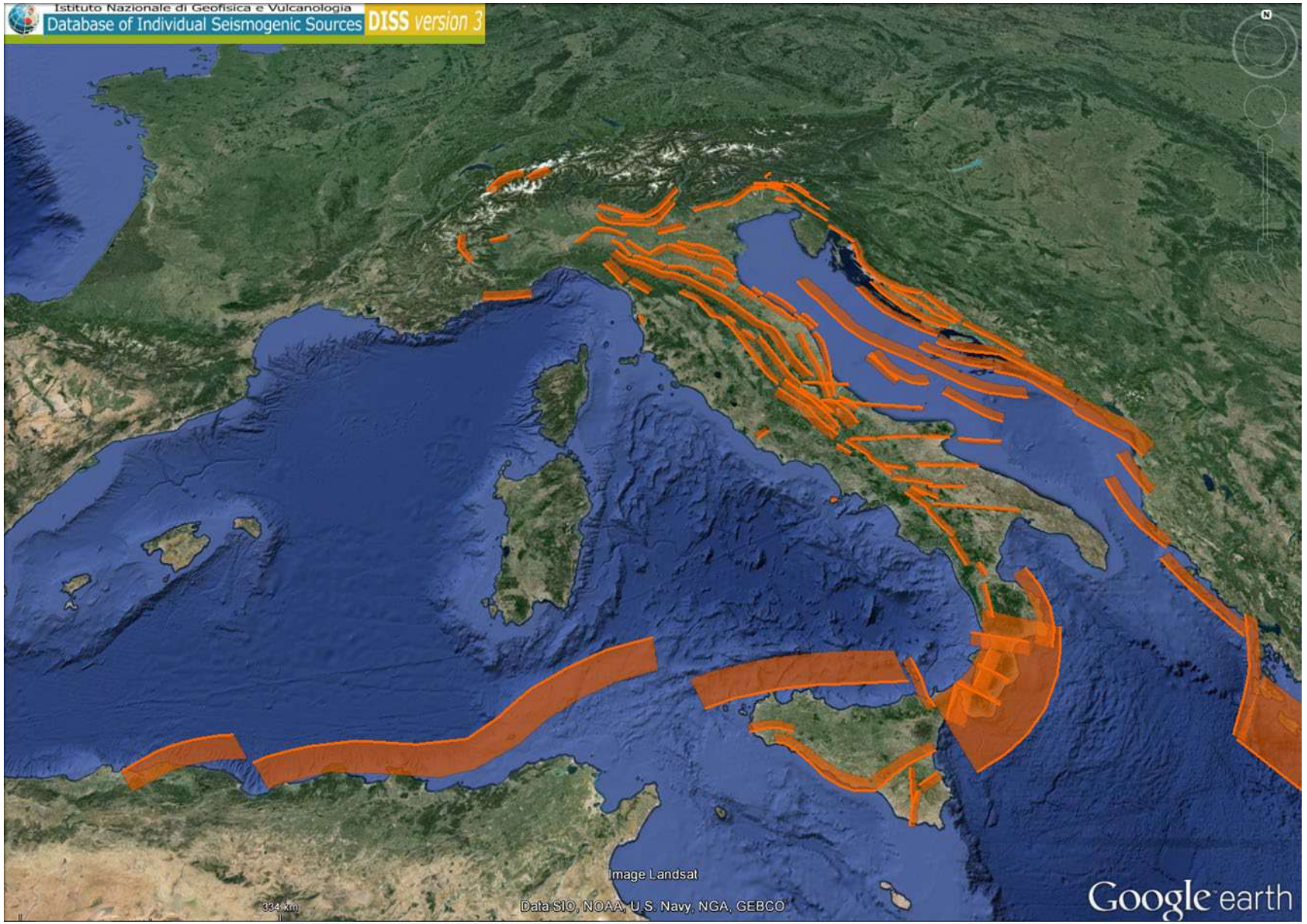
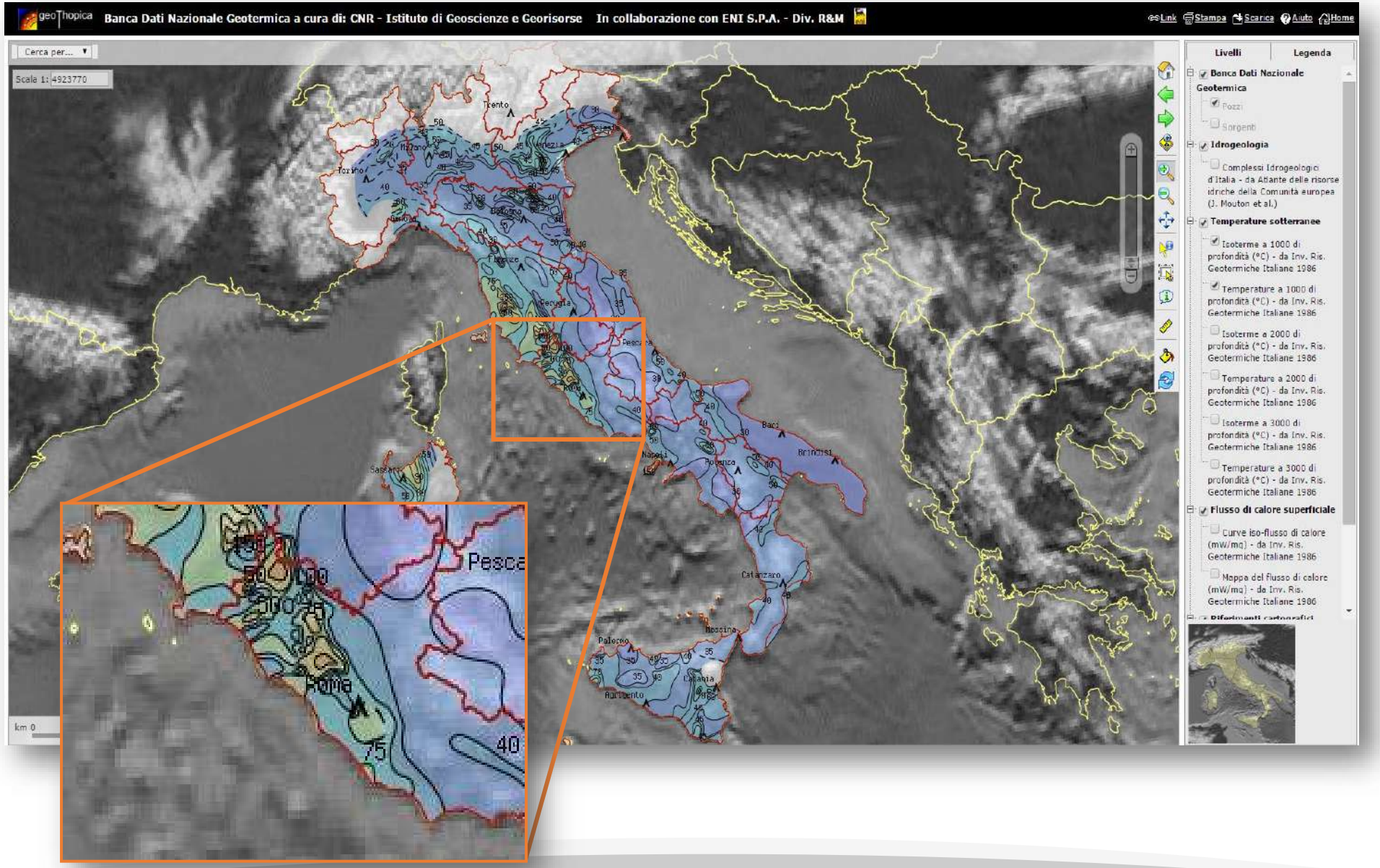




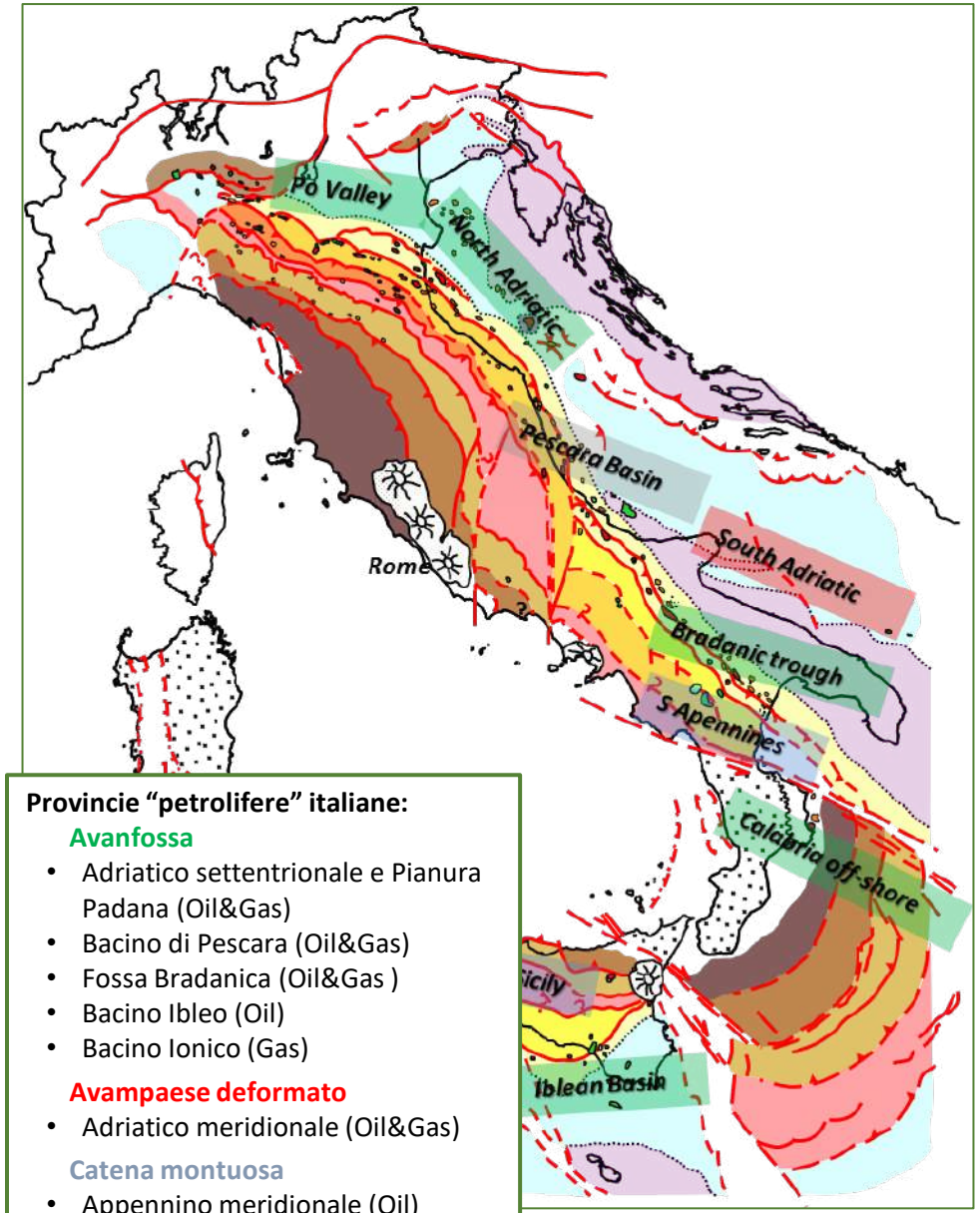
# LA CONOSCENZA – strutture sismogenetiche



# LA CONOSCENZA – risorse geotermiche



# LA CONOSCENZA – geologia degli idrocarburi




**Provincie "petrolifere" italiane:**

**Avanfossa**

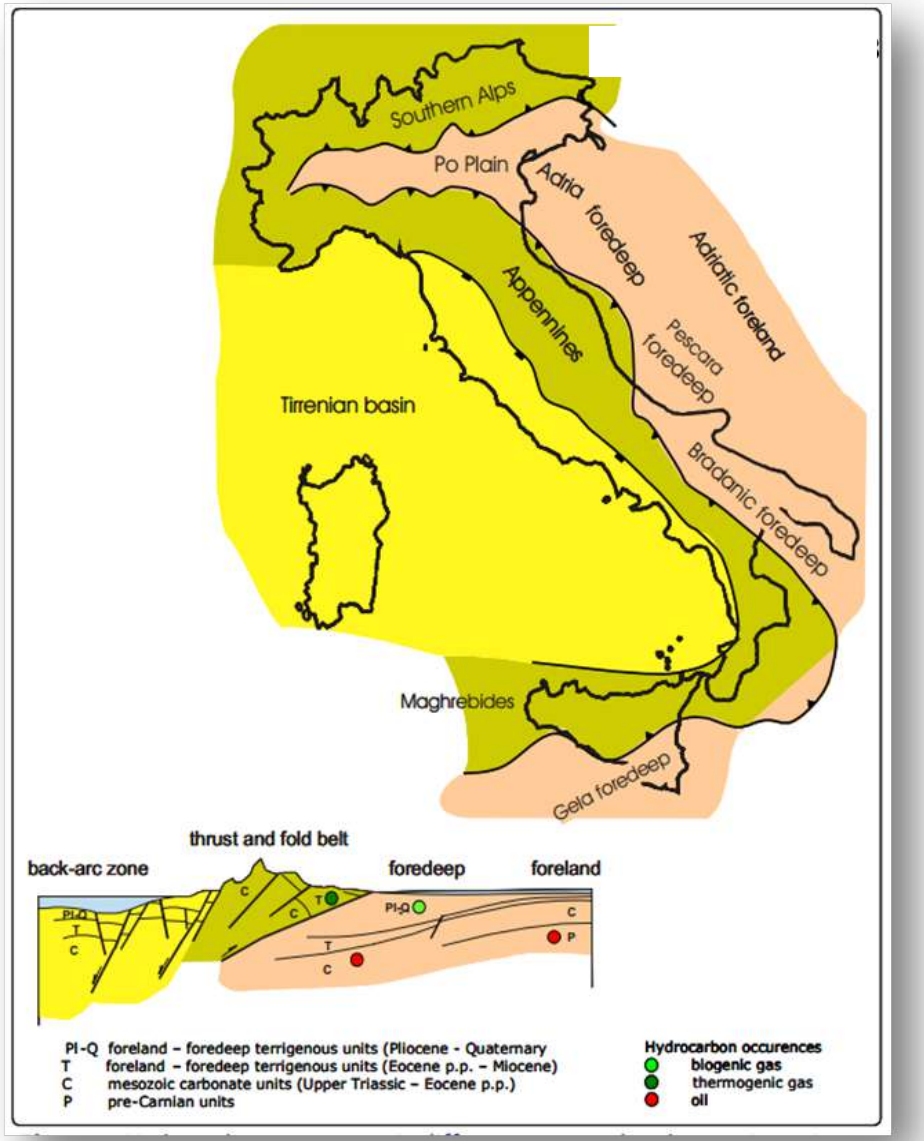
- Adriatico settentrionale e Pianura Padana (Oil&Gas)
- Bacino di Pescara (Oil&Gas)
- Fossa Bradanica (Oil&Gas )
- Bacino Ibleo (Oil)
- Bacino Ionico (Gas)

**Avampaese deformato**

- Adriatico meridionale (Oil&Gas)

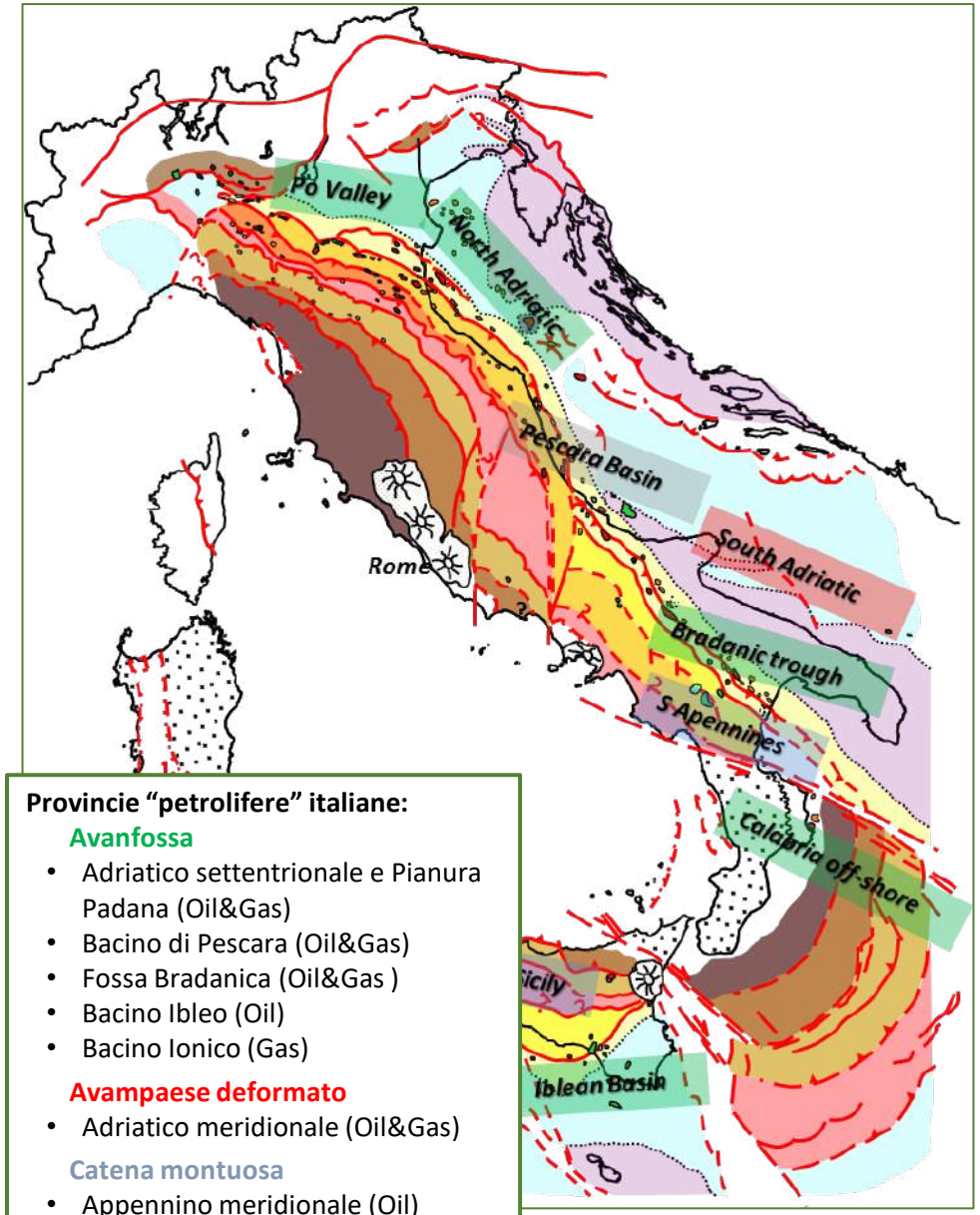
**Catena montuosa**

- Appennino meridionale (Oil)
- Sicilia (Gas)




