CARBONATE PLATFORM MARGINS AND CARBONATE *REEFs*

The carbonate ***reefs*** are excellent indicators of environmental conditions (climate, water depth, oxygenation).
Their recognition along the seismic profiles is fundamental for the reconstruction of the ancient sedimentary domains.

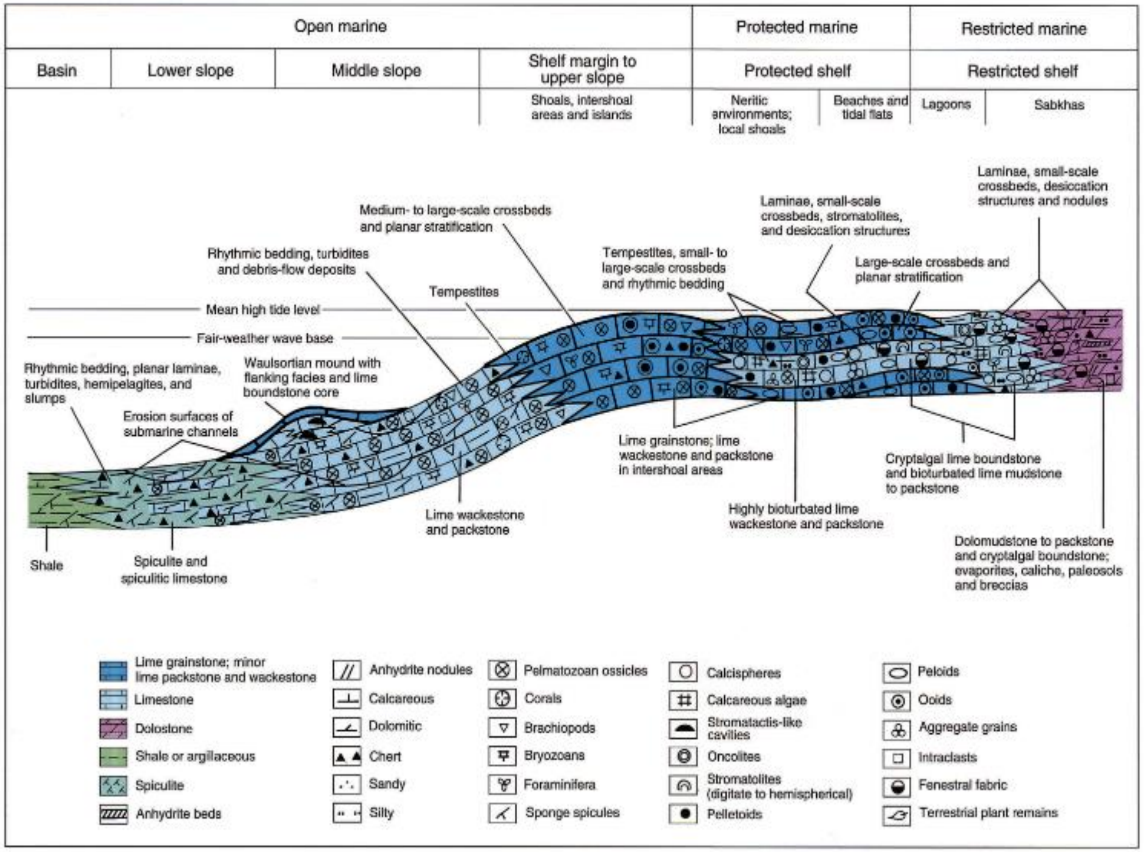


Figure 14.18 Generalized model of a Carboniferous carbonate platform (from Richards, 1989a).

Carbonate Platform
(*shallow water domain*)

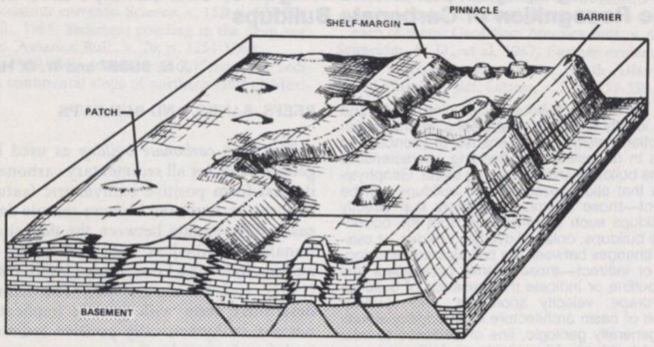


FIG. 1—Types of carbonate buildups most easily recognized from seismic interpretation. Conventional classification of reefs and banks, although preferred, is not easily applicable to seismic data.