*Bertello et al., 2008*

# LA CONOSCENZA – geologia degli idrocarburi

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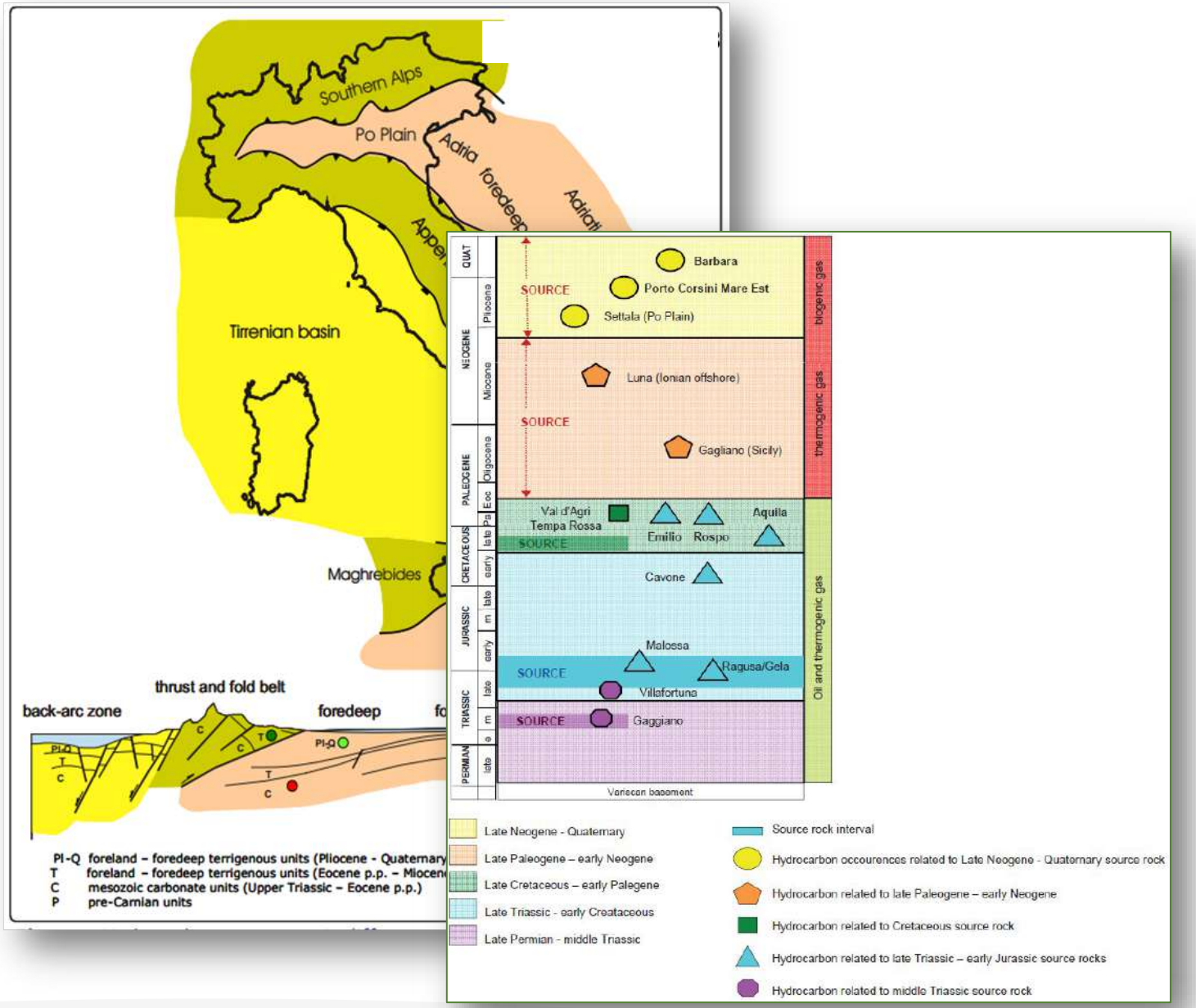
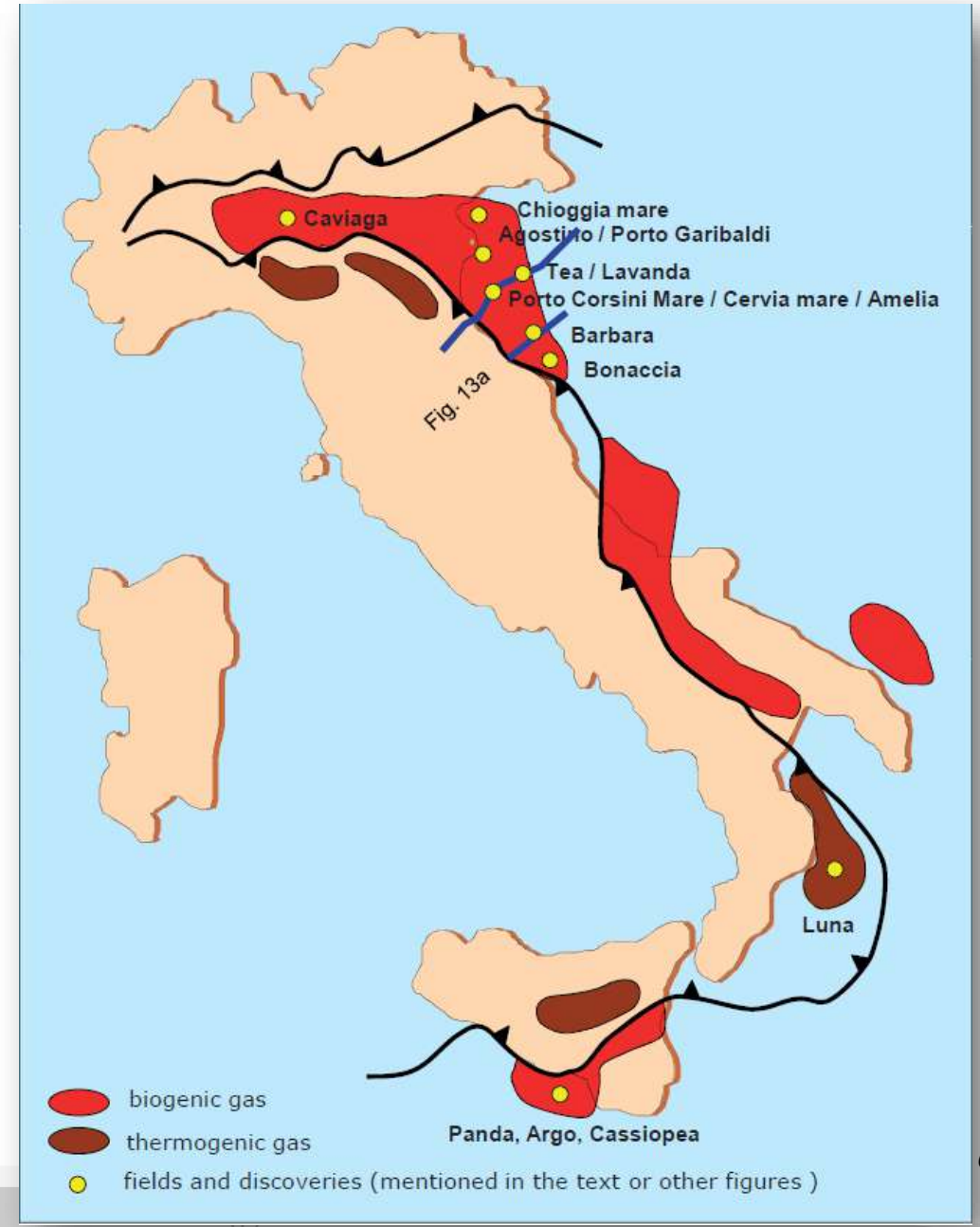


# LA CONOSCENZA – geologia degli idrocarburi


*Cazzini et al., 2015*

1. **Glossario**
2. Le **geoscienze** in un mondo che cambia
   - **2.1 Agenda 2030** e i 17 Sustainable Development Goals-SDGs
   - **2.2 SDG7**: Energia
   - **2.3 Statistiche** dell'energia: mondo, UE, Italia
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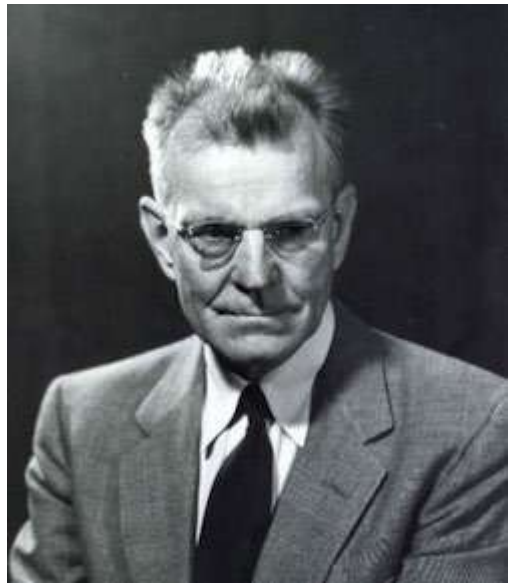


**Marion King Hubbert**

- Geologo e geofisico per la Shell dal 1943 al 1964.
- Ricercatore di geofisica per la United States Geological Survey fino al 1976
- Professore di geologia e geofisica all'Università di Stanford dal 1963 al 1968 e all'Università di Berkeley dal 1973 al 1976.
- Membro della National Academy of Sciences e della American Academy of Arts and Sciences, presidente della Geological Society of America.

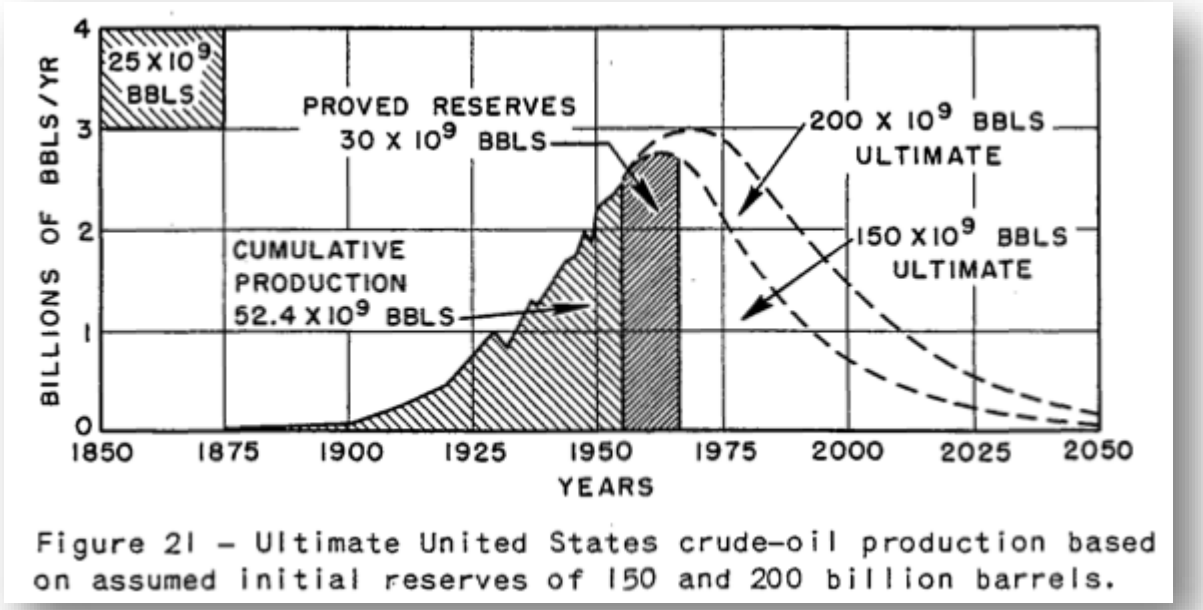
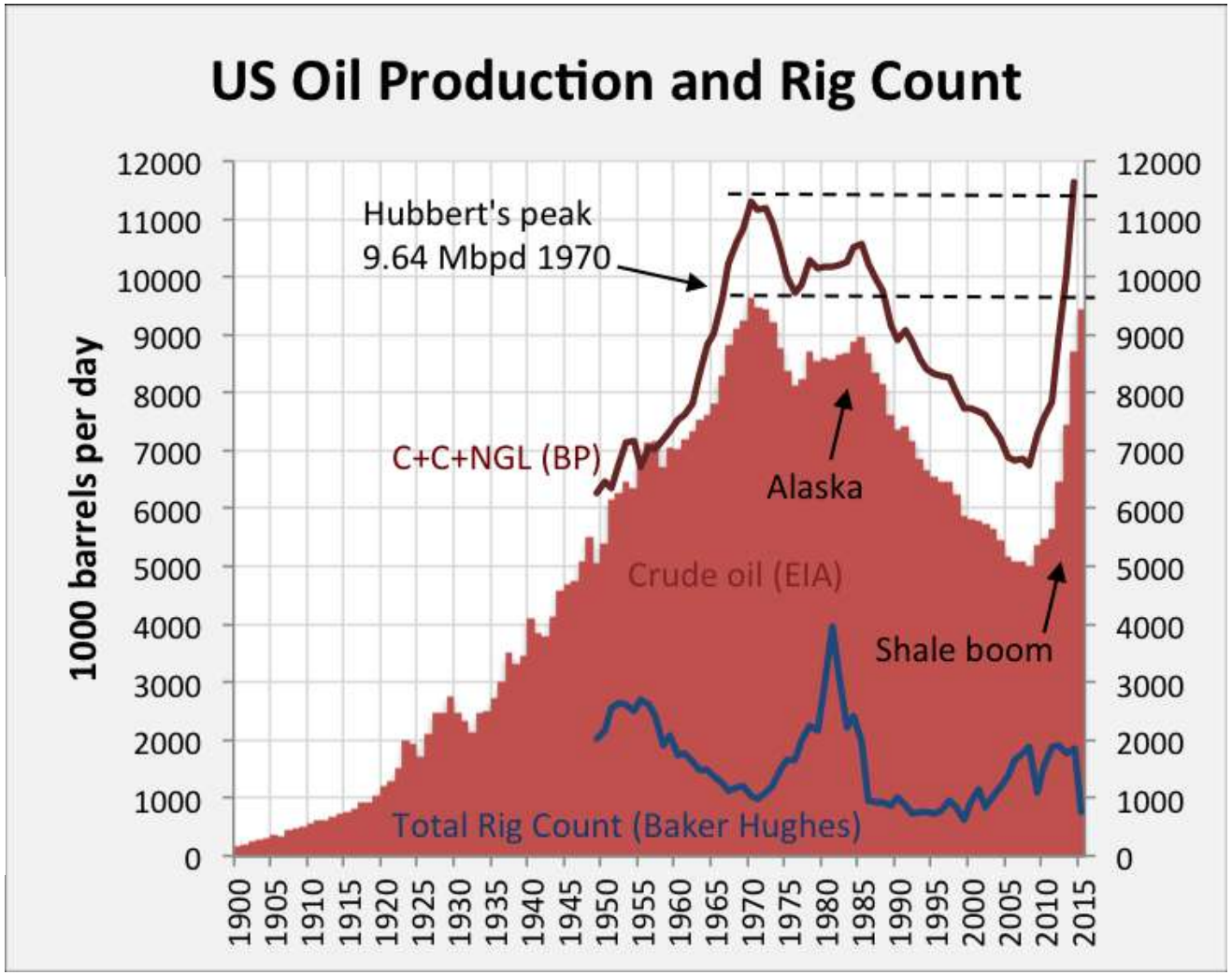



Figure 21 – Ultimate United States crude-oil production based on assumed initial reserves of 150 and 200 billion barrels.

*Picco e caduta della produzione statunitense per un recupero finale di 150 e 200 miliardi di barili (Hubbert, 1956).*

*Produzione di petrolio greggio degli Stati Uniti (EIA). L'industria petrolifera USA credeva che questa crescita sarebbe continuata per sempre;* ***nel 1956 M. King Hubbert avvertì che la crescita della produzione USA sarebbe finita nel 1970****.*
*La scoperta del petrolio in Alaska ha creato una spalla sulla curva del declino, ma le previsioni sono rimaste valide fino al 2008, con l'avvento di shale-oil e shale-gas. Il «picco di Hubbert» del 1970 è stato eguagliato e superato nel 2015.*



## *ma quanti idrocarburi ci sono ancora?*

**OIL**

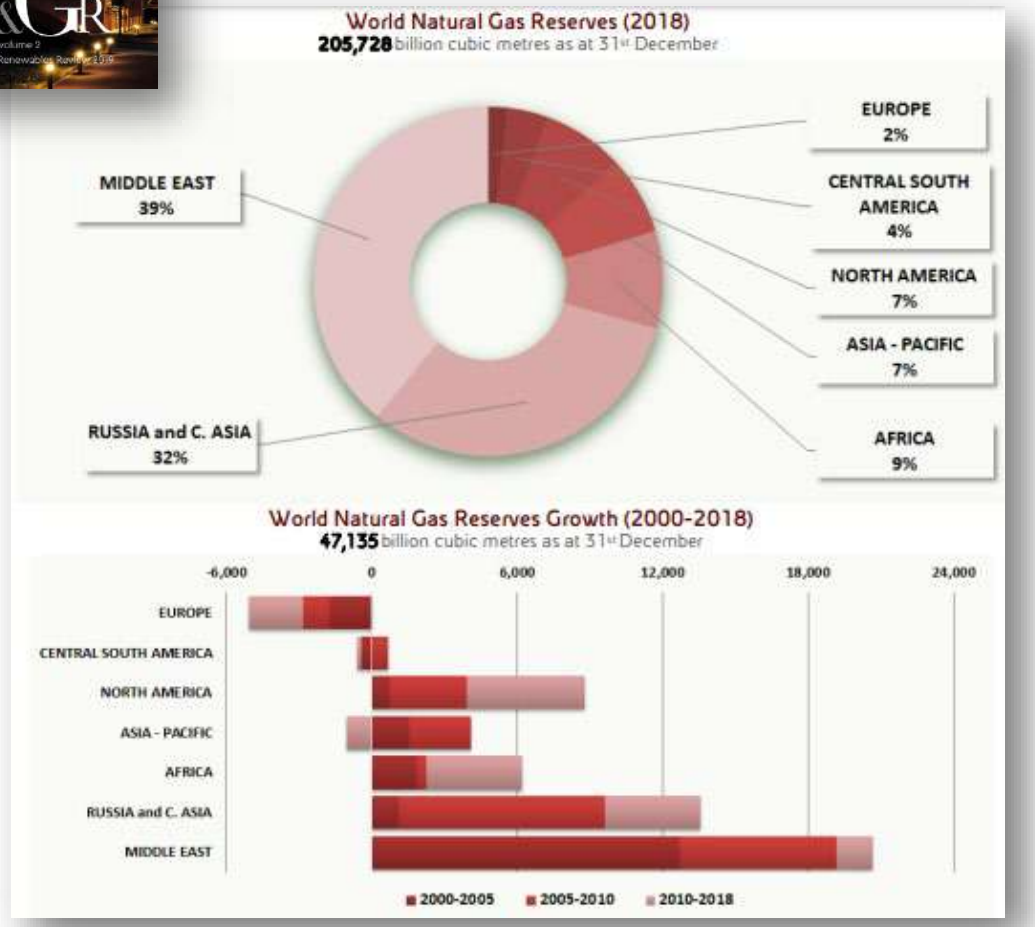
| | Field Name | Location | Discovery | Start prod. | Peaked | ORR, RRR (Bbbl) | Prod. (MMbbl/d) |
|---|---|---|---|---|---|---|---|
| 1 | Ghawar | Saudi Arabia | 1948 | 1951 | 2005, disputed | 88-104 | 5 |
| 2 | Burgan | Kuwait | 1937 | 1948 | 2005 | 66-72 | 1.7 |
| 3 | Upper Zaku | Abu Dhabi, UAE | 1963 | 1982 | Prod. increasing | 50 (21) | 0.750 |
| 4 | Ahvaz | Iran | 1958 | | 1970s | 37 | 0.750 |
| 5 | Gachsaran | Iran | 1927 | 1930 | 1974 | 66 | 0.480 |
| 6 | Cantarell | Mexico | 1976 | 1981 | 2004 | 35 (18) | 0.340 |
| 7 | Ku-Maloob-Zaap | Mexico | 1979 | 1981 | Prod. increasing | | 0.867 |
| 8 | Bolivar Coastal | Venezuela | 1917 | 1922 | | 30-32 | 2.6-3 |
| 9 | Aghajari | Iran | 1938 | 1940 | | 28 | 0.300 |
| 10 | Lula | Brazil | 2007 | | | 5-8 | 0.1 |
| 11 | Safaniy | Kuwait, S.Arabia | 1951 | | | 30 | 1.2 |
| 12 | Esfandiar | Iran | | | | 30 | |
| 13 | Rumaila | Iraq | 1953 | | | 17 | 1.3 |
| 14 | Tengiz | Kazakhstan | 1979 | 1993 | 2010 | 26-40 | 0.53 |
| 15 | Kirkuk | Iraq | 1927 | 1934 | | 8.5 | 0.480 |
| 16 | Shaybah | Saudi Arabia | | | | 15 | |
| 17 | Agha Jari | Iran | 1937 | | | 8.7 | 0.200 |
| 18 | Majnoon | Iraq | 1975 | | | 11-20 | 0.5 |
| 19 | Samotlor | Russia, W Siberia | 1965 | 1969 | 1980 | 14-16 | 0.844 |
| 20 | Shaikan Sheikh Adi | Iraq Kurdistan | 2009 | 2013 | Prod. increasing | 4-6 | 0.04 |
| 21 | Romashkino | Russia Volga-Ural | 1948 | 1949 | in decline | 16-17 | 0.301 |
| 22 | Prudhoe Bay | USA, Alaska | 1967-68 | 1977 | 1988 | 25 (~13) | 0.66 |
| 23 | Sarir | Libya | 1961 | 1961 | | 12 (6.5) | |