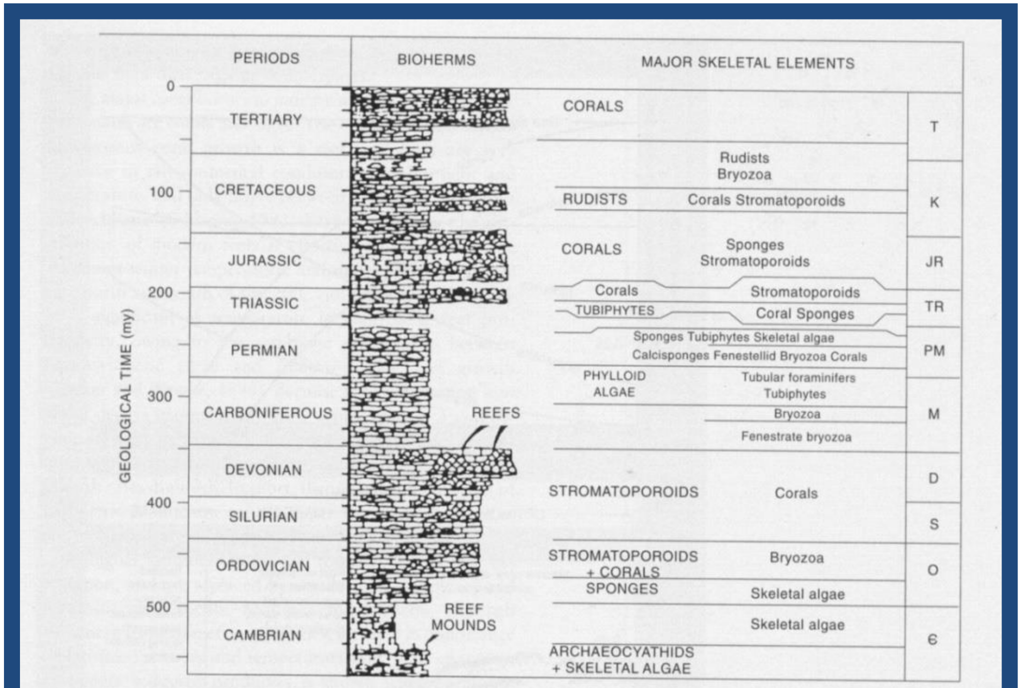
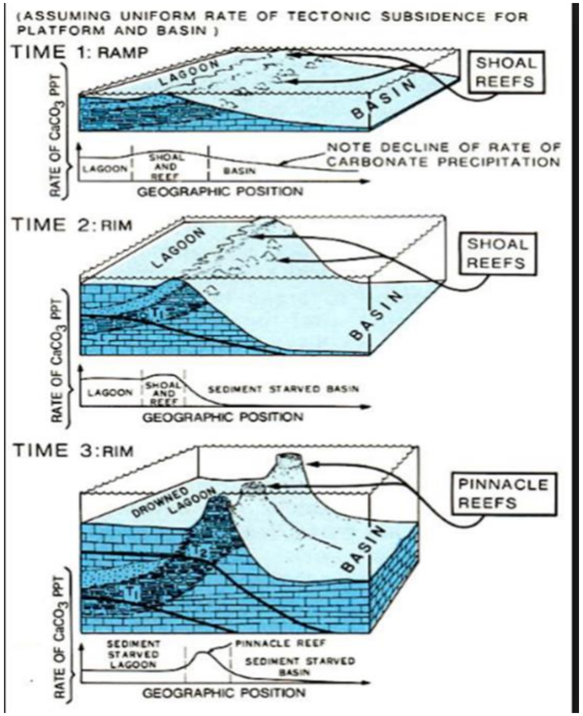
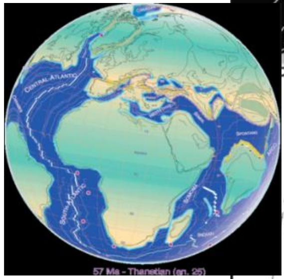
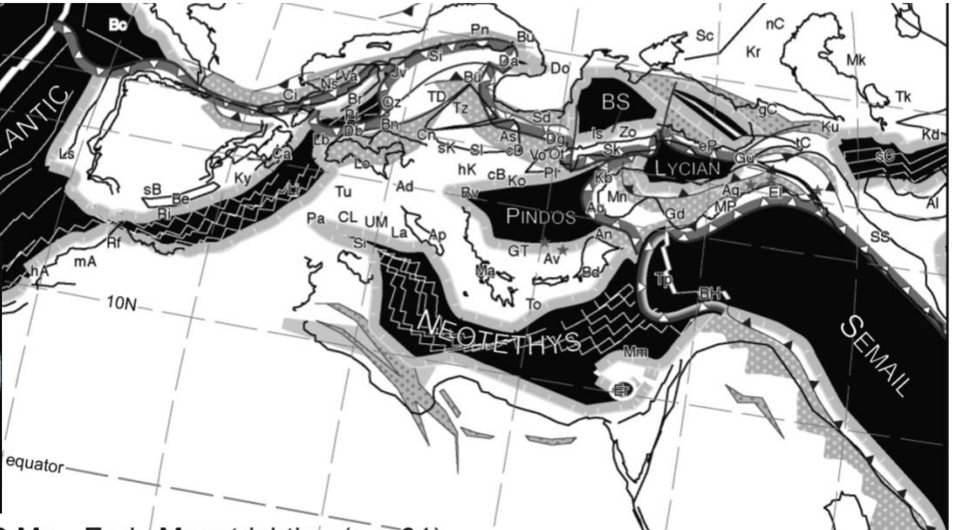


Fig. 10.3 Simplified stratigraphic column indicating the major framework-building organisms through time (from James, 198

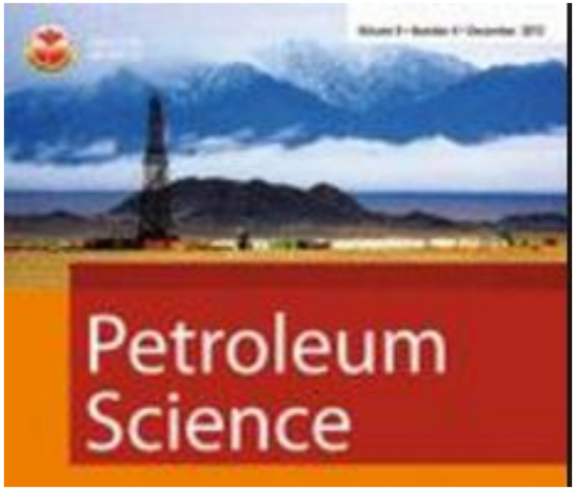




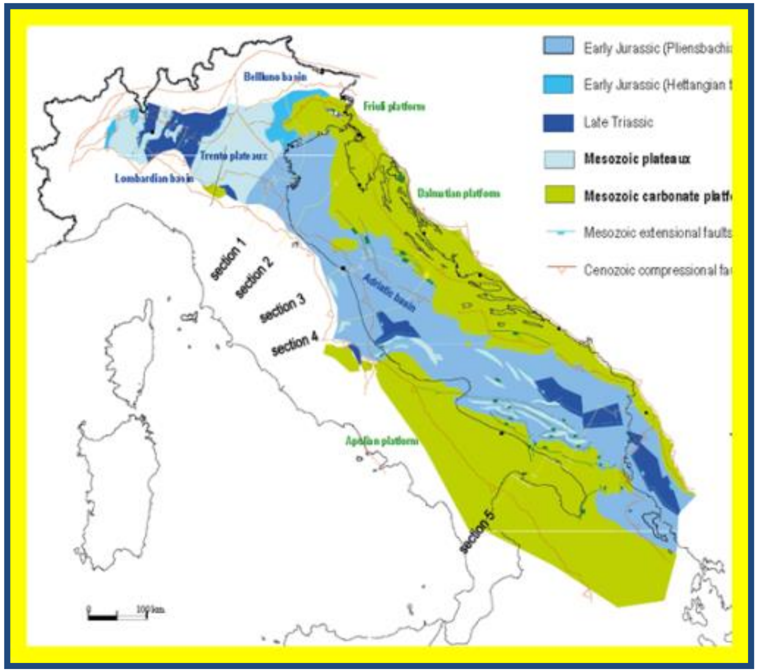


70 Ma - Early Maastrichtian (an. 31)

CARBONATE PLATFORM MARGINS AND CARBONATE REEFs

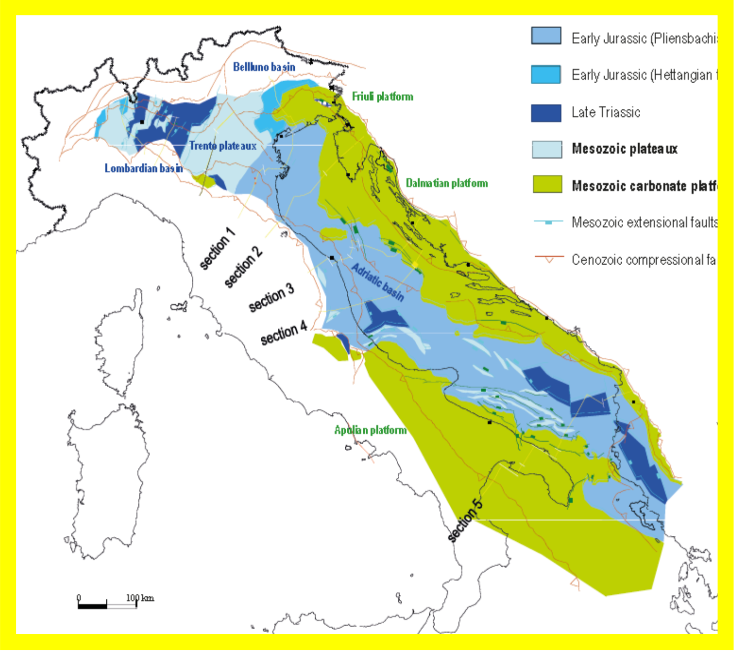


The carbonate ***reefs*** are generally excellent hydrocarbon stratigraphic traps:
in Canada 60% of oil production comes from reefs, which developed in the Devonian, also present in many oil regions of the USA.
In Italy, the oil fields of southern Italy are located along the edge of the Apulia platform (e.g. in the south-Adriatic: Aquila, Giove wells, etc.) or near it (Rospo Mare) or in the Apulia Platform, buried under the thrusts of the southern Apennines (Val d'Agri, Tempa Rossa, etc).