# *ma quanti idrocarburi ci sono ancora?*

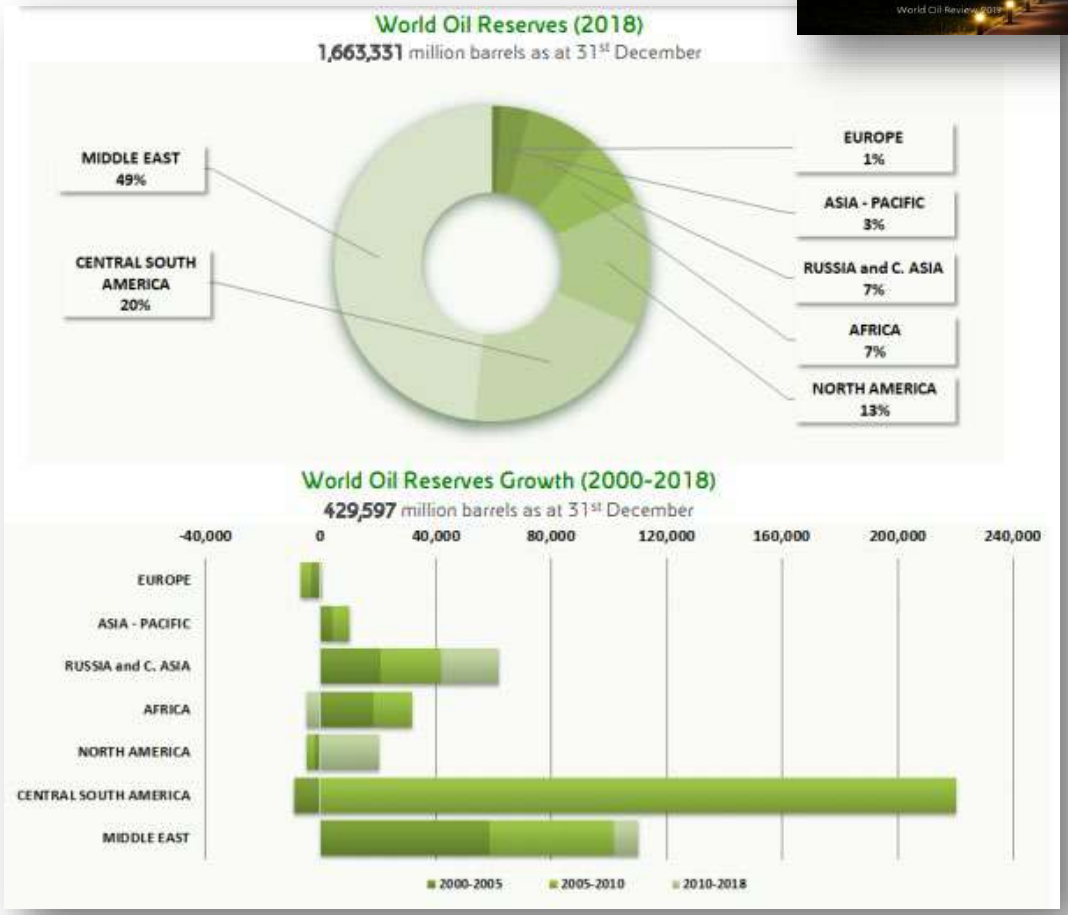
## GAS

| № | Field name | Country | Year | Original Recoverable Reserves |
|---|---|---|---|---|
| 1 | South Pars | Iran and Qatar | 1971 | 35,000 $Bm^3$ |
| 2 | Urengov | Russia | 1966 | 6,300 $Bm^3$ |
| 3 | Yamburg | Russia | 1969 | 3,900 $Bm^3$ |
| 4 | Hassi R'Mel | Algeria | 1956 | 3,500 $Bm^3$ |
| 5 | Shtokman | Russia | 1988 | 3,100 $Bm^3$ |
| 6 | **Galkynysh** | **Turkmenistan** | **2006** | **2,800 $Bm^3$** |
| 7 | Zapolyarnoye | Russia | 1994 | 2,700 $Bm^3$ |
| 8 | Hugoton | USA | 1930's | 2,300 $Bm^3$ |
| 9 | Groningen | Netherlands | 1959 | 2,100 $Bm^3$ |
| 10 | Bovanenkovo | Russia | 1972 | 2,000 $Bm^3$ |
| 11 | Medvezhye | Russia | 1967 | 1,900 $Bm^3$ |
| 12 | Dauletabad | Turkmenistan | 1974 | 1,400 $Bm^3$ |
| 13 | Karachaganak | Kazakhstan | 1979 | 1,370 $Bm^3$ |
| 14 | North Pars | Iran | 1967 | 1,340 $Bm^3$ |
| 15 | **Kish** | **Iran** | **2006** | **1,300 $Bm^3$** |
| 16 | Orenburg | Russia | 1966 | 1,300 $Bm^3$ |
| 17 | Kharasavey | Russia | 1966 | 1,200 $Bm^3$ |
| 18 | Shah Deniz | Azerbaijan | 1999 | 1,200 $Bm^3$ |
| 19 | **Golshan** | **Iran** | **2007** | **850 $Bm^3$** |
| 20 | **Zohr** | **Egypt** | **2015** | **850 $Bm^3$** |
| 21 | Tabnak | Iran | 1967 | 620 $Bm^3$ |
| 22 | Kangan | Iran | 1967 | 570 $Bm^3$ |

# *ma quanti idrocarburi ci sono ancora?*





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## Il caso Zohr

*«non bisogna mai smettere di esplorare»*

*(Claudio De Scalzi, CEO ENI, fisico nucleare, da sempre nell'esplorazione ENI)*

**Zohr**: la **più grande scoperta (2015) di gas** nel **Mar Mediterraneo,** in grado di soddisfare buona parte della domanda egiziana di gas naturale per decenni.

Riserve: **850 miliardi di metri cubi di gas in posto:** una delle **maggiori scoperte di gas a livello mondiale**.

- 3.400 m di profondità
- 1.450 m di tavola d'acqua
- 850 miliardi di metri cubi di gas in posto
- 180 km da Al-Gamil (centrale trattamento on-shore)

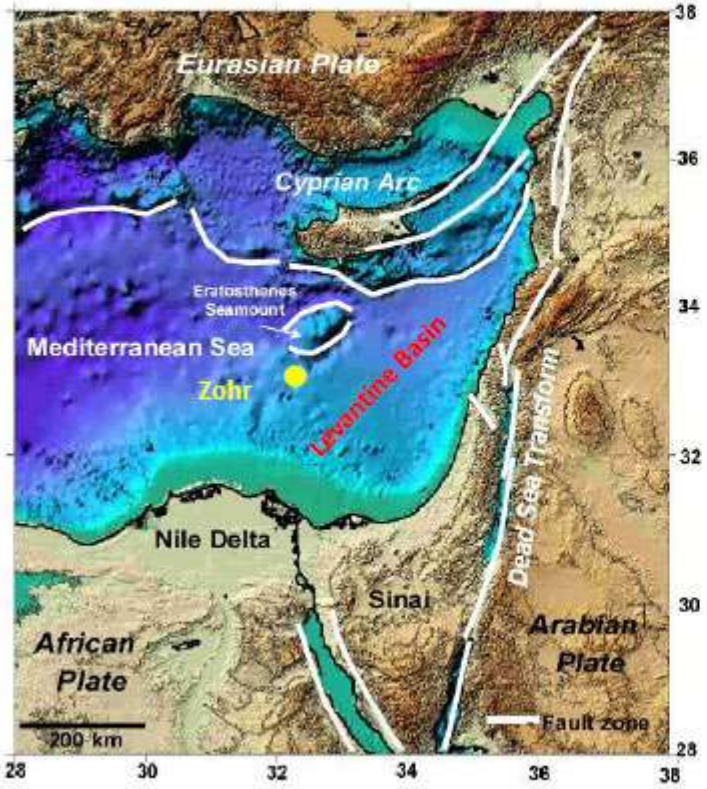
# *Il giacimento di Zohr*

**Zohr Giant Gas Discovery – A Paradigm Shift in Nile Delta and East Mediterranean Exploration***

A. Cozzi[1], A. Cascone[2], L. Bertelli[2], F. Bertello[2], S. Brandolese[3], M. Minervini[4], P. Ronchi[2], R. Ruspi[2], and H. Harby[2]

Search and Discovery Article #20414 (2018)**
Posted February 5, 2018

## Levantine Basin and 2000-2011 Gas discoveries



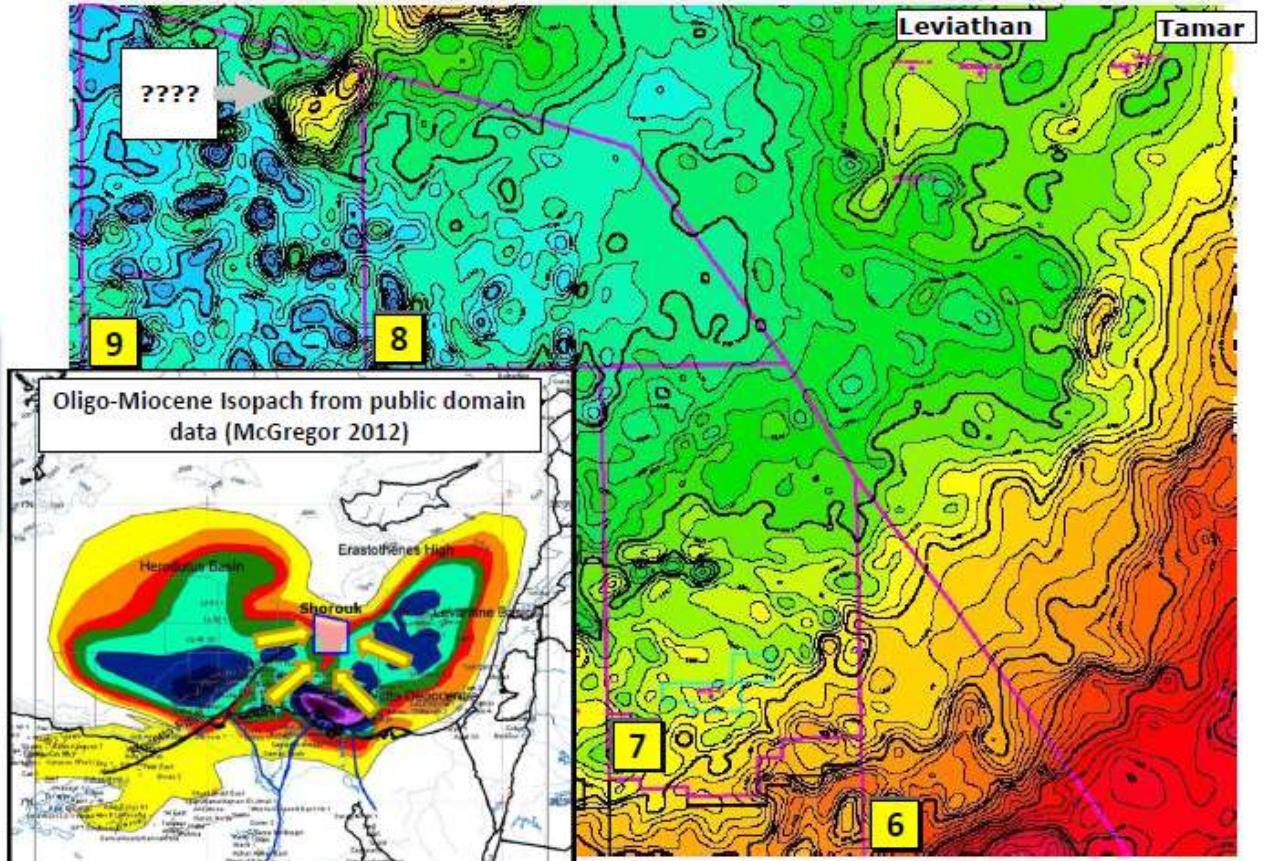

Modified after Gardosh (2009)

- **2000**: Gaza Strip; several gas discoveries in the **Pliocene sandstones** in Gaza Strip offshore (Noa, Mari B, Gaza Marine)
- **2009**: Israel; **Tamar** Discovery (Noble Op.), **Miocene turbidites**
- **2010**: Israel; **Leviathan** Discovery (Noble Op.)
- **2011**: Cyprus; **Aphrodite** discovery (Noble Op.)

- **2010** Eni started a strategic project covering all Eastern Mediterranean Areas

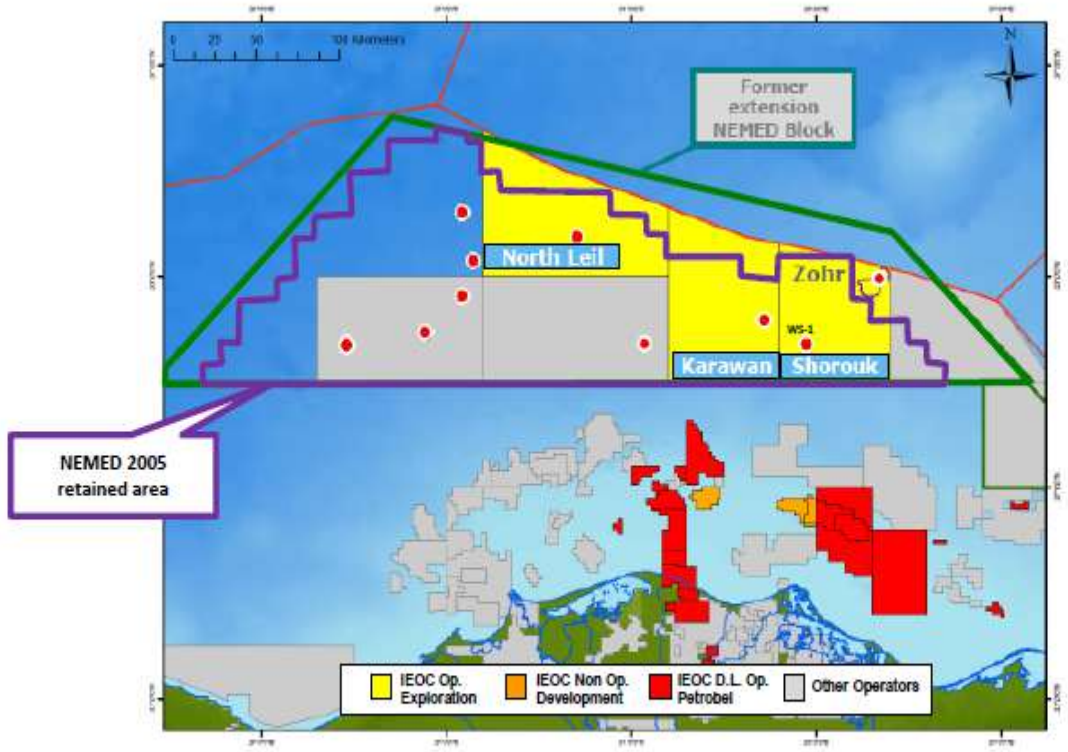
## Did we have the Levantine Play in Egyptian waters?

**Zohr Prospect is located on the structural divide among the Herodotus (W), Nile Delta (S) and Levantine Basin (E)**



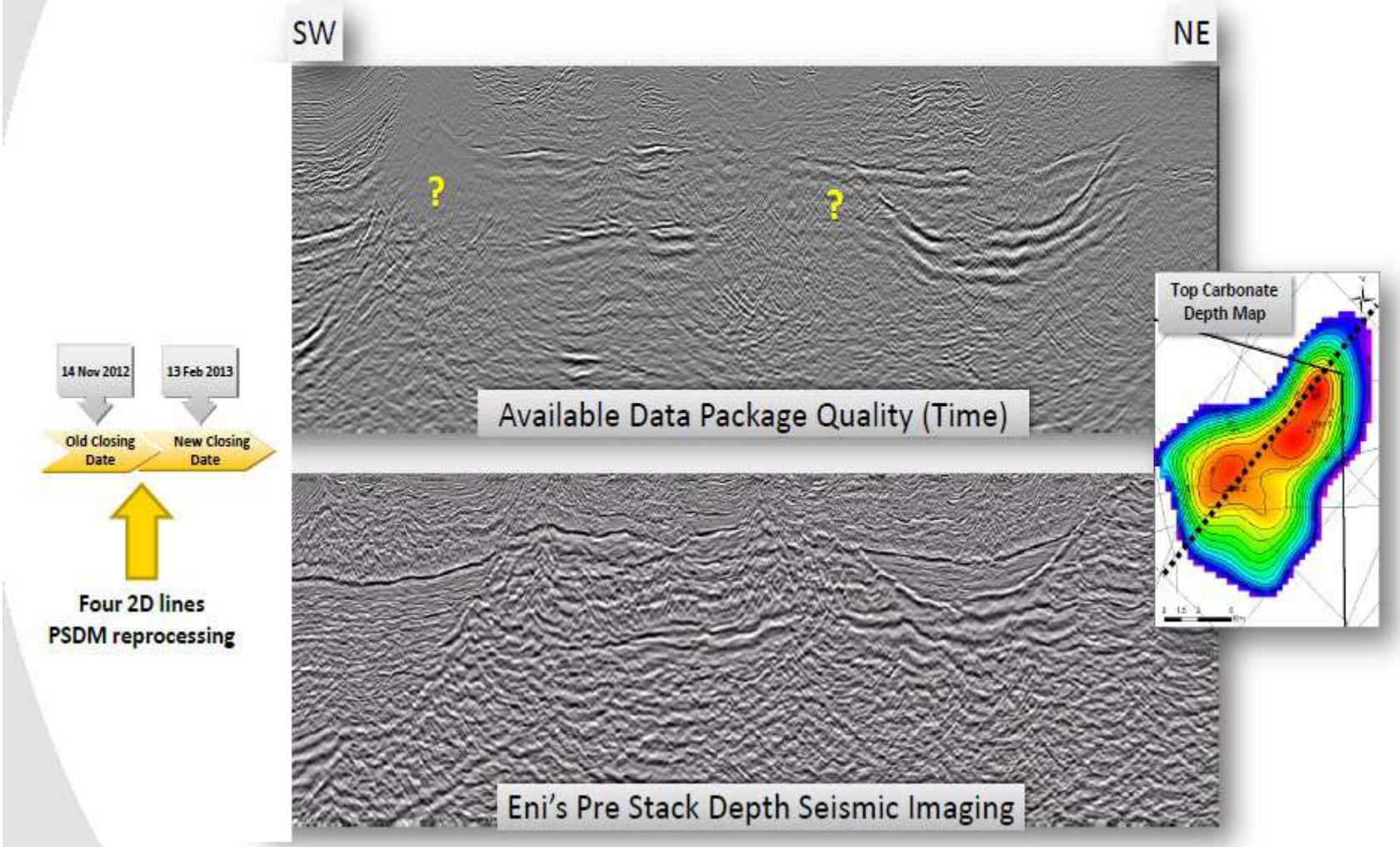

*Cozzi et al, 2018*

## Nile Delta DW & UDW - previous exploration history

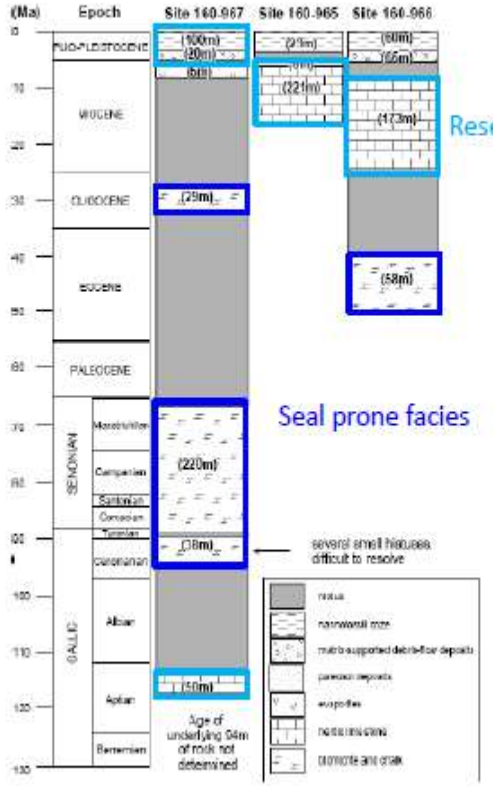


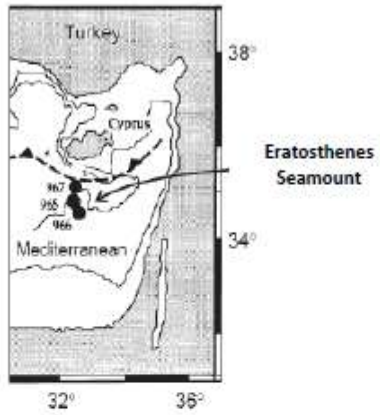

- *The Egyptian DW and UDW were extensively explored between 1999 and 2011 in the wide NEMED Block operated by a O&G Major through a massive 2D/3D seismic campaign and the drilling of **10 exploration wells***
- *The Operator was targeting the extension of the classic Tertiary clastic play of the Nile Delta, which turned out to be **not commercial**. One well (Wadi Sura-1) was drilled inside the current Shorouk Block and was unsuccessful*

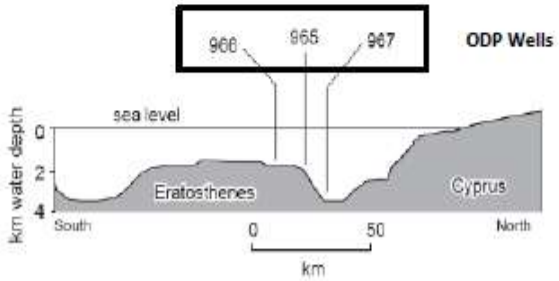
## Geological intuition and powerful Eni proprietary seismic imaging technology



# ODP data suggested Miocene and Cretaceous reservoir targets




After Flecker et al. (1998)

**Deep Sea Drilling Project (DSDP)**
**1966-1983**: primo contratto tra National Science Foundation (NSF) e The Regents, University of California.
Le perforazioni e i carotaggi nell'Oceano Atlantico, nel Pacifico e nell'Oceano Indiano, nel Mediterraneo e nel Mar Rosso hanno fornito prove definitive della deriva dei continenti e del rinnovamento dei fondali marini nelle zone di frattura, confermando la teoria della deriva continentale di **Alfred Wegener** e rafforzando l'idea di un'unica e antica massa terrestre, **Pangaea**.
Età più antica dei fondali marini: 200 milioni di anni, in confronto con l'età di 4,5 miliardi di anni della Terra. Mentre nuova crosta «nasce» dalle fratture, vecchia crosta scende di nuovo sotto le placche tettoniche (subduzione) o viene corrugata verso l'alto per formare catene montuose.