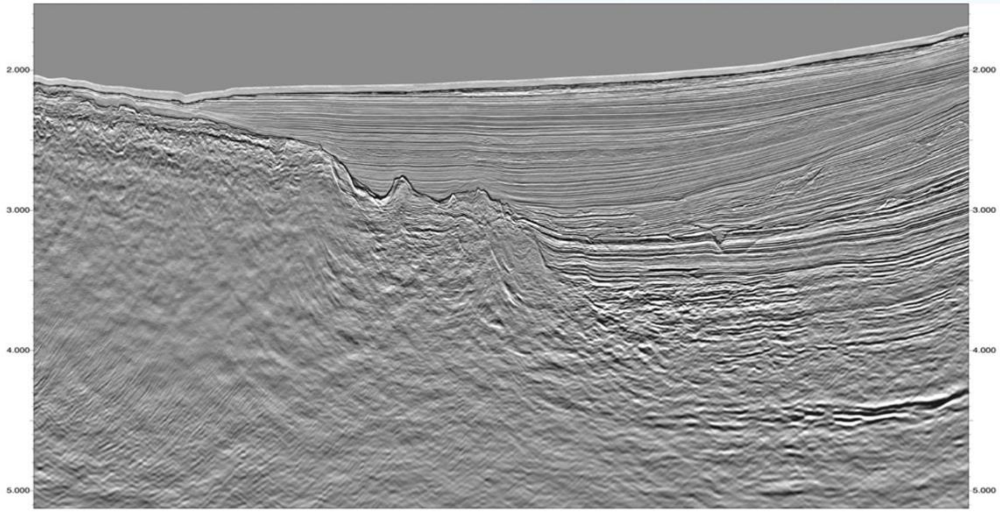


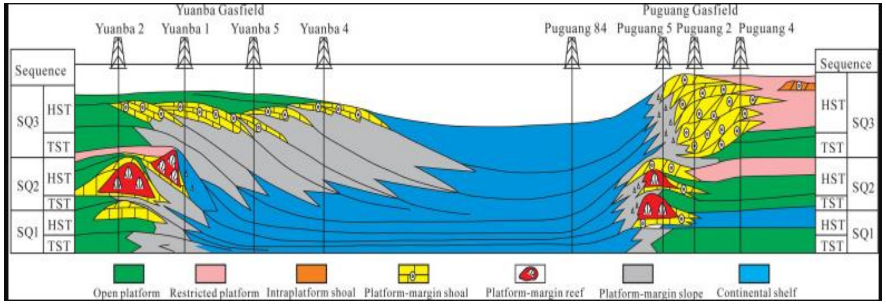
The recent exploration of the Croatian offshore is also mainly focused on the margin of the Dinaric carbonate platform.

The carbonate platform margins often represent an important target of investigation, as they constitute the transition between the shallow water domain and the basin domain, sometimes very deep. The two domains generally separated during a tectonic phase (typically in the continental margins). The closest example to us concerns the Friulian / Istrian / Dalmatian carbonate platforms, often called **Adria Carbonate Platform**, and the **Apulian Carbonate Platform**, separated by the pelagic basin domains of (Belluno / Umbrian-Marchigiano / Ionian basins) generally during the Liassic period, in connection with the oceanic Tethys opening.



These margins are often characterized by high porosity (possible *reservoir*), due to fracture systems, dolomitization, *slope deposits*, etc., sometimes close to rocks with a high content of organic carbon (possible *source rocks*). They are therefore an important target of seismic interpretation.





Platform Margin

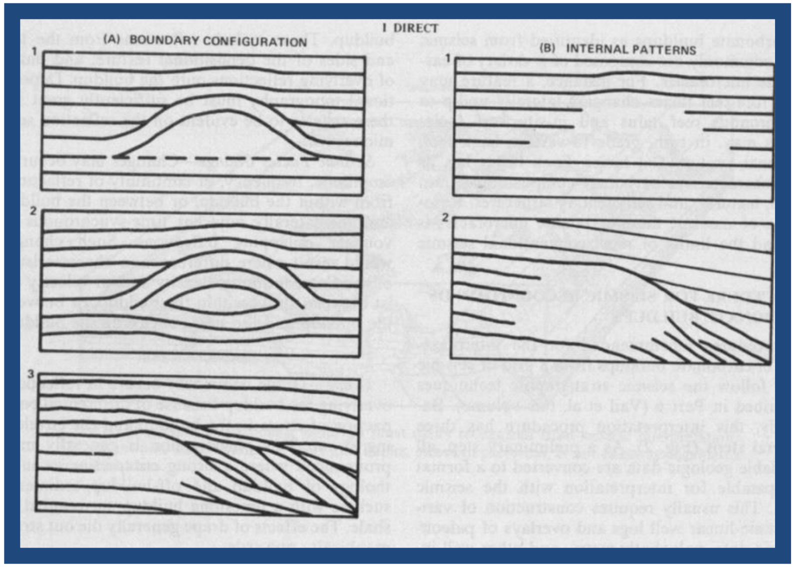
Direct Seismic Evidence

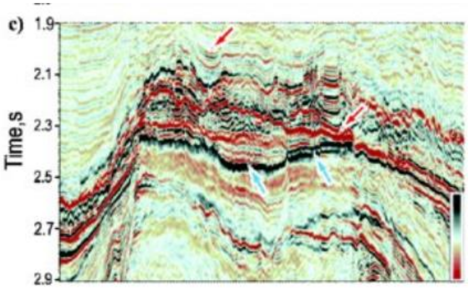
Margin Configuration (on the left)

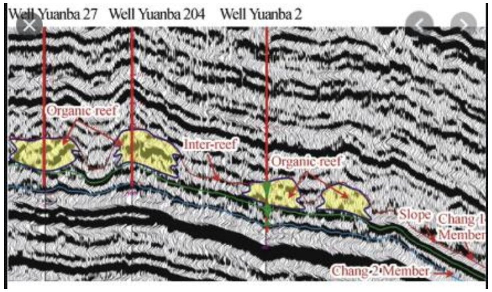
1 & 2 Mound shape and abrupt interruption of adjacent reflectors
3 – different seismic facies on the two sides of the structure

Internal Configuration (on the right)