**1975:** Repubblica Federale Tedesca, Giappone, Regno Unito, Unione Sovietica e Francia si uniscono agli Stati Uniti (***IPOD, International Phase of Ocean Drilling***).

**1985-2003**: ***Ocean Drilling Program (ODP).*** Il nuovo programma coinvolge: Australia, Belgio, Danimarca,
Finlandia, Islanda, Irlanda, Italia, Paesi Bassi, Norvegia, Spagna, Portogallo, Svezia, Svizzera

**2003-2013*: Integrated Ocean Drilling Program (IODP)***. Cambiano contratti e accordi.

**2013-2023**: ***Integrated Ocean Discovery Program*** (IODP). www.iodp.org/

## *(DSDP, ODP, IODP)*

**Deep Sea Drilling Project (DSD**
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Le perforazioni e i carotaggi nel
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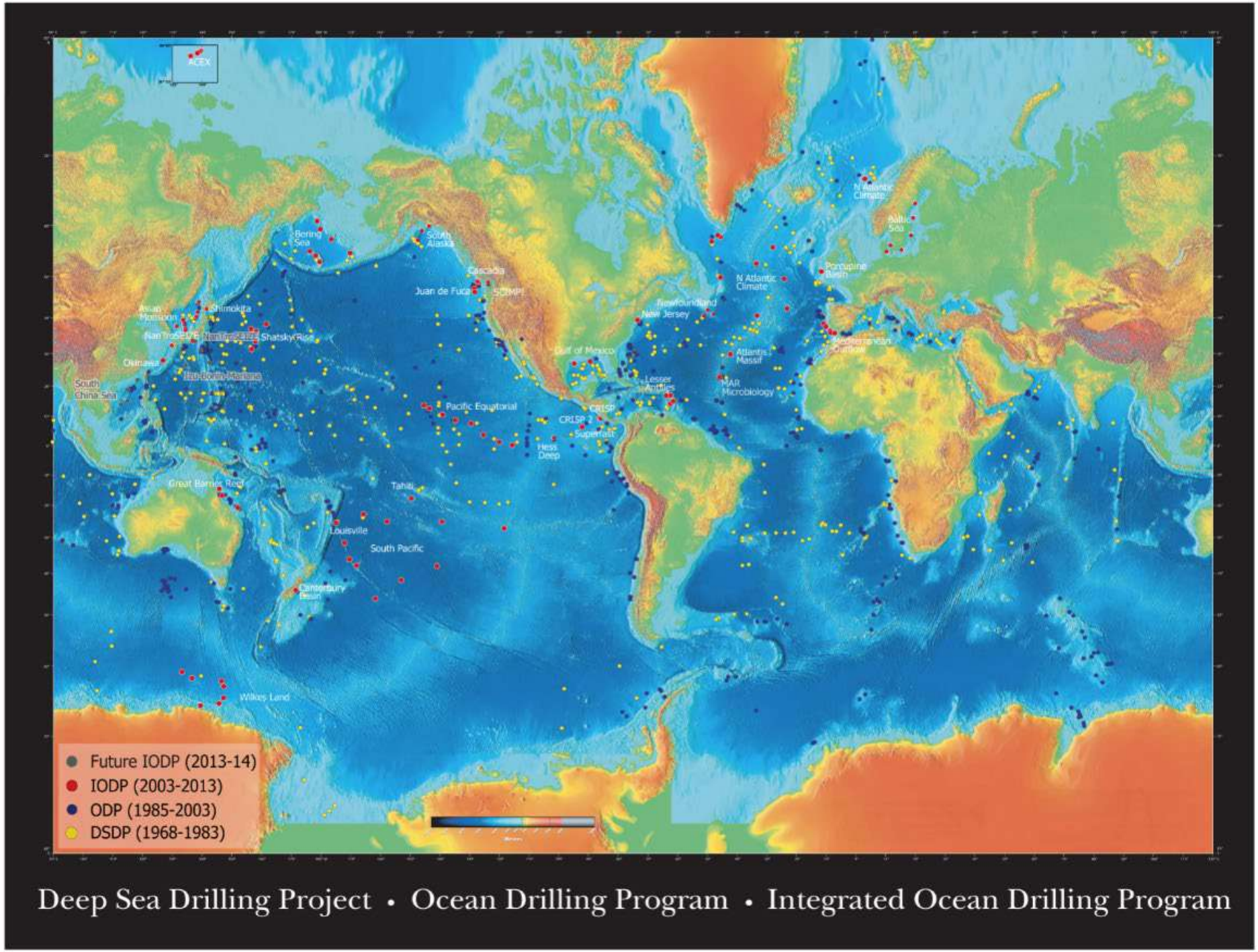
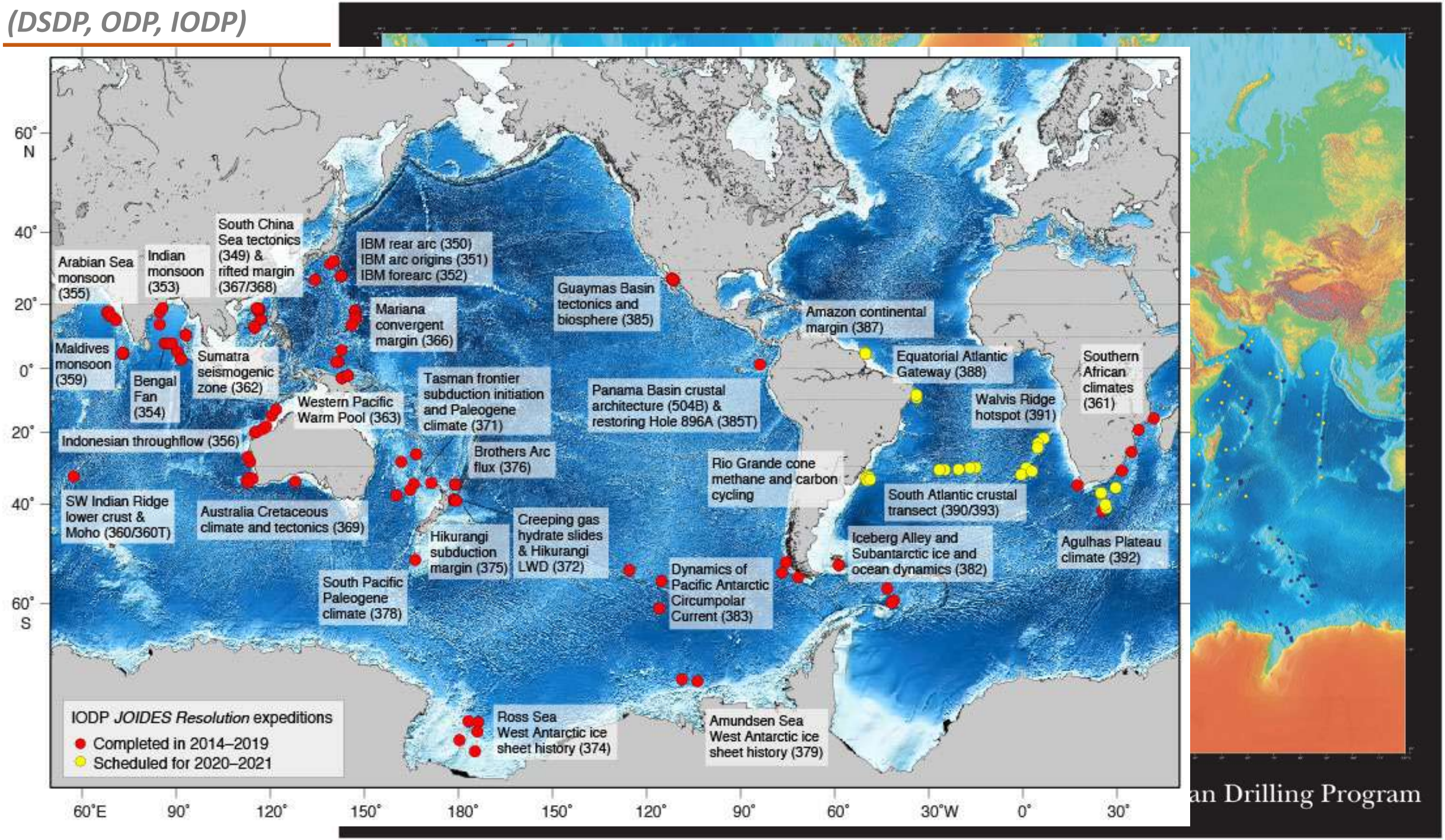
Svizzera

**2003-2013*: Integrated Ocean***

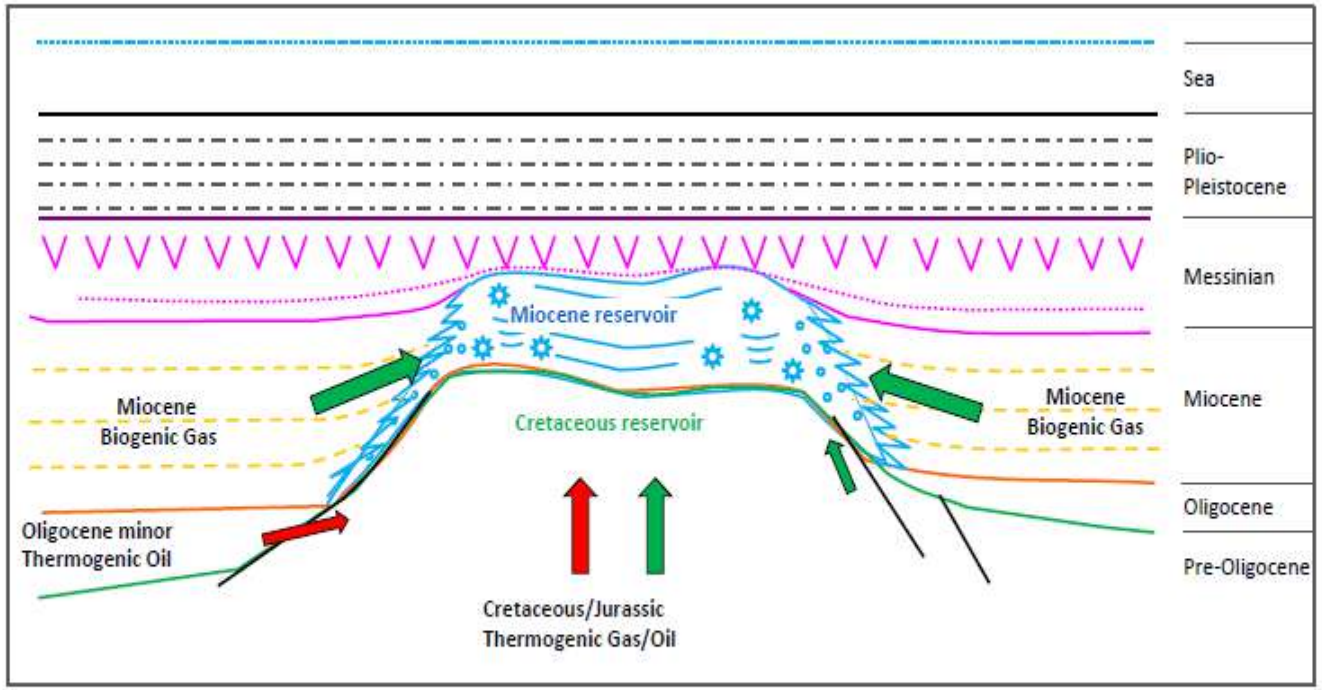
**2013-2023**: ***Integrated Ocean***



## (DSDP, ODP, IODP)



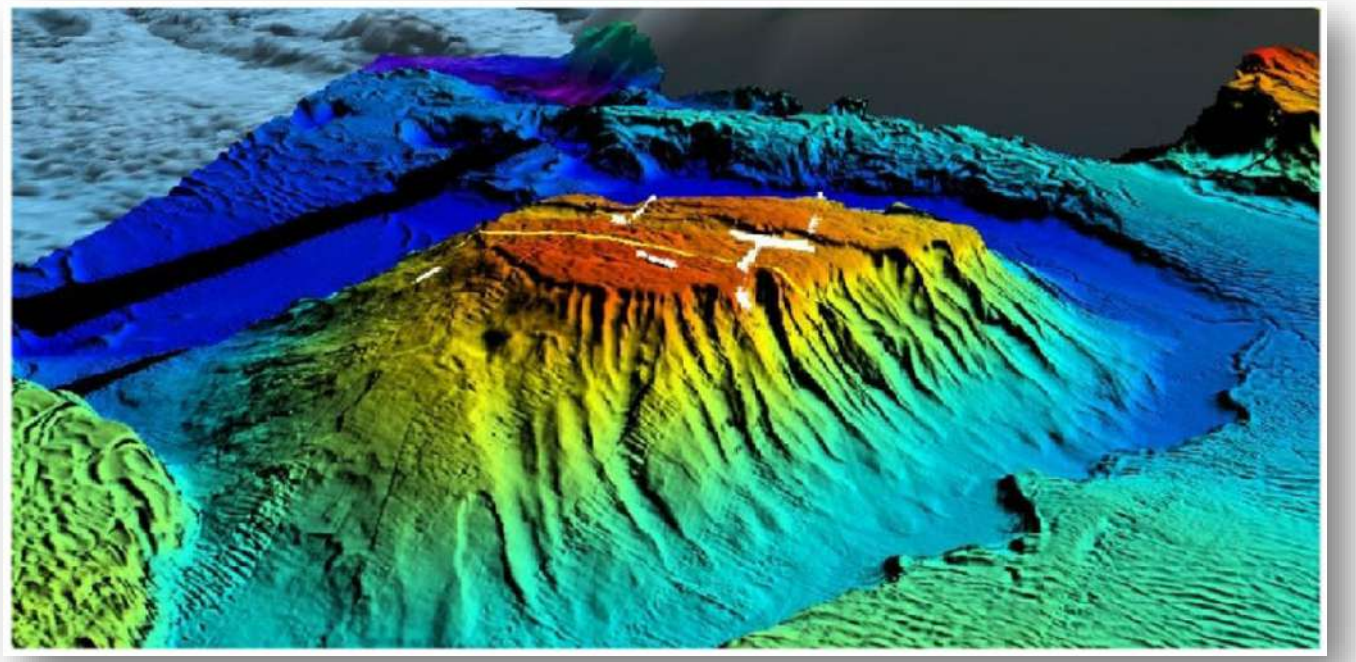
## The Zohr Play conceived




- *Untested Play*
- *High Risk – High Reward but it could change the future of EXP in Egypt and East Mediterranean in general*

# *Lo sviluppo di un nuovo play-concept – L'importanza della conoscenza diretta*

## *La classificazione delle Piattaforme Carbonatiche*



Strata GeoResearch. Isolated Carbonate Platforms of Mediterranean: Geological Features and Hydrocarbon Potential, Multiclient Basin Studies (2018)

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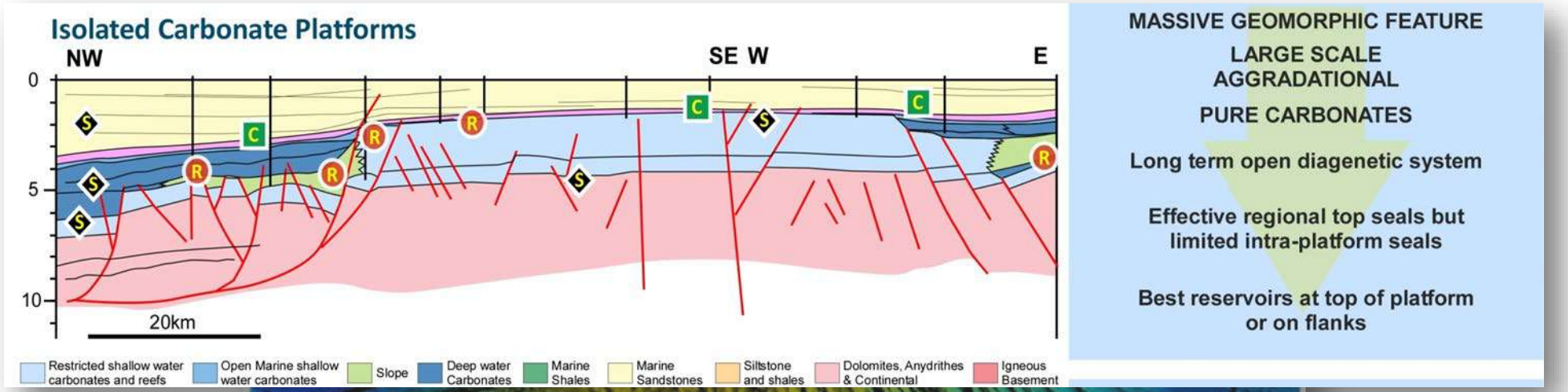
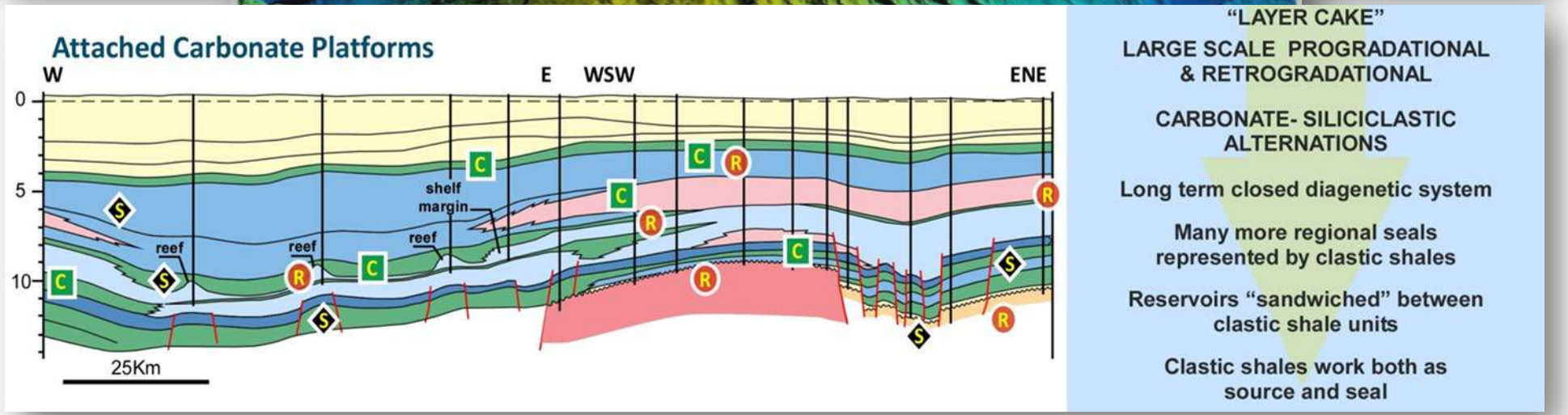
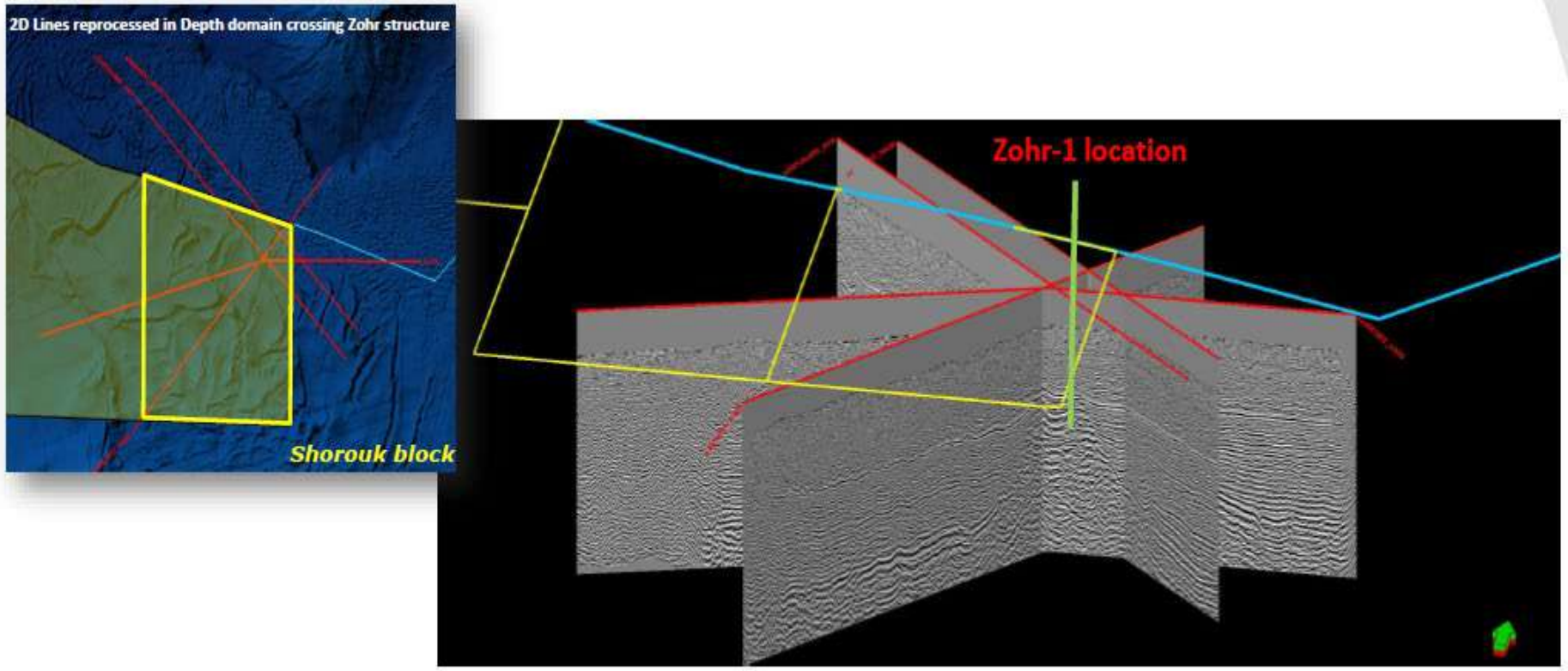


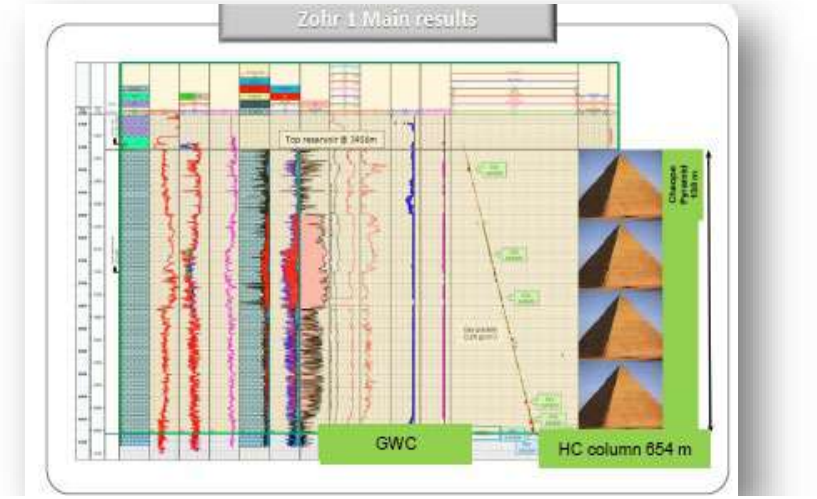


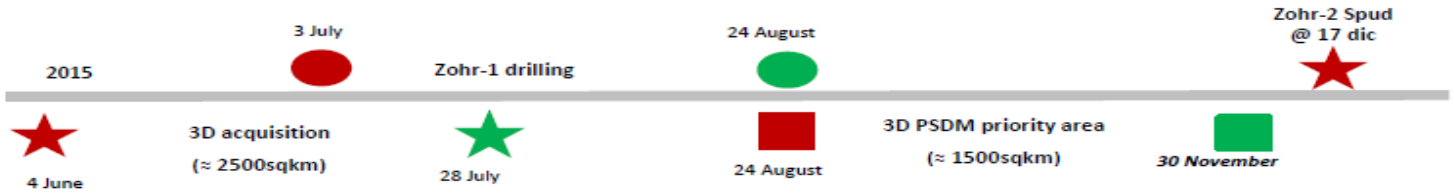

Strata GeoResearch. Isolated Carbonate Platforms of Mediterranean: Geological Features and Hydrocarbon Potential, Multiclient Basin Studies (2018)

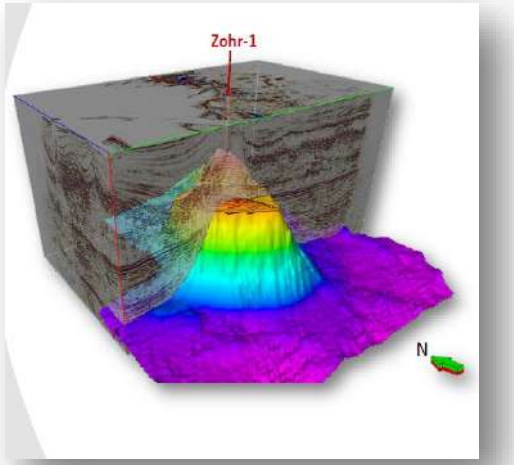
## The four 2D PSDM seismic lines used to locate Zohr-1 discovery well

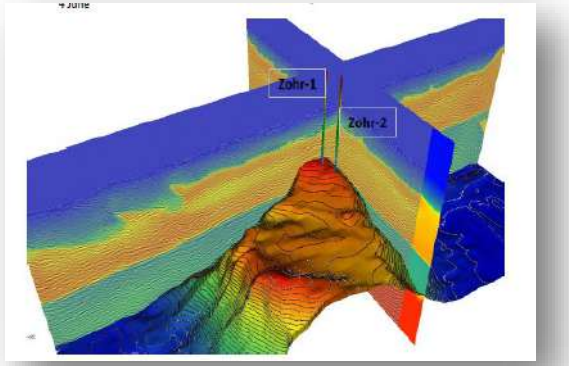


# *Il giacimento di Zohr*



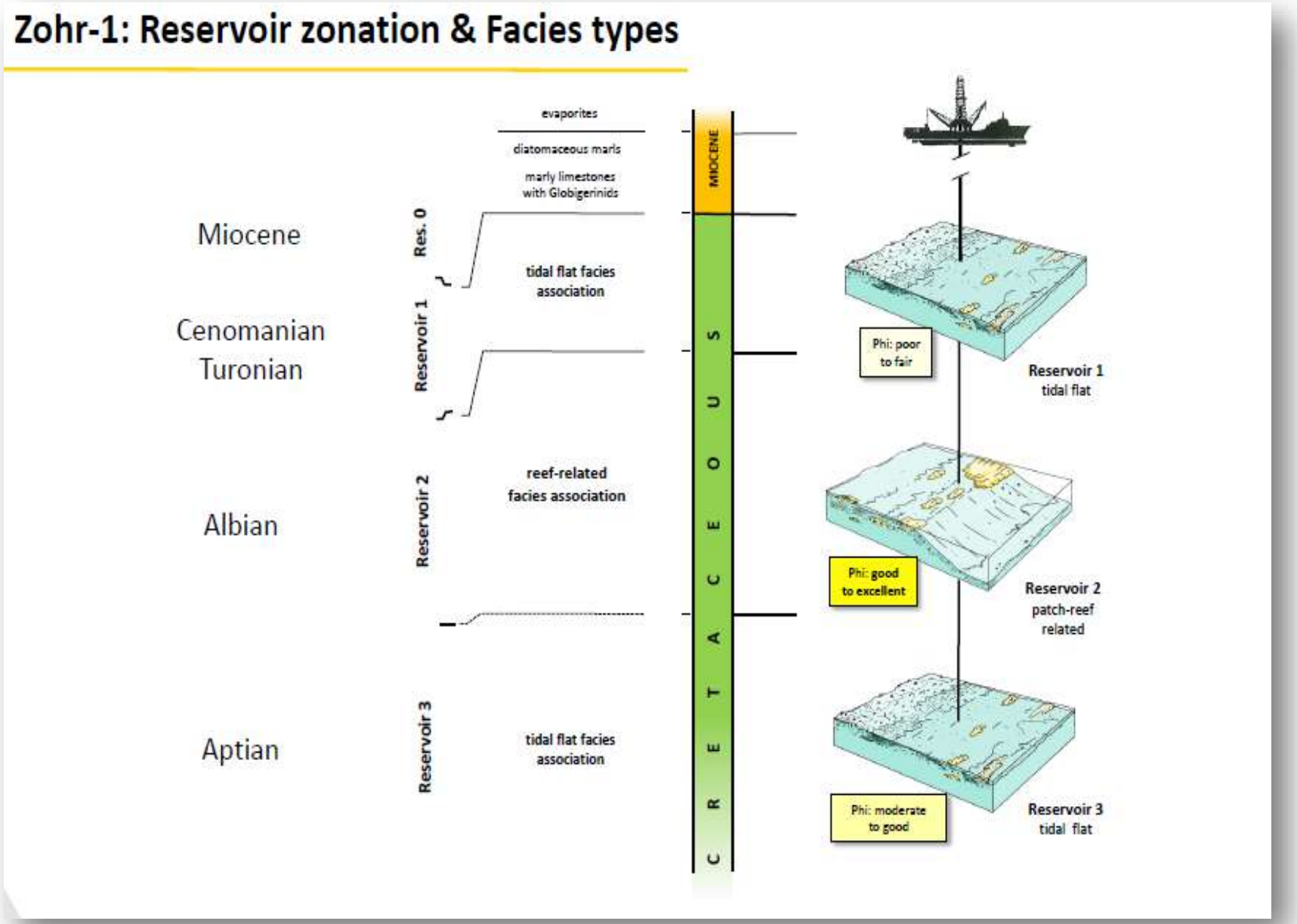




- Zohr#1 located only with 2D seismic
- 3D seismic acquired during the drilling of Zohr#1
- In-house High Performance Computing softwares and professional skills
- Outstanding biogenic gas in a Miiocene-Cretaceous carbonate platform complex
- World-class carbonate reservoir
- Discovered volumes estimated at 30 TCF of GOIP (>850Billion m3)

**New play concept:**
**Isolated Carbonate Platform ICP**


Zohr-1: Reservoir zonation & Facies types
evaporites
diatomaceous marls
marly limestones with Globigerinids
MIOCENE
Miocene
Res. 0
tidal flat facies association
Cenomanian
Turonian
Reservoir 1
Albian
Reservoir 2
reef-related facies association
Aptian
Reservoir 3
tidal flat facies association
C R E T A C E O U S
Phi: poor to fair
Reservoir 1 tidal flat
Phi: good to excellent
Reservoir 2 patch-reef related
Phi: moderate to good
Reservoir 3 tidal flat

1. **Glossario**
2. Le **geoscienze** in un mondo che cambia
   - **2.1 Agenda 2030** e i 17 Sustainable Development Goals-SDGs
   - **2.2 SDG7**: Energia
   - **2.3 Statistiche** dell'energia: mondo, UE, Italia
   - **2.4 Transizione energetica e geoscienze**: una opportunità da cogliere
3. Le geoscienze delle risorse energetiche: il **petroleum geologist**
   - 3.1 Quando è stato perforato il **primo pozzo** di petrolio in USA? E in Italia?
   - **3.2 Quanti pozzi** di petrolio e di gas sono stati perforati in Italia?
   - 3.3 La **ricerca petrolifera** è fine a sé stessa?
   - **3.4 Quanto petrolio e quanto gas** ancora ci sono?
   - 3.5 Quale è il **ruolo del geologo** nell'esplorazione del sottosuolo?
   - 3.6 Il **lavoro di campagna** non serve più? Il geologo sarà sostituito dai **computer**?

## Shallow Marine Carbonate Platforms - Today Analogues

Atolls in the Maldives? Great Bahama Bank?


*Zohr NFW was Chasing an ancient Shallow Marine Carbonate Platform 2000 m below mud line sealed by an evaporitic complex*

# *Lo sviluppo di un nuovo play-concept – L'importanza della conoscenza diretta*

*Gli «analoghi» di Zohr*

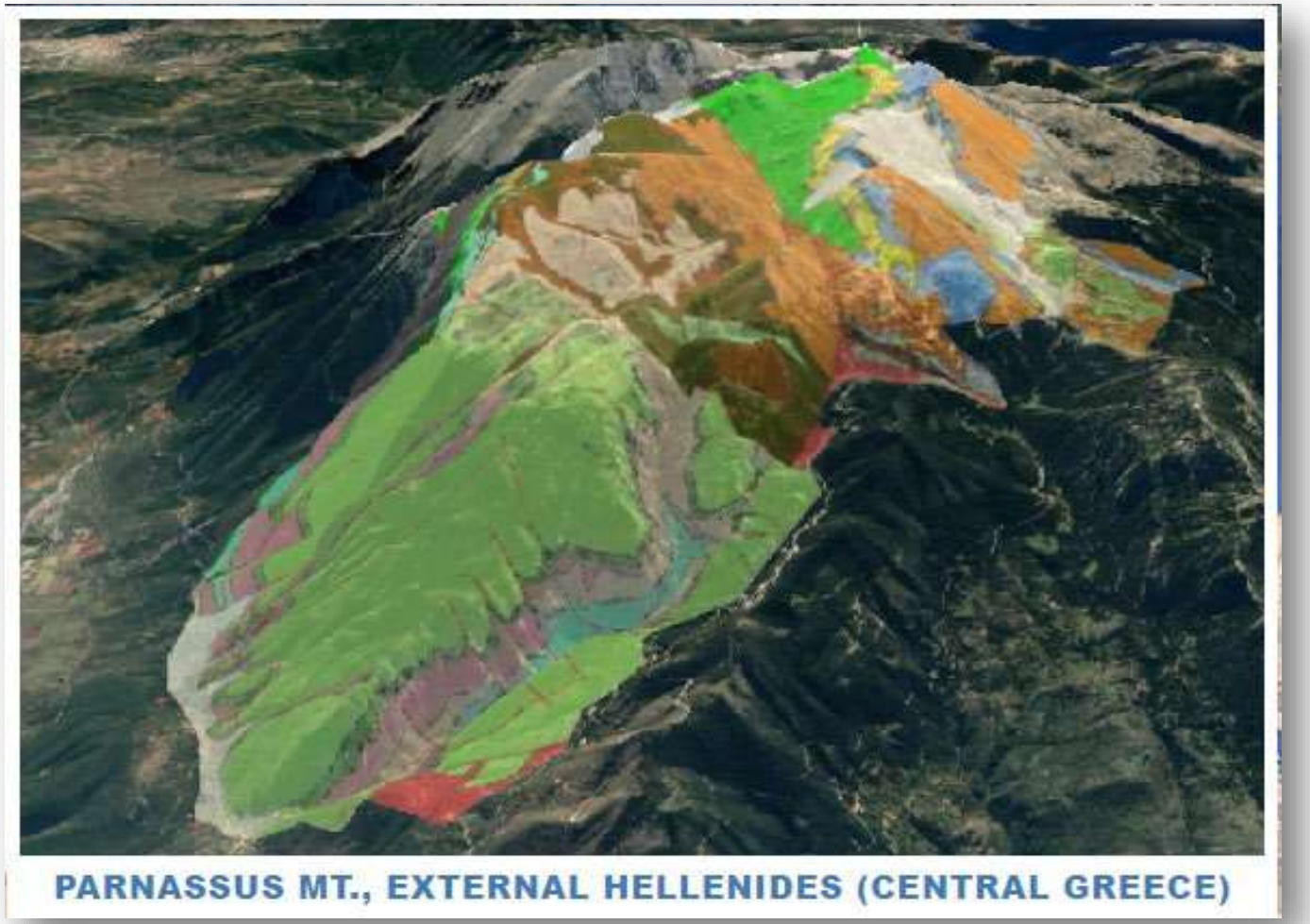
*1. Il Gruppo del Sella, Dolomiti*



# *Lo sviluppo di un nuovo play-concept – L'importanza della conoscenza diretta*

## *Gli «analoghi» di Zohr*

## *2. Il Monte Parnaso, Grecia*






Strata GeoResearch. Isolated Carbonate Platforms of Mediterranean: Geological Features and Hydrocarbon Potential, Multiclient Basin Studies (2018)

# Lo sviluppo di un nuovo play-concept – L'importanza della conoscenza diretta

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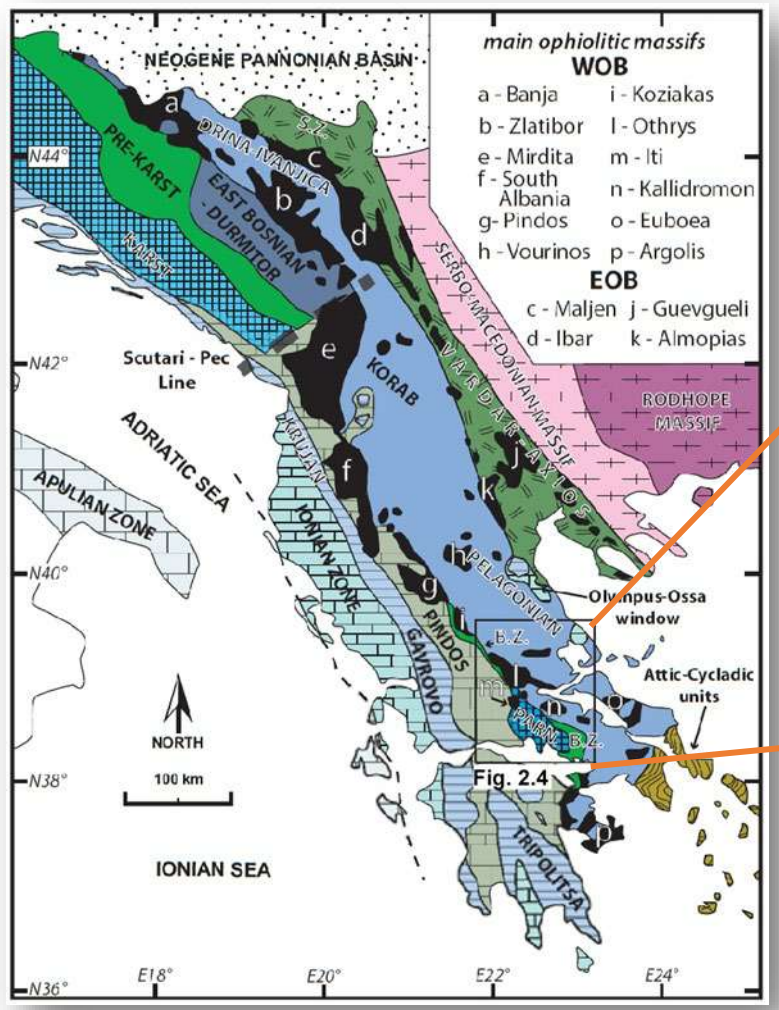