1 – absence of reflectors
2 – structure growth above a *“hinge line”*







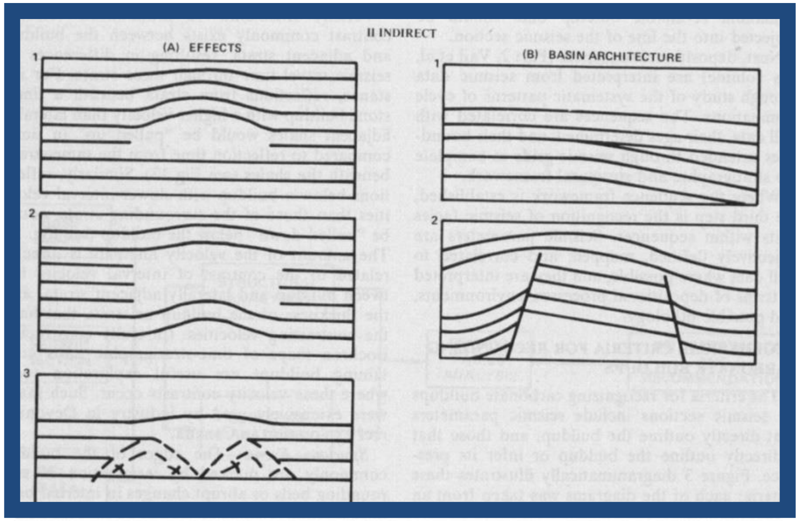
Indirect Seismic Evidence

Effects (on the left)

1- drapery over the structure
2- *pull-up velocity*
3- diffraction on the structure margins

Architecture (on the right)

1- growth above “*hinge line*”
2- growth above a structural high



Distinguishing Characteristics of Reefs

Figure 5.16 is a summary of criteria for distinguishing reefs on seismic sections. These criteria include:

(1) Reflections that partially outline reefs.

(2) Reflection voids, distinguishable by the sharp termination of reflections that onlap the reef.

(3) Changes in amplitude, frequency, or continuity of reflections at reef edges.

(4) Differences between reflection patterns on one side of the reef compared to those on the other; this is often especially marked for shelf-margin and barrier reefs where the back-reef and fore-reef patterns may differ markedly.

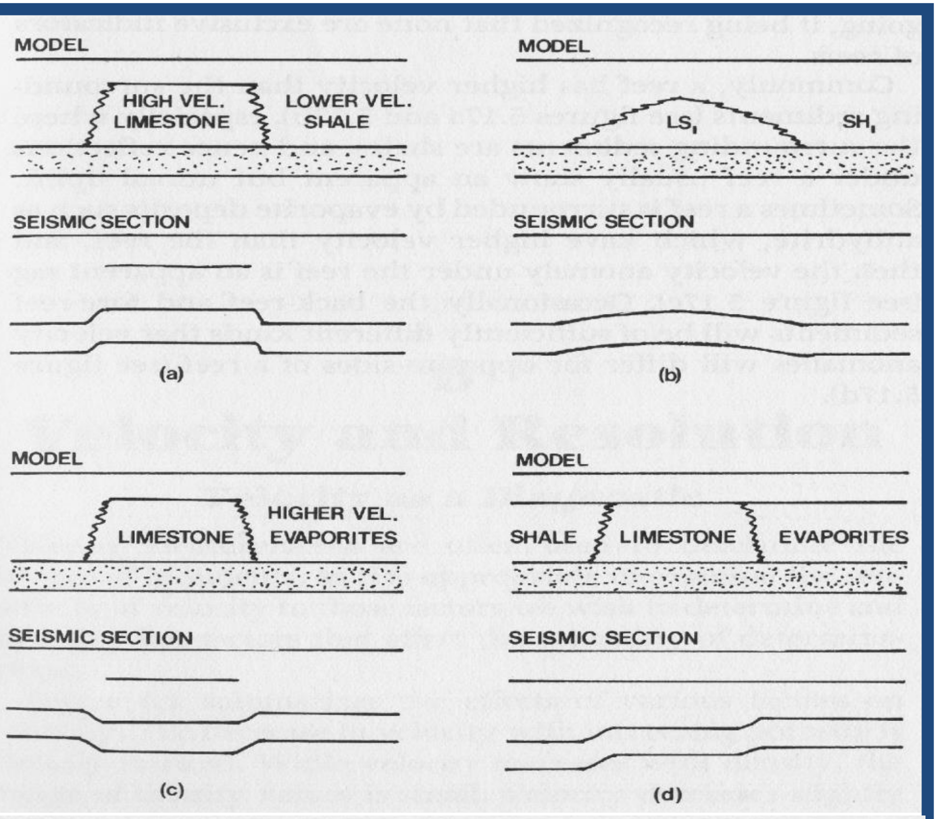
(5) The presence of diffractions and other types of events that mark reef edges.

(6) Differential compaction effects that produce a drape in the sediments over the reef; this is generally due to the off-reef sediments being more compactable than the reef itself, but occasionally the porous parts of a reef collapse and produce compaction effects. Compaction effects usually become gradually less with distance above the reef.

(7) Velocity anomaly for reflections underneath the reef (see below and figure 5.17).

(8) Location where reef growth should be propitious, such as on a hinge line, at the edge of a shelf, or on the uptilted edge of a fault block.

(9) Regional factors, such as the knowledge that the climate or environment associated with a particular reflection was propitious for reef growth.

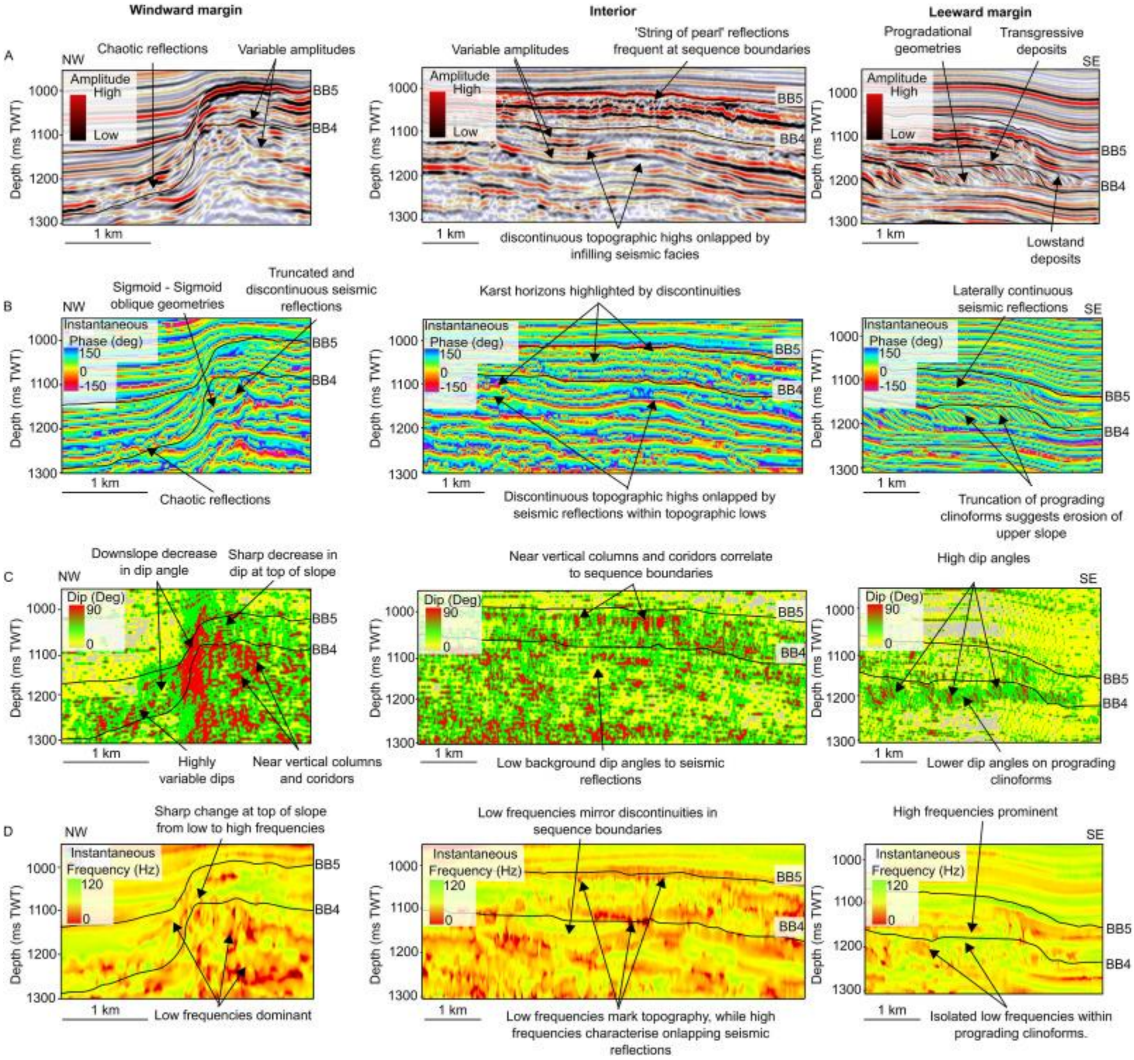


Reefs are usually evidenced by a combination of the foregoing, it being recognized that none are exclusive indicators of reefs.

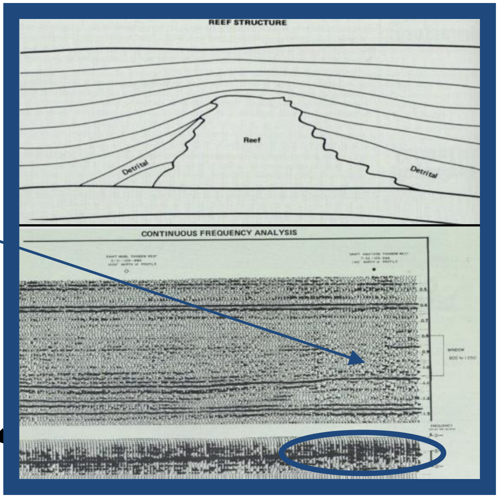
Commonly, a reef has higher velocity than the surrounding sediments (see figures 5.17a and 5.17b), especially where the surrounding sediments are shales, and hence reflections under a reef usually show an apparent but unreal uplift. Sometimes a reef is surrounded by evaporite deposits such as anhydrite, which have higher velocity than the reef, and then the velocity anomaly under the reef is an apparent sag (see figure 5.17c). Occasionally the back-reef and fore-reef sediments will be of sufficiently different kinds that velocity anomalies will differ for opposite sides of a reef (see figure

Differential compaction at a *build-up*

Effects on frequency content: above the build-up structure the sedimentary sequence shows higher frequency content. Other seismic attributes can be useful (e.g chaos & dips)