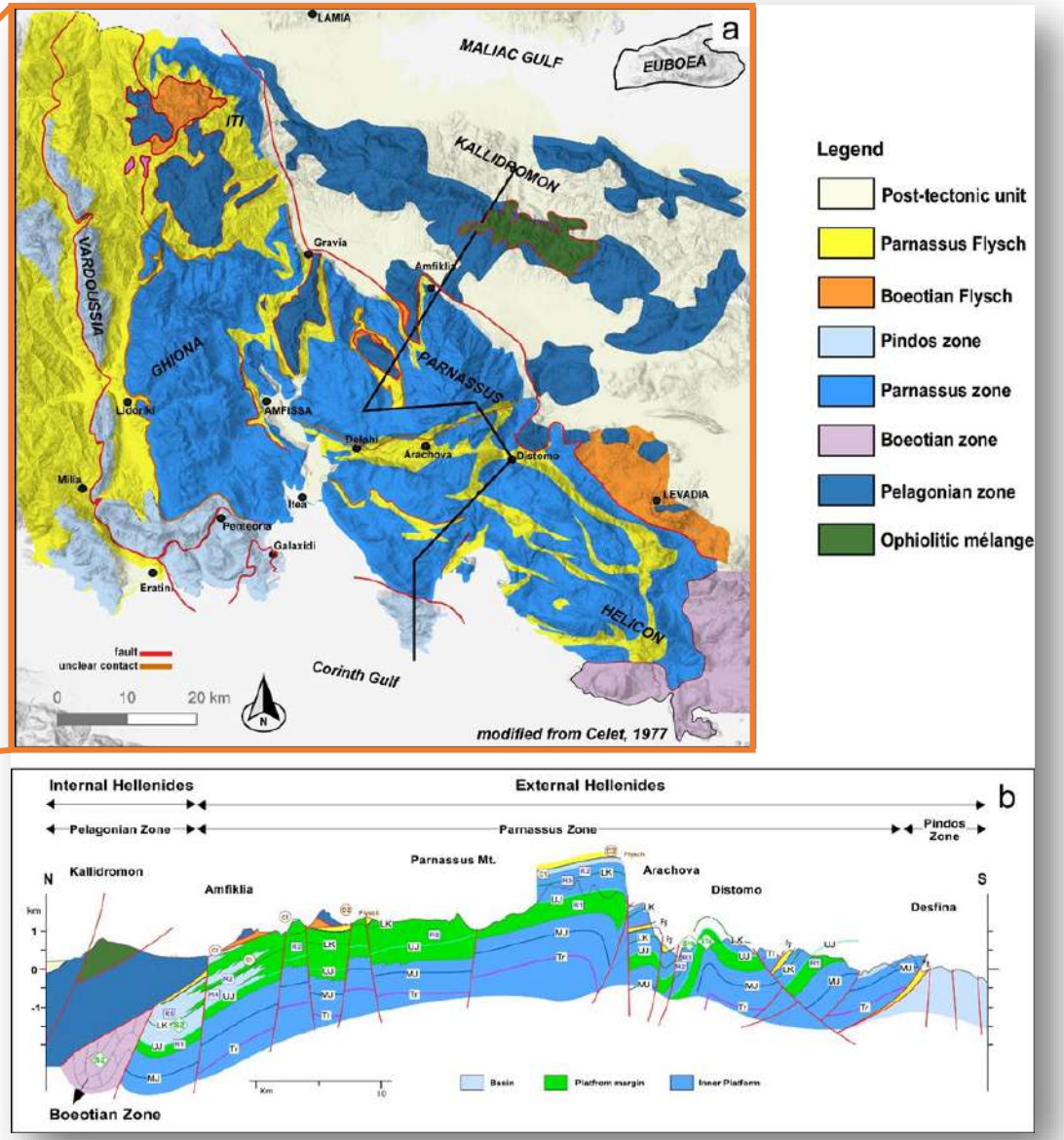




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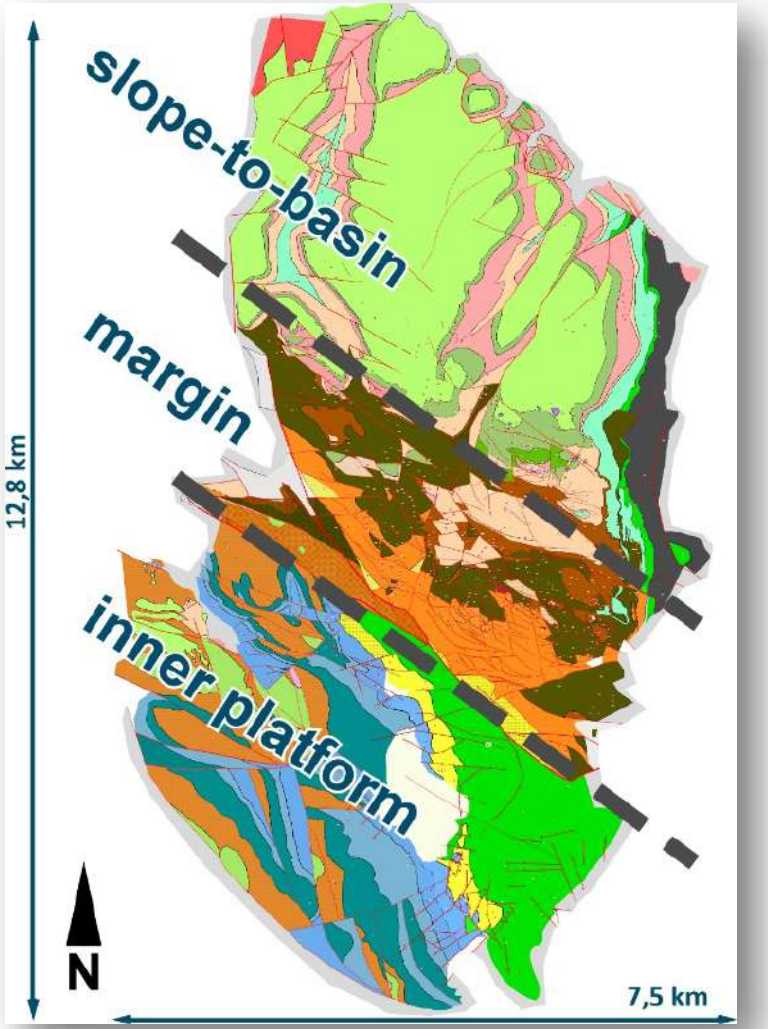


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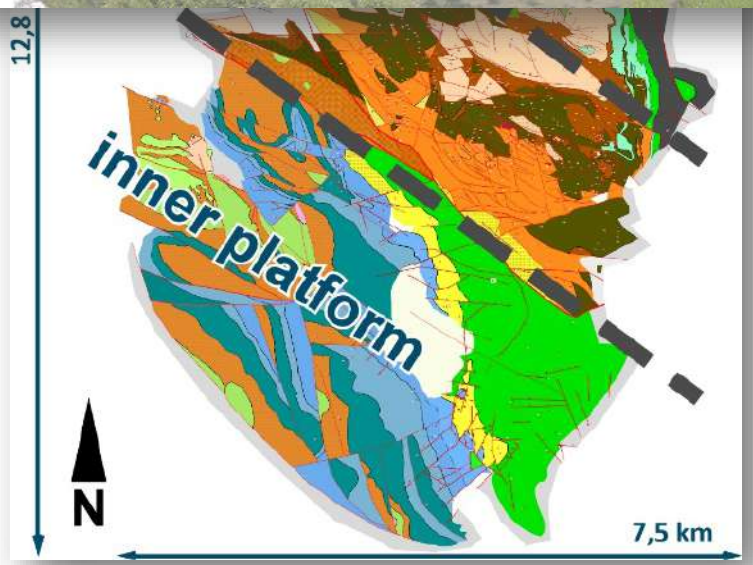
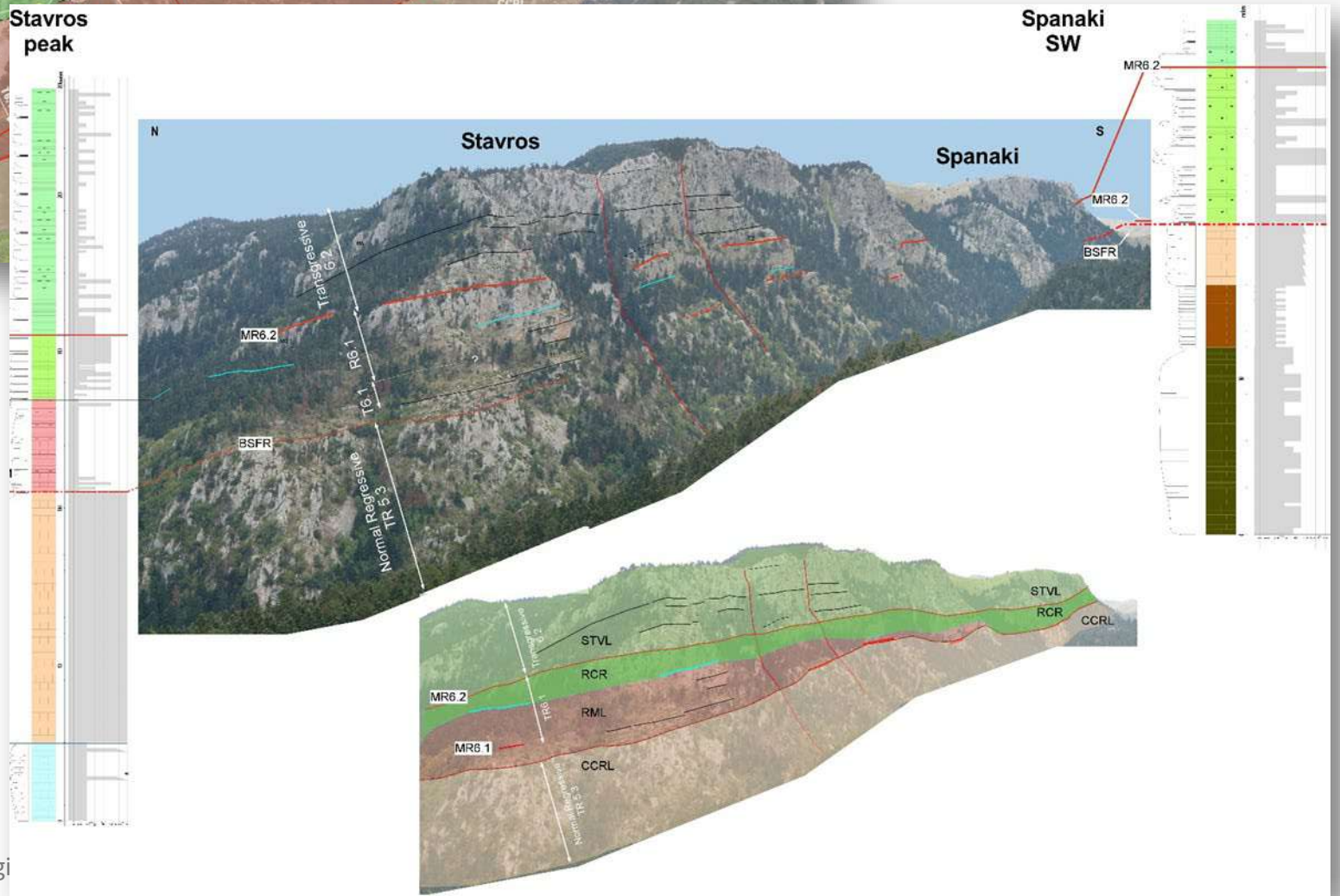
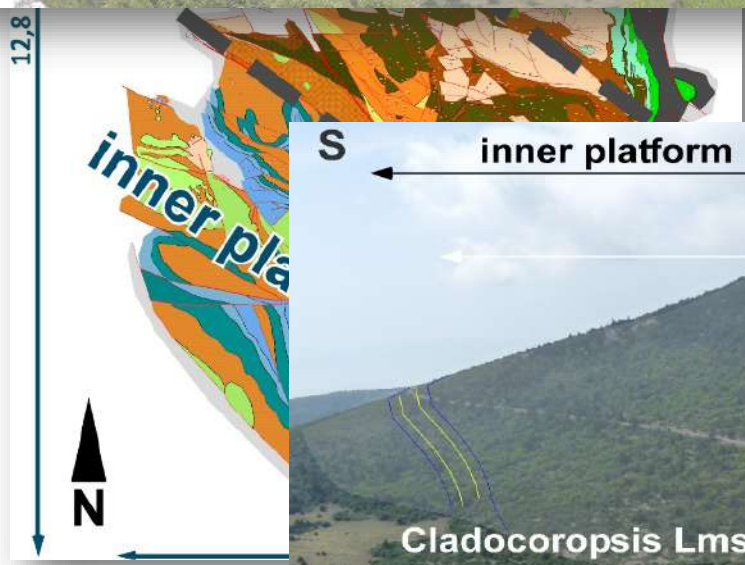


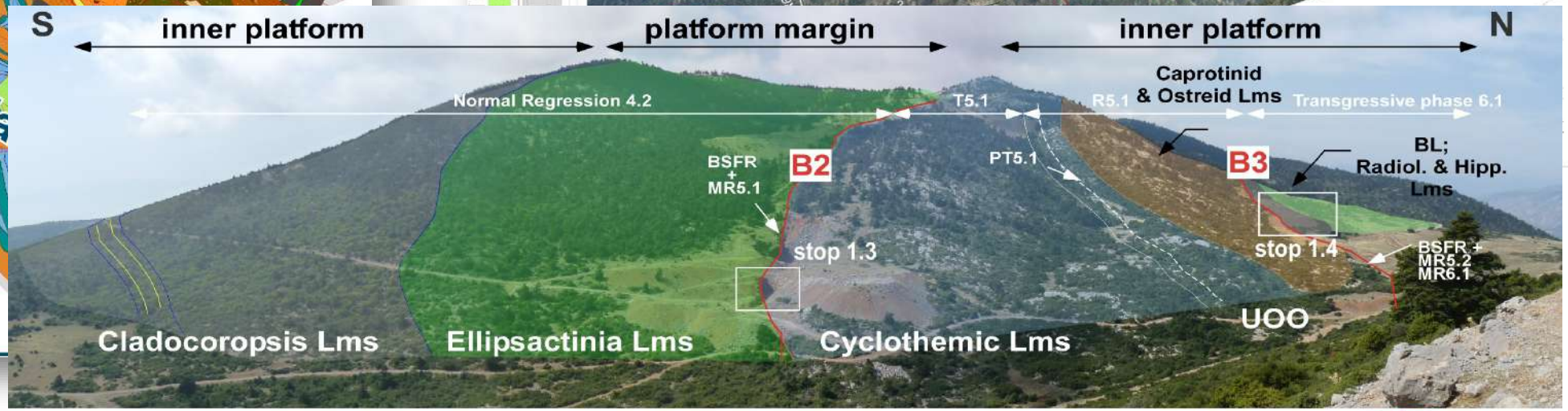



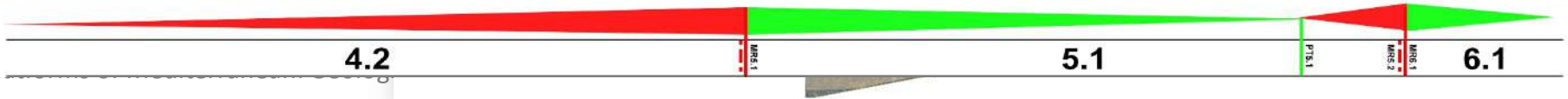

STRATA GEORESEARCH

# *Lo sviluppo di un nuovo play-concept – L'importanza della conoscenza diretta*



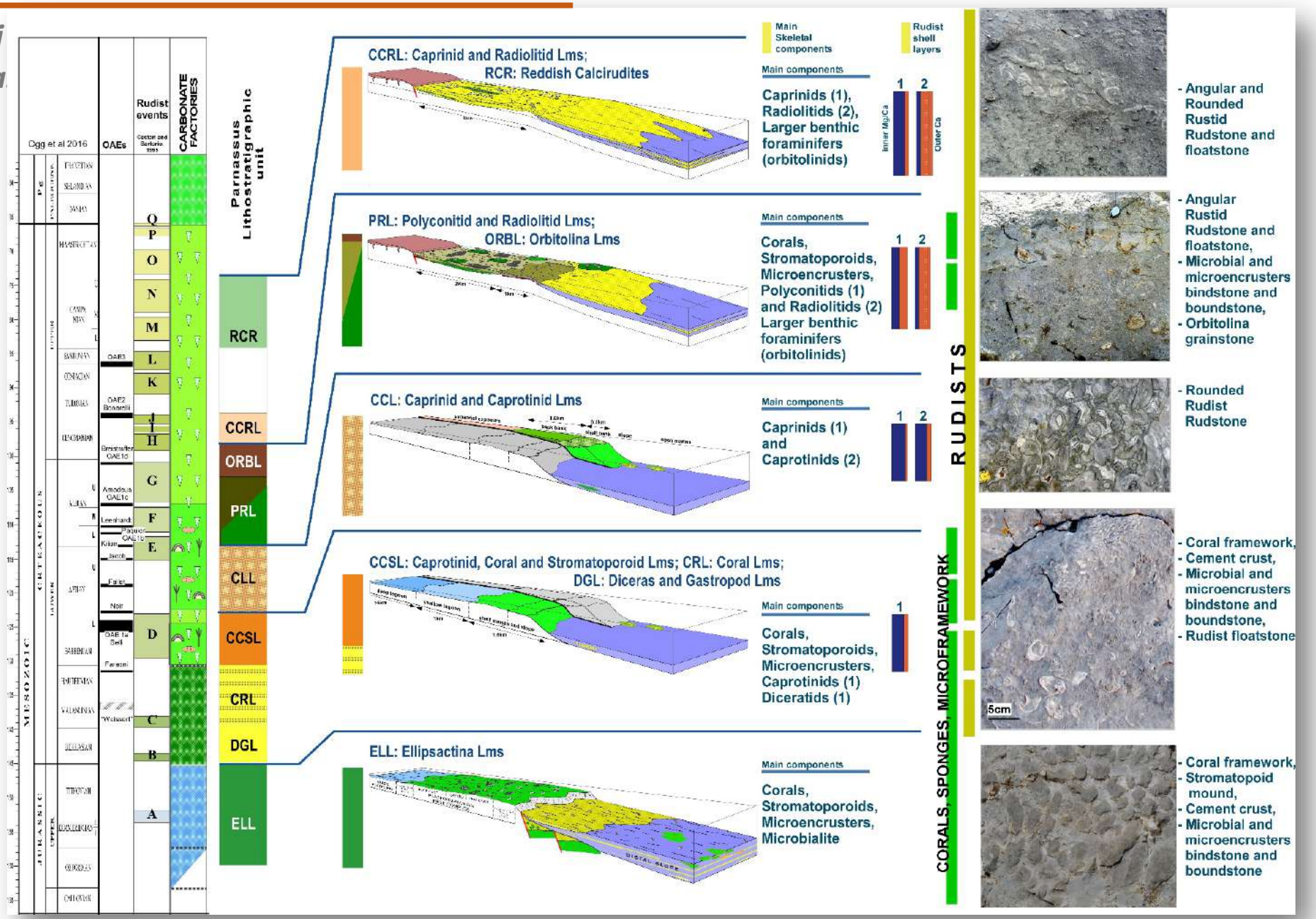


# Lo sviluppo di un nuovo play-concept – L'importanza della conoscenza diretta

## Gli «analoghi» di
## 2. Il Monte Parna






Strata GeoResearch. Isolated Carbonate Platforms of Mediterranean: Geological Features and Hydrocarbon Potential, Multiclient Basin Studies (2018)

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## *Gli «analoghi» di*
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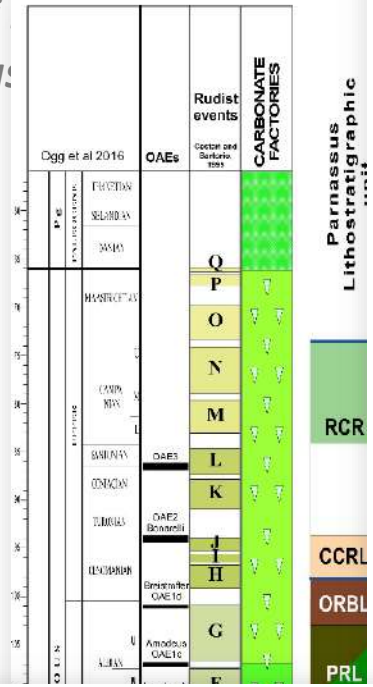