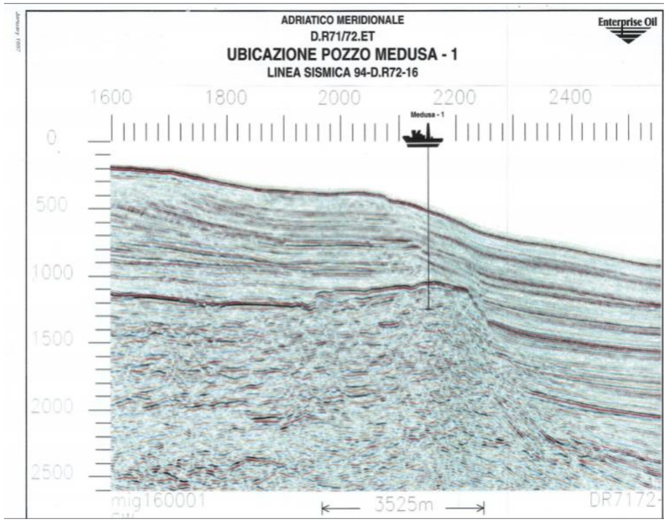


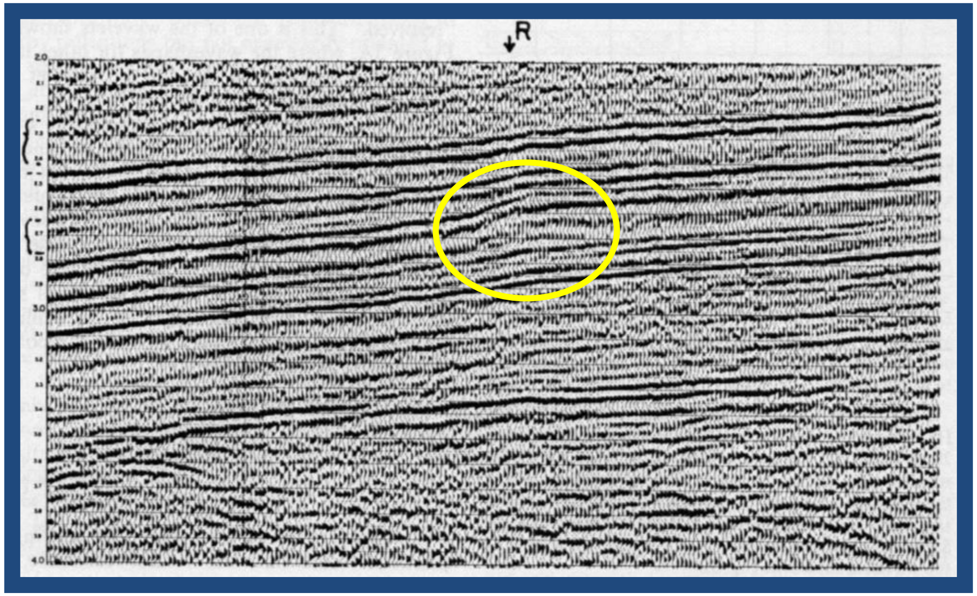
Van Tuyl et al., 2018



frequency spectrum

Apulia Carbonate Platform margin



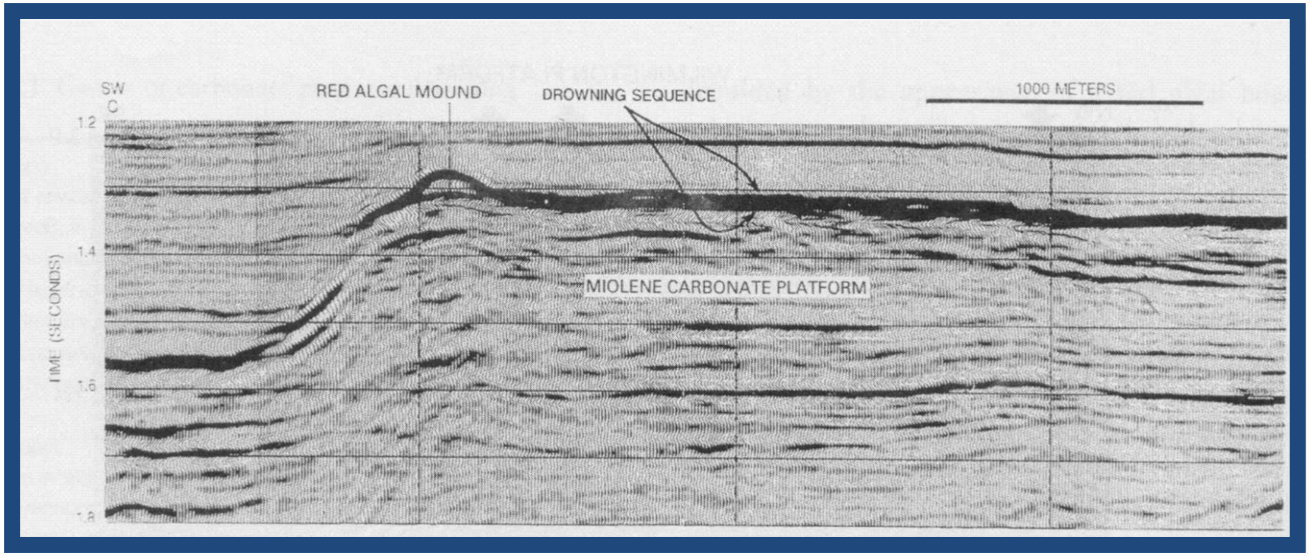


Example of platform margin:

often, the margins, especially if they are deep, can have size at the limit of the seismic resolution

In this profile the margin shape is amplified by the presence of a reef.

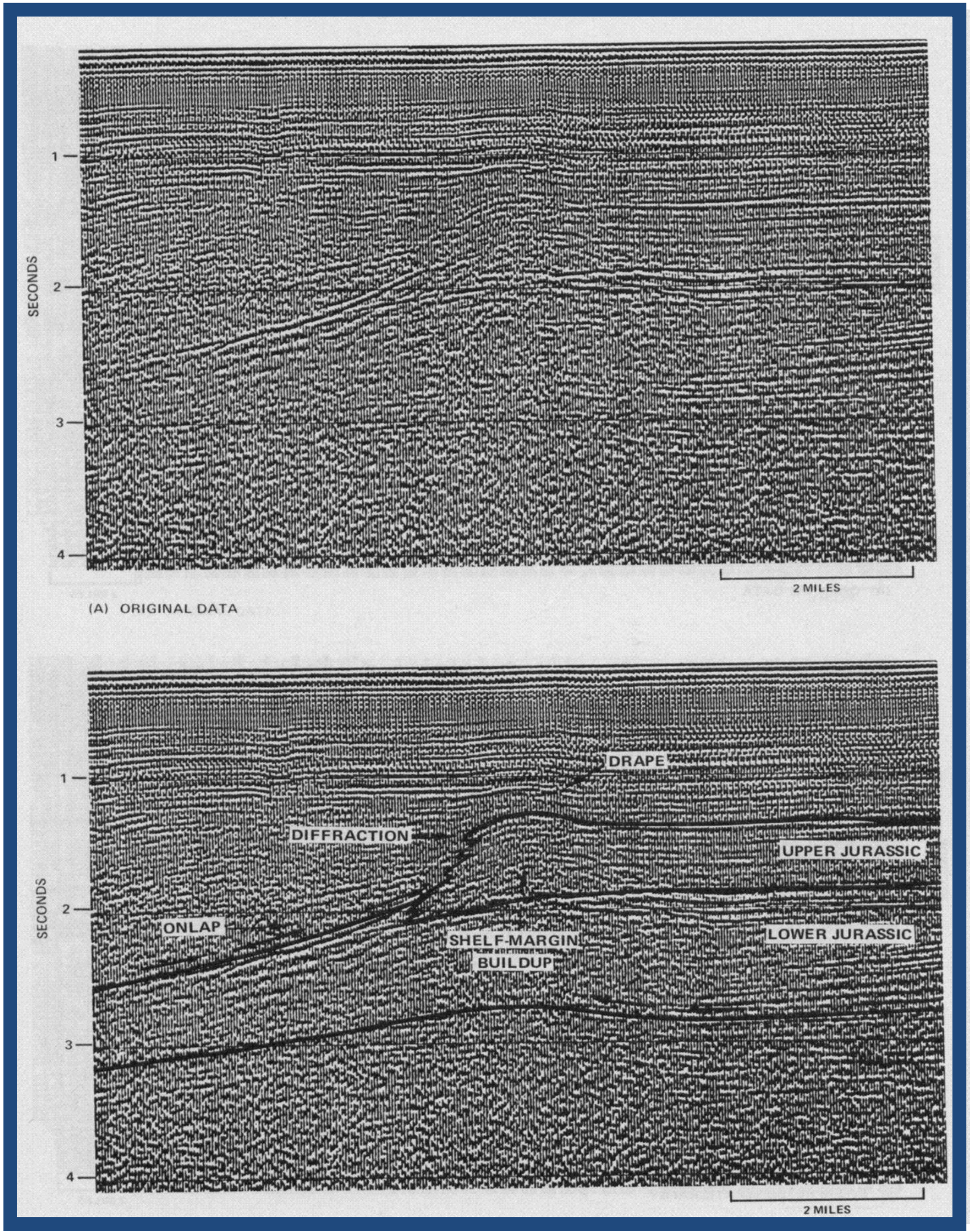
Note the different seismic facies of the *shallow water (sw)* on the right (platform), and *basinal* on the left



Example of Platform Margin

We can distinguish :

- Different seismic facies of different domains
  - < carbonate platform *sw* on the right
  - < basinal on the left
- diffraction from the margin
- the *pull-up velocity*
- the draping
- differential compaction in the covering sediments



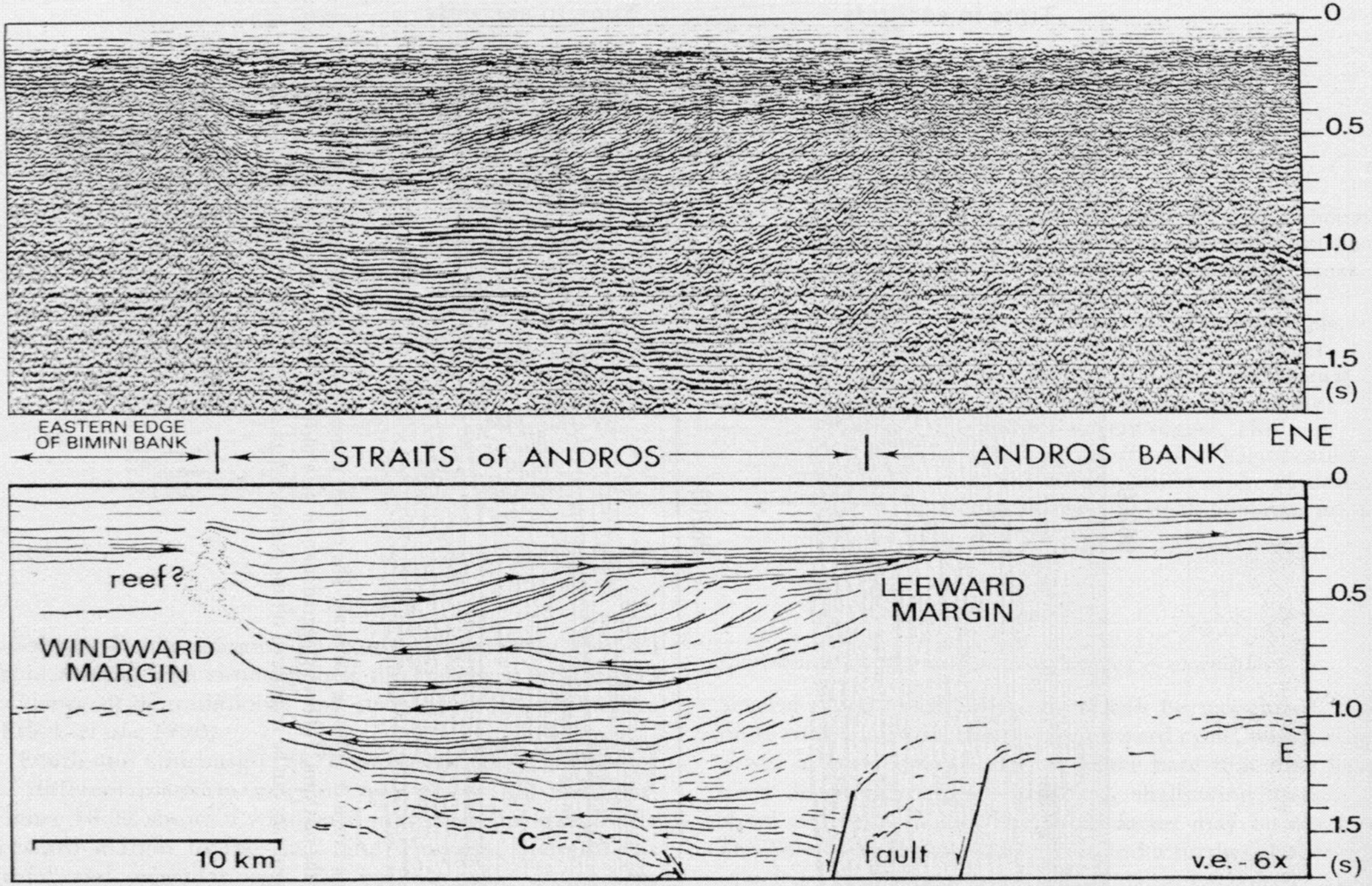
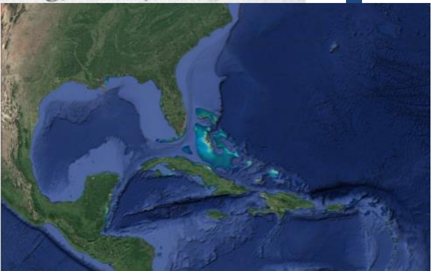


Fig. 10.27 Windward (left) and leeward (right) platform margins of the Bahamas (from Eberli and Ginsburg, 1987). See text fo details



Example of a carbonate platform margin in the *Bahamas*

Scheme for the E-Adriatic Shelf Margin proposed by Grandic (1999)

in this model we can note:

- a system of extensional faults (Liassic faults of the passive Tethyan margin),
- escarpment deposits (high porosity and therefore good probability to act as a reservoir for hydrocarbons);
- presence of evaporites in depth would have given rise to salt domains, giving rise to the Island of Jabuka (or I. del Pomo) and further positive structures

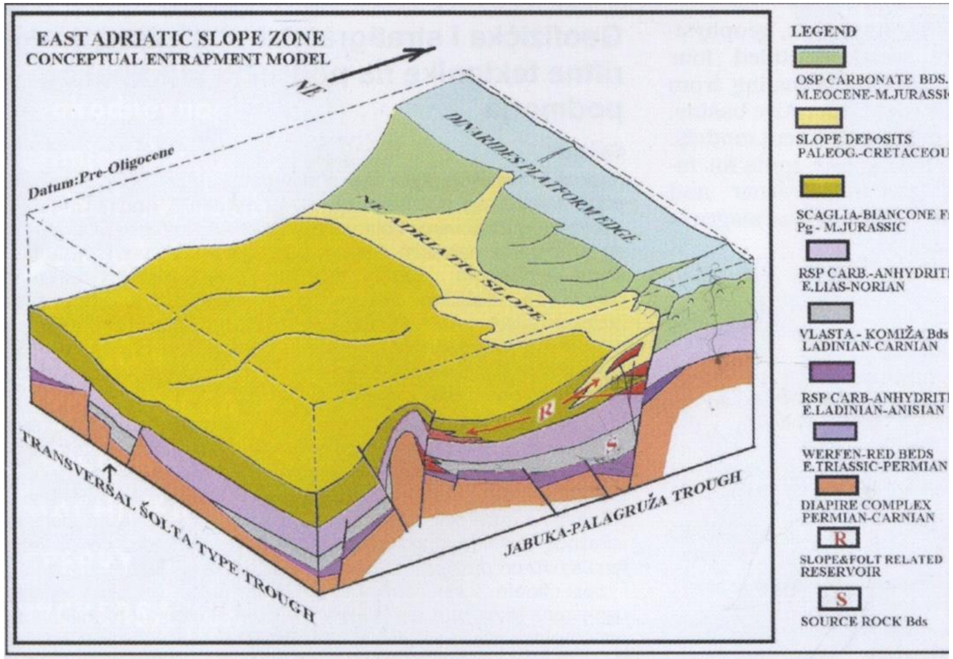
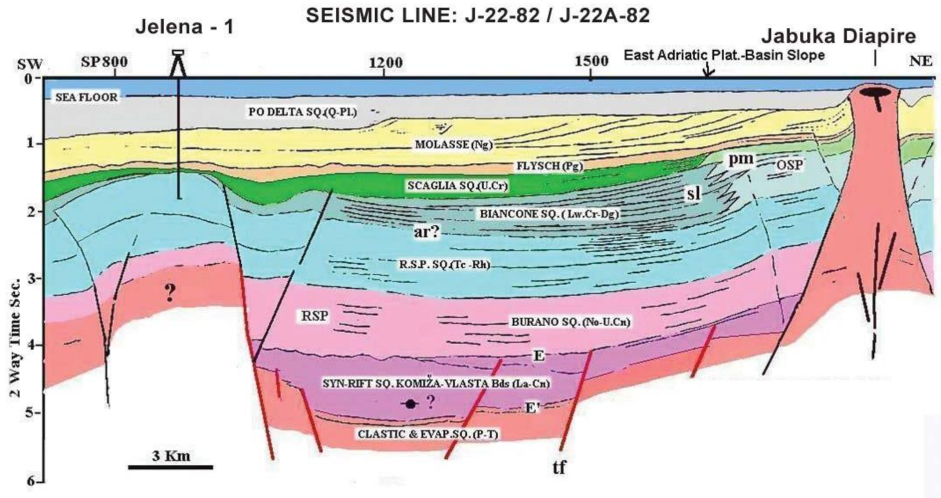