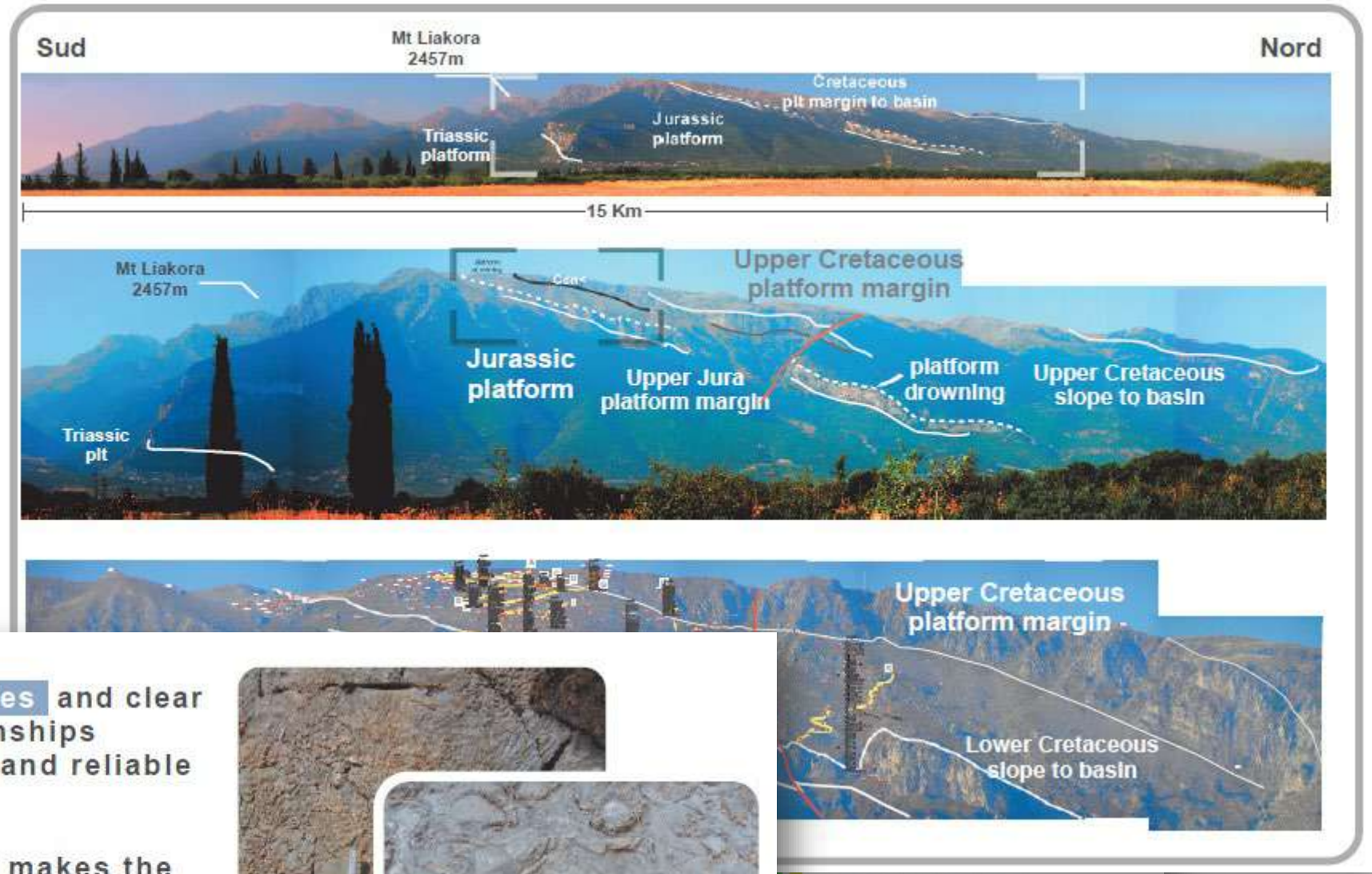


The **full spectrum of carbonate facies** and clear stratigraphic and geometric relationships provide well-constrained, detailed and reliable **depositional facies models**

The long-term stratigraphic record makes the Parnassus an ideal site to study the response of **Mesozoic Carbonate Systems** to changes in the accommodation space related to regional and global events



- Coral framework,
- Stromatopoid mound,
- Cement crust,
- Microbial and microencrusters bindstone and boundstone



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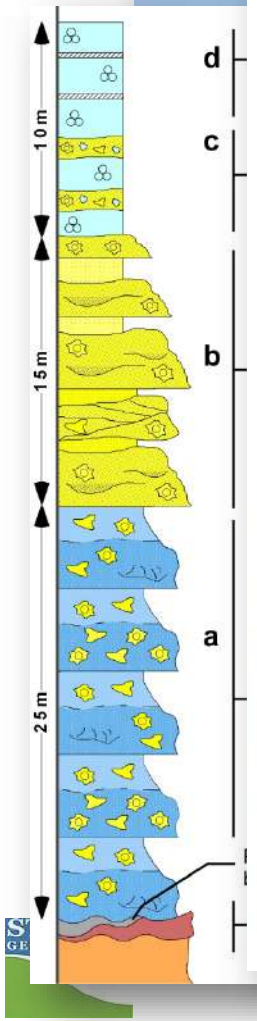
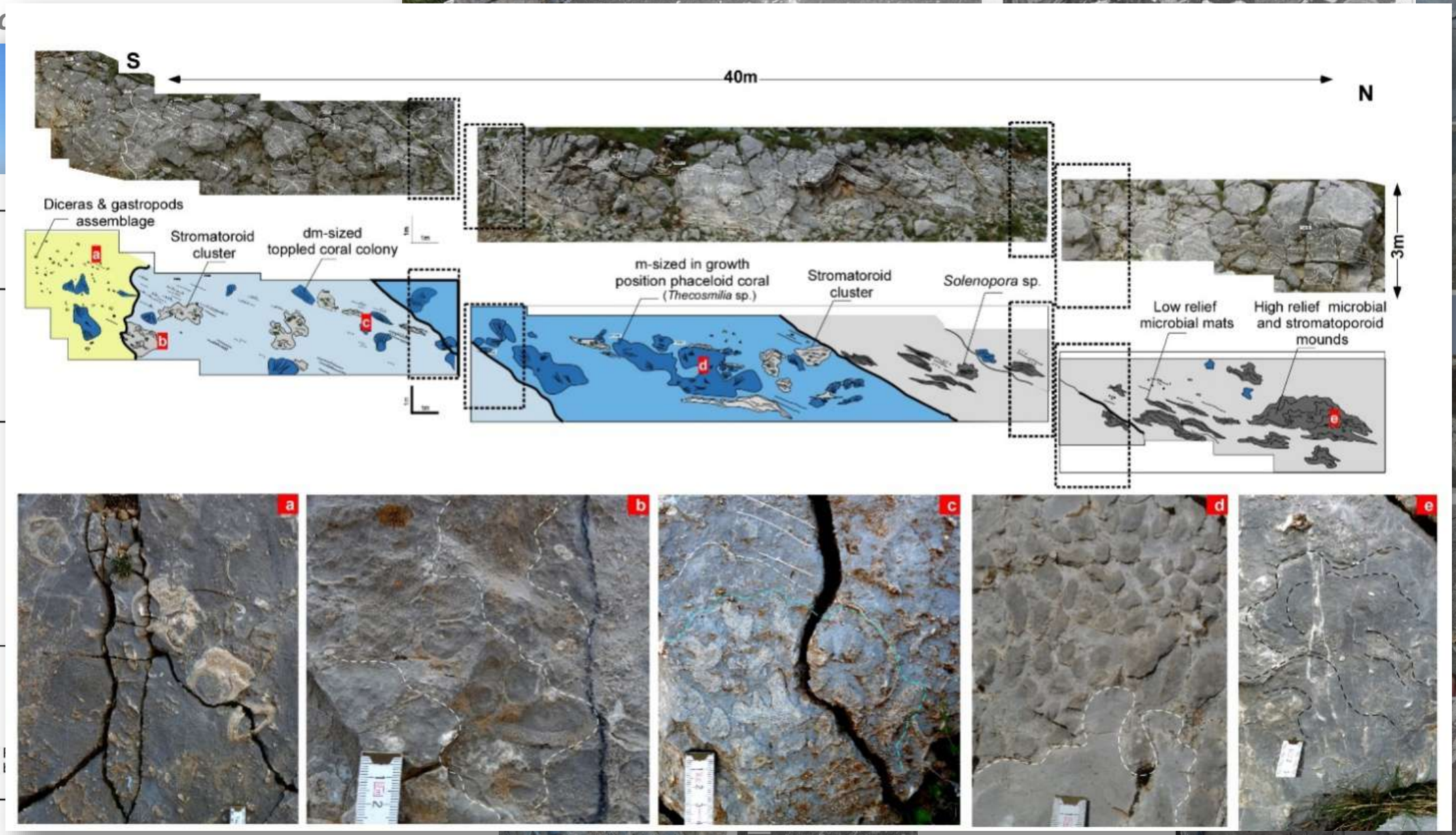
# *Lo sviluppo di un nuovo play-concept – l'importanza della conoscenza*

*Gli «analo*

*2. Il*



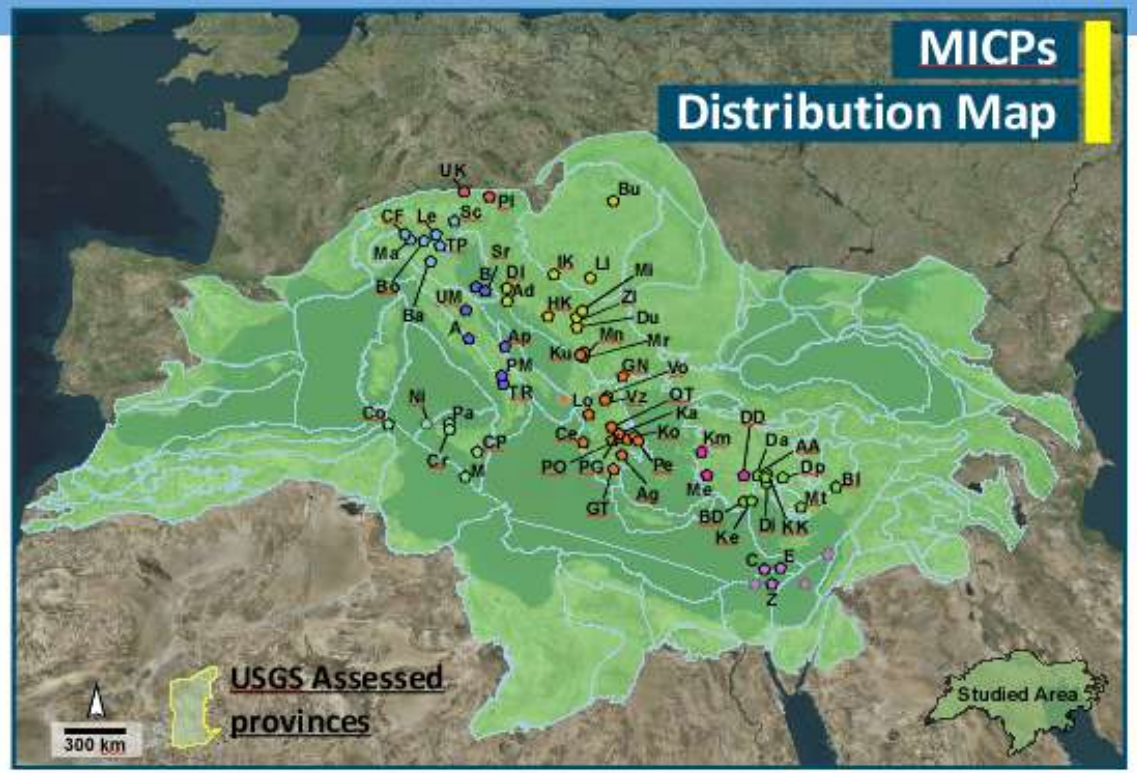



# *Lo sviluppo di un nuovo play-concept – L'importo*

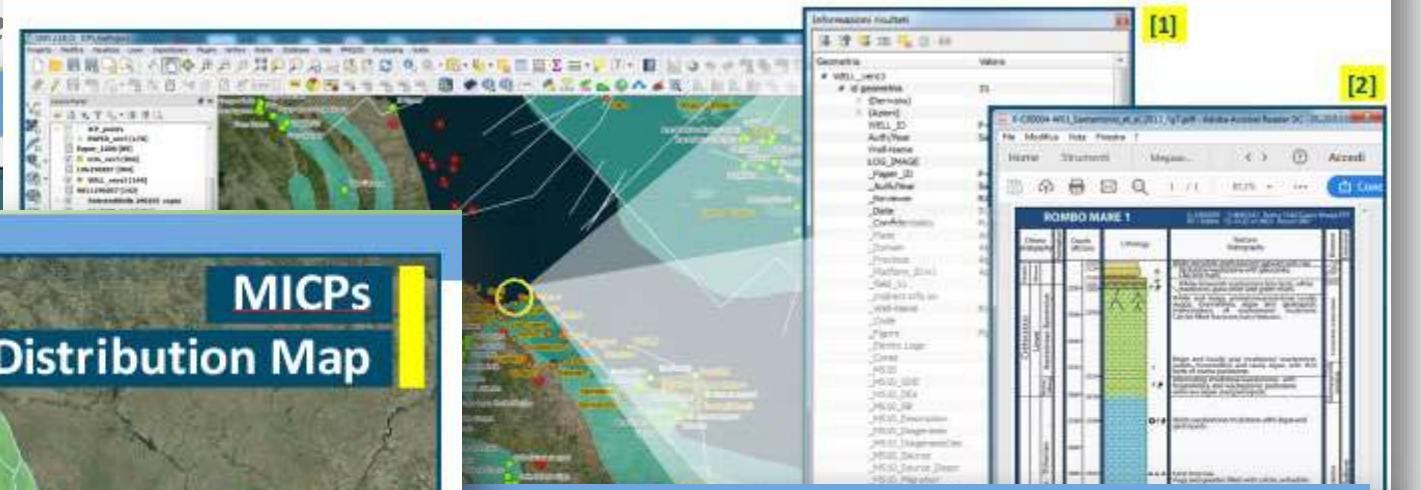
## *Le Piattaforme Carbonatiche Isolate (ICP) nel Medite*

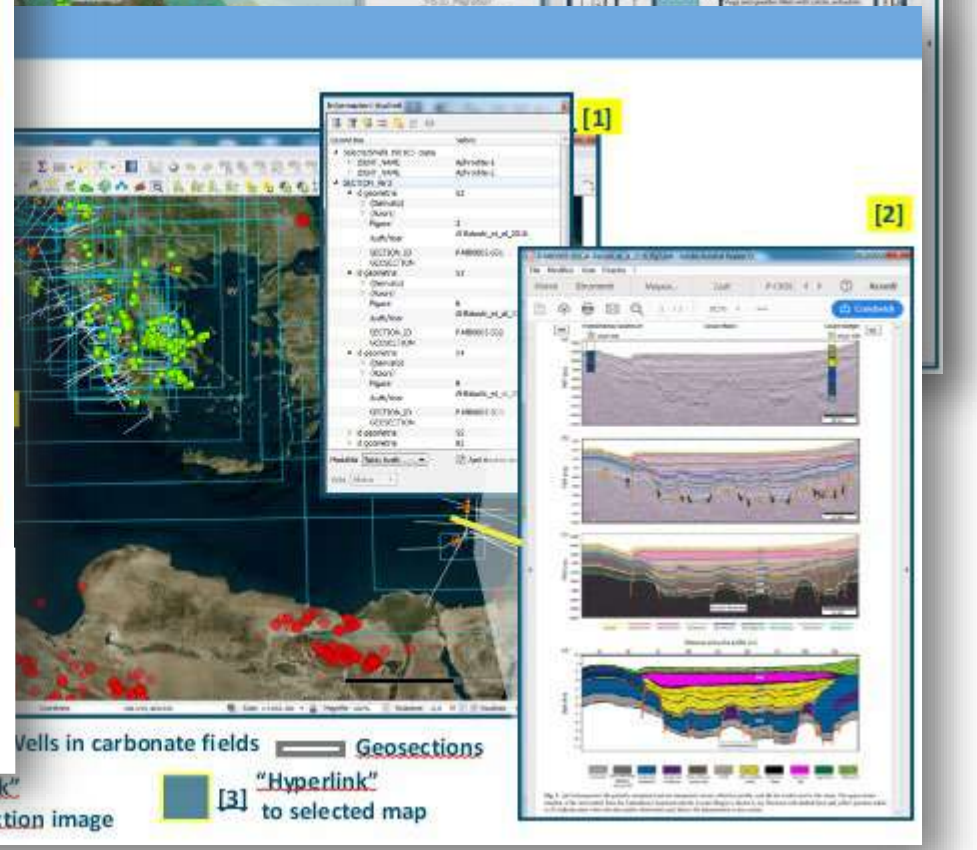
### Logs and Wells

### MICPs




### Log and Well Vectors



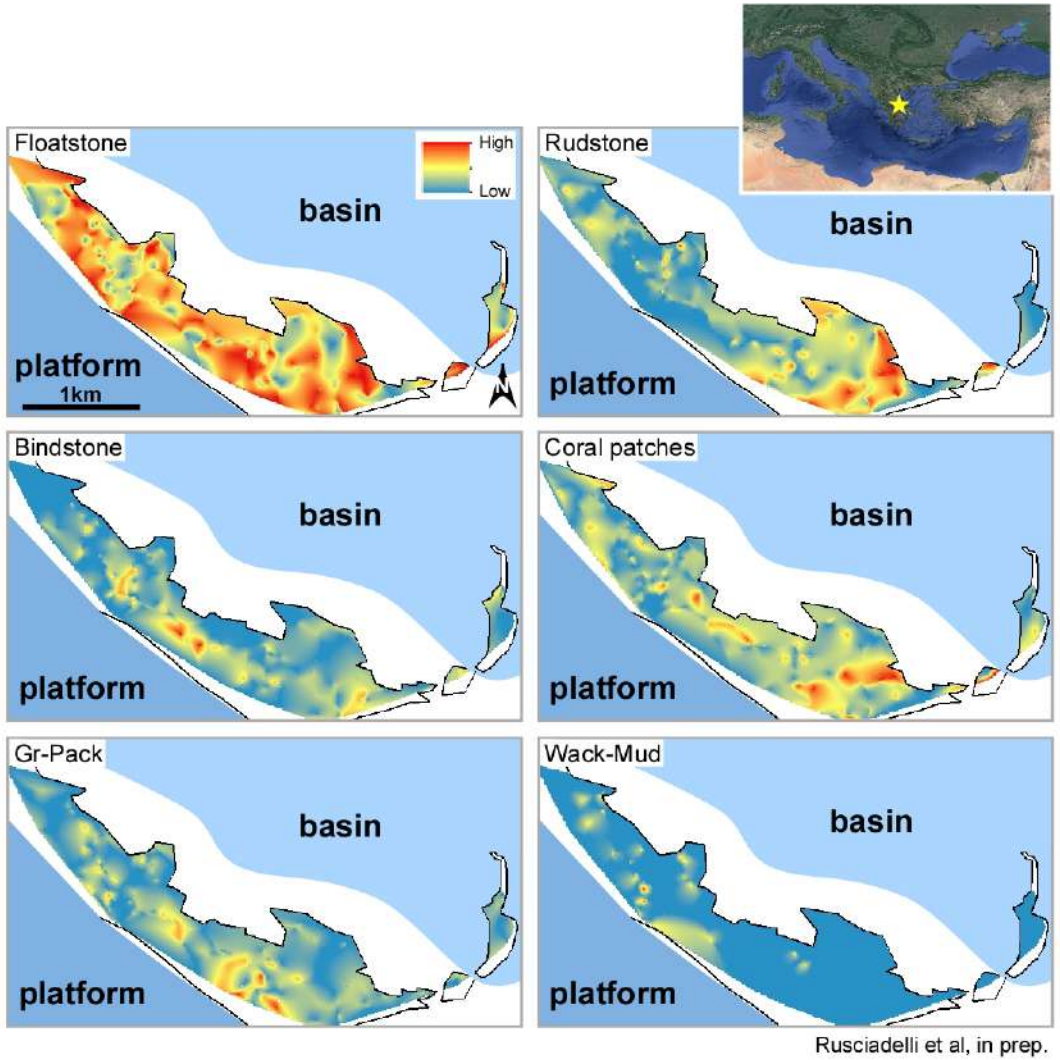



# *Lo sviluppo di un nuovo play-concept – L'importanza della conoscenza diretta*

## *Le variazioni di facies negli affioramenti del margine del Cretacico inf (Mt Parnaso, Grecia)*

- Reservoir-scale prediction of facies distribution is a primary issue
- Outcrops provide valid case studies when not biased by poorly constrained interpretation of lateral facies changes

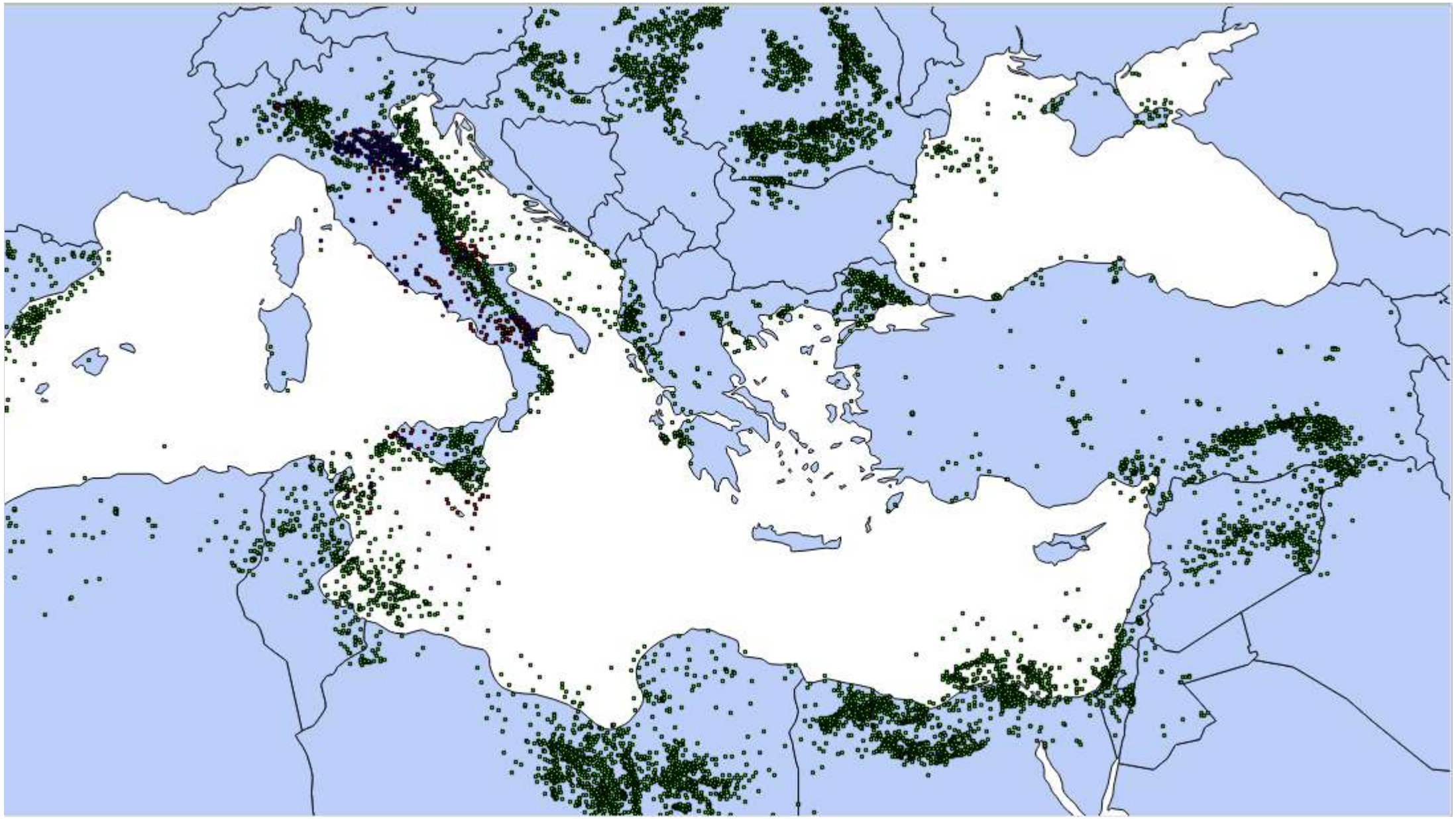
- Complex pattern of facies distribution
- Facies associations with facies content variable in space and time
- High heterogeneity in facies distribution
- Conceptual facies models are poor predictors




Rusciadelli et al, in prep.

Strata GeoResearch. Isolated Carbonate Platforms of Mediterranean: Geological Features and Hydrocarbon Potential, Multiclient Basin Studies (2018)

# *L'attività petrolifera nel Mediterraneo*



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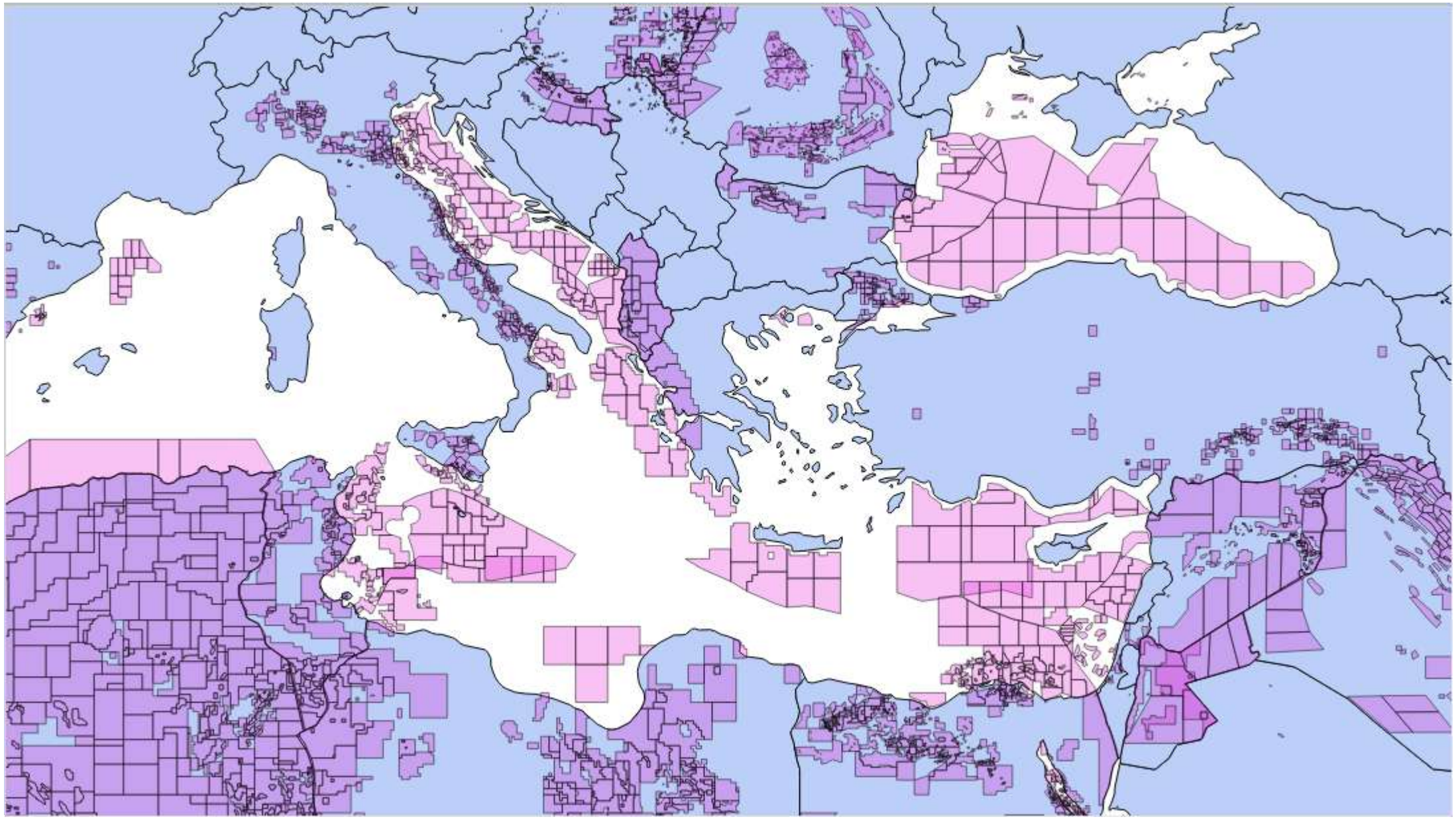
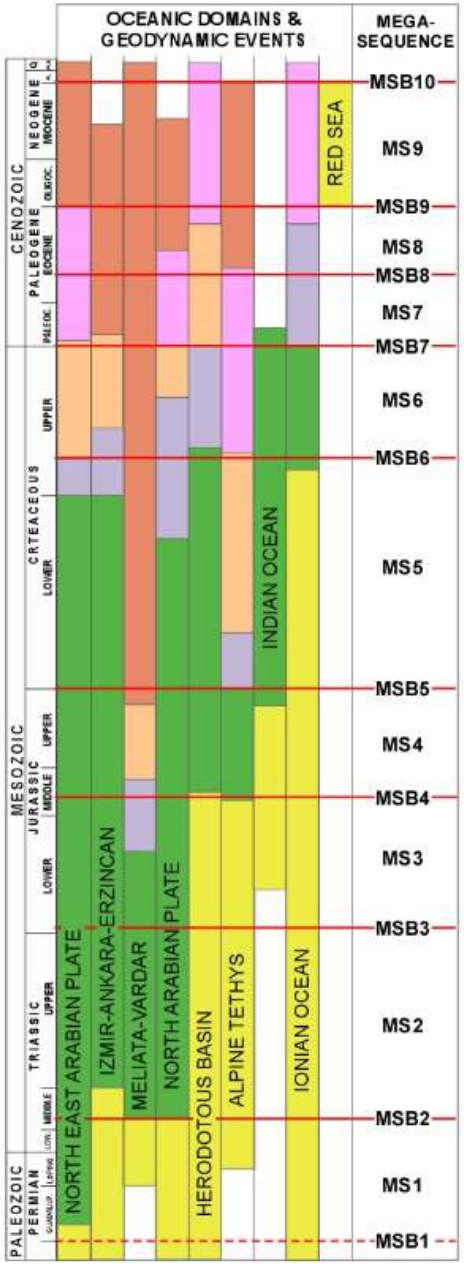
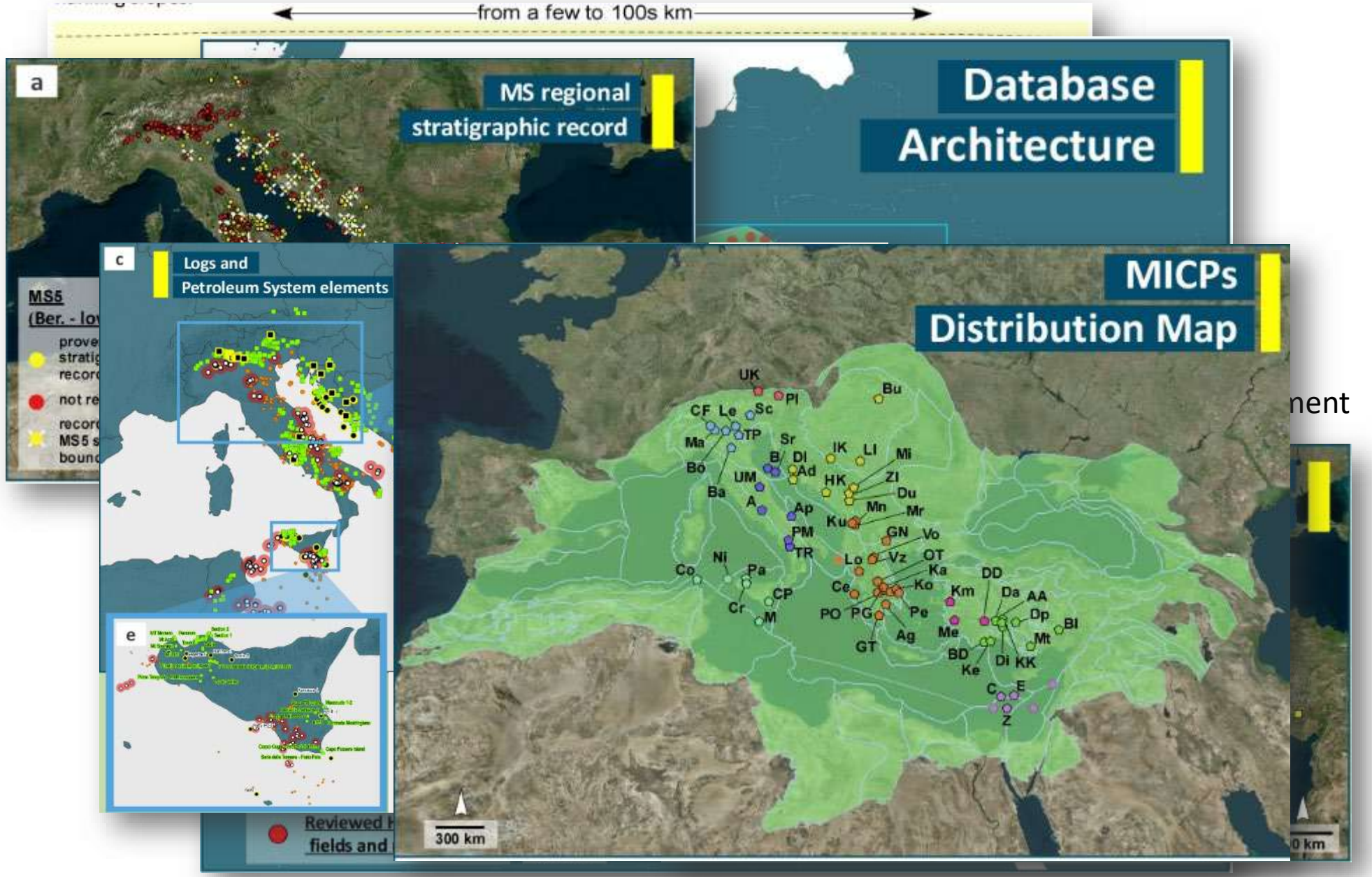


Strata GeoResearch. Isolated Carbonate Platforms of Mediterranean: Geological Features and Hydrocarbon Potential, Multiclient Basin Studies (2018)

# *…is delle ICP*


OCEANIC DOMAINS & GEODYNAMIC EVENTS
MEGA-SEQUENCE
CENOZOIC
MESOZOIC
PALEOZOIC
MSB10
MS9
MSB9
MS8
MSB8
MS7
MSB7
MS6
MSB6
MS5
MSB5
MS4
MSB4
MS3
MSB3
MS2
MSB2
MS1
MSB1
RED SEA
INDIAN OCEAN
IONIAN OCEAN
NORTH EAST ARABIAN PLATE
IZMIR-ANKARA-ERZINCAN
MELIATA-VARDAR
NORTH ARABIAN PLATE
HERODOTOUS BASIN
ALPINE TETHYS
Geodynamic Processes
Rifting
Post-rift
Intra-oceanic subduction
Obduction
Subduction
Collision


from a few to 100s km
a
MS regional stratigraphic record
Database Architecture
c
Logs and Petroleum System elements
MS5
(Ber. - lo
MICPs Distribution Map
UK
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CF
Le
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TP
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Sr
Bo
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IK
LI
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UM
Ba
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HK
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Du
Ap
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Ku
PM
GN
Vo
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Vz
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CP
Cr
M
PO
PG
Pe
Dp
Ag
Me
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300 km

## *Conclusioni…*

- **The discovery of a major gas field at Zohr (20th in the worldwide ranking, 850 Bcm of gas)** made by Eni in Egyptian waters in 2015 opened a new play-concept in the Eastern Mediterranean and a possible re-vamping of similar play-concepts in the Central and Western Mediterranean, as well as in the Far Pacific (**Luconia**, one of the largest and least-known reef complexes in the South China Sea). The widespread distribution of this promising play has been confirmed by:
  - **Feb 2018:** discovery of Calypso (offshore Cyprus, ENI): >100 Bcm of gas
  - **Feb 2019**: discovery of Glaucus (offshore Cyprus, ExxonMobil): 142-227 Bcm of gas
- **ICPs are a relevant feature of Mediterranean geology & host important hydrocarbon reservoir**
  - Developed in the context of the opening & closure of Tethys
  - 2 different types of ICP can be identified based on scale, duration, nature of carbonate factory & tectono-stratigrap
  - Carbonate factories evolve with time
- **All petroleum system elements can be found within Mediterranean ICPs**
  - Temporal and spatial distribution is controlled by tectono-stratigraphic development of ICP
  - Integration of subsurface data with surface analogues is a powerful tool for understanding the distribution of petroleum system elements

**Geology has been the key factor in facilitating high-level decision to invest in the area**

***"never stop to explore"***

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  - **Feb 201**
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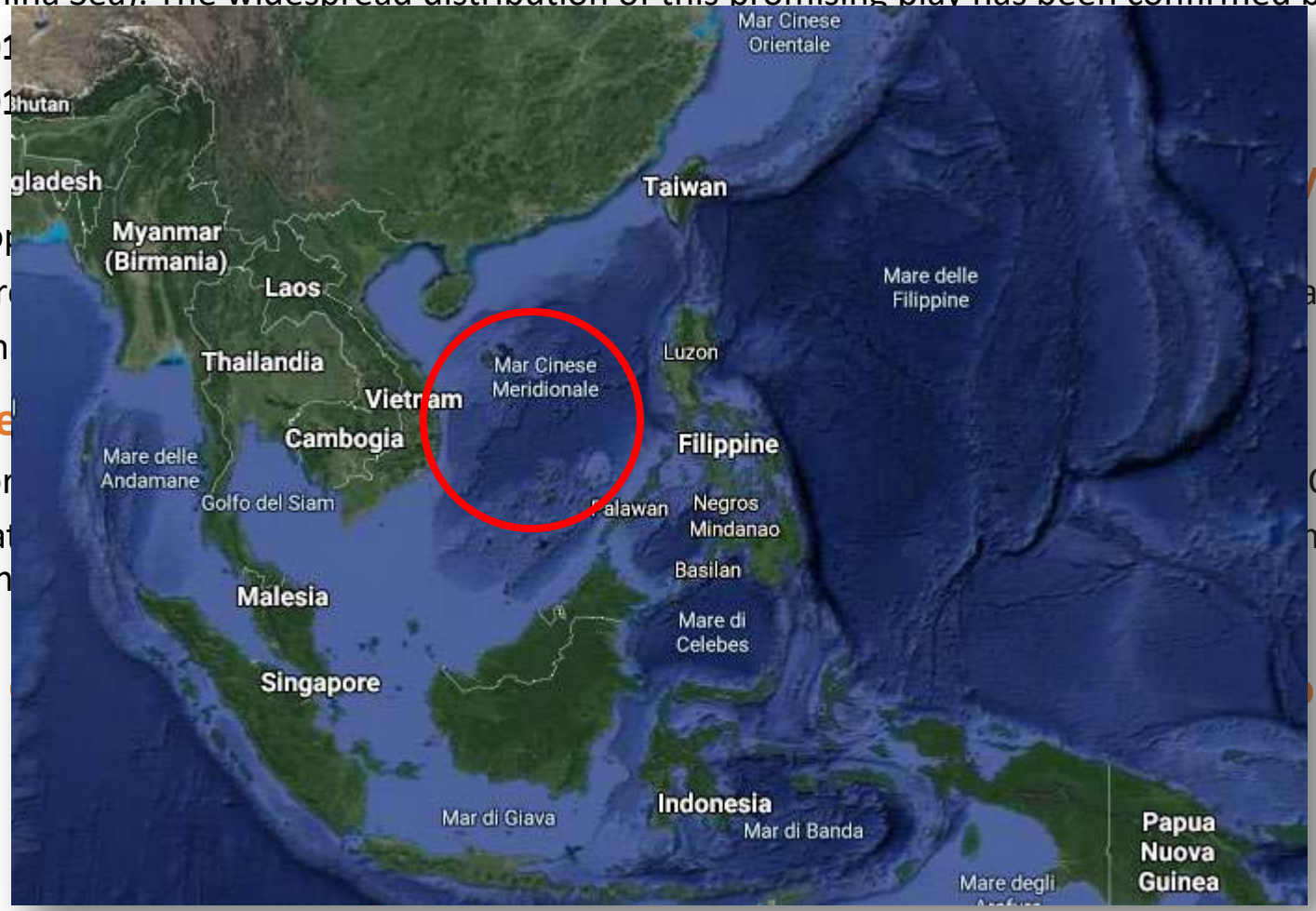
  - Develop
  - 2 differ **actory & tectono-stratigrap**
  - Carbon
- **All petrole**
  - Tempor **CP**
  - Integrat **nding the distribution of petroleum system** elemen
- **n to invest in the area**

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## *Perché le previsioni a volte sbagliano clamorosamente?*

*Due tipi di incertezze possono portare a grandi errori di previsione di sistemi complessi: le incognite sconosciute (**unknown unknowns**) e le incognite conosciute (**known unknowns**).*
*Le prime, dette **epistemiche**, riguardano il fatto che nei sistemi complessi ci sono più variabili di quante se ne possano considerare. Le seconde, dette **stocastiche**, si riferiscono alla natura intrinsecamente non lineare di molti sistemi complessi, tra cui quelli energetici.*
*Gli eventi che portano ai primi tipi di errori sono definiti "cigni neri" (**black swan**), quelli che portano ai secondi "cigni morenti" (**dying swan**).*

*(Alberto Clò)*