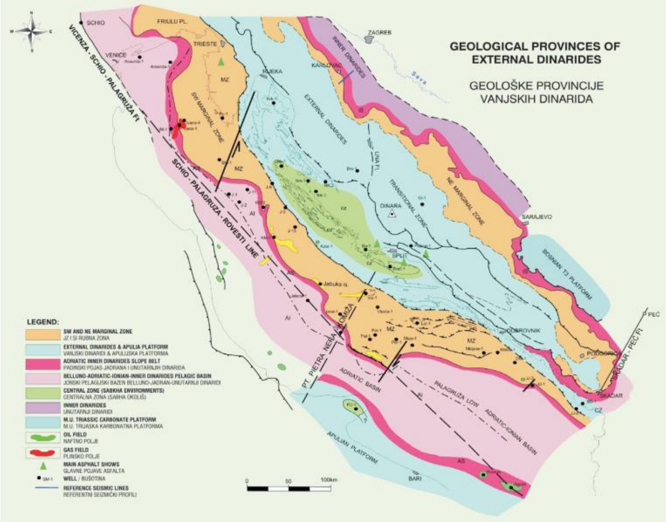
Fig. 18. This hydrocarbon conceptual model was created mostly on the basis of the well and seismic interpretation between the Maja-1 well and the Palagruža high (After GRANDIĆ et al 1999)

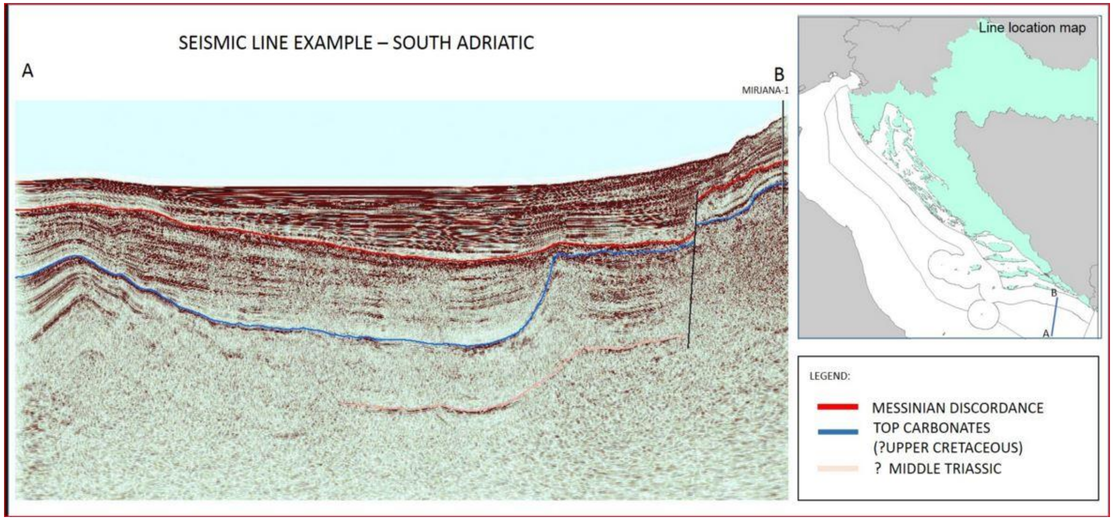


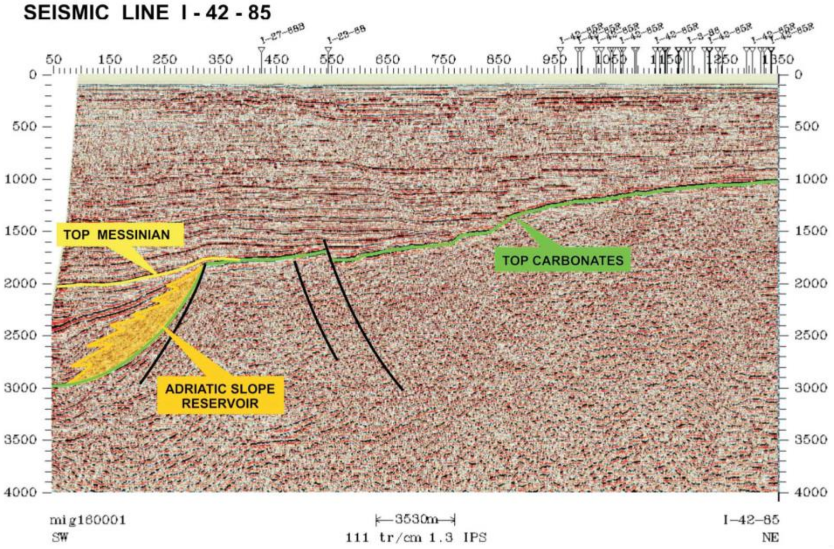
SYMBOLS EXPLANATIONS
OBJAŠNJENJE SIMBOLA

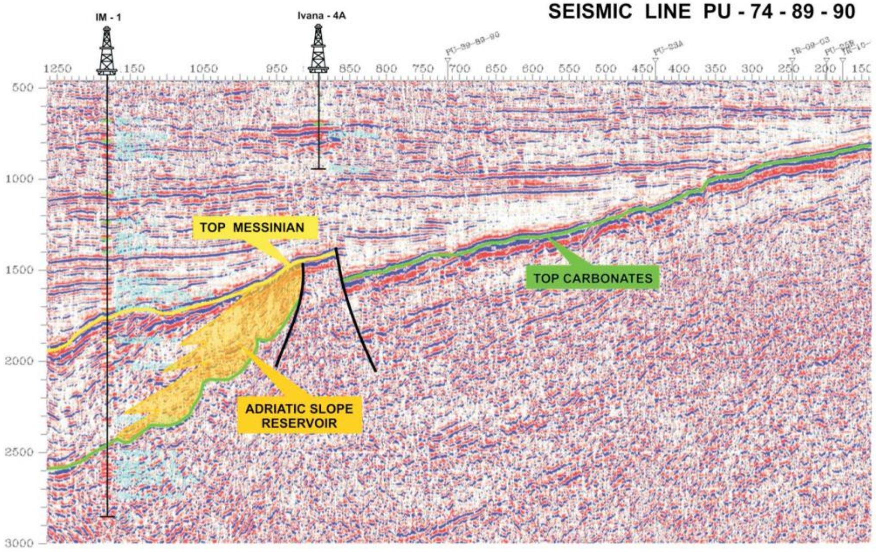
pm	**CARBONATE PLATFORM MARGIN** RUB KARBONATNE PLATFORME	ar	**ROSSO AMMONITICO EQUIV.** EKVIVALENT ROSSO AMMONITICO
OSP/RSP	**OPEN/RESTRICTED CARB. PLATF.** OTVORENA I ZATVORENA KARB. PLATFORMA	-●-	**SOURCE ROCK (Komiža type?)** MATIČNE STIJENE (Komiža tipa)
sl	**UPPER SLOPE CLASTIC (RESERVOIR)** KLASTITI GORNJE PADINE (LEŽIŠNE STIJENE)	E - E'	**BASE CARBONATE / KOMIŽA BDS.** BAZA KARBONATA (KOMIŽA SLOJEVI)
tf	**TRIASSIC RIFT RELATED FAULT** TRIJASKI RASJEDI		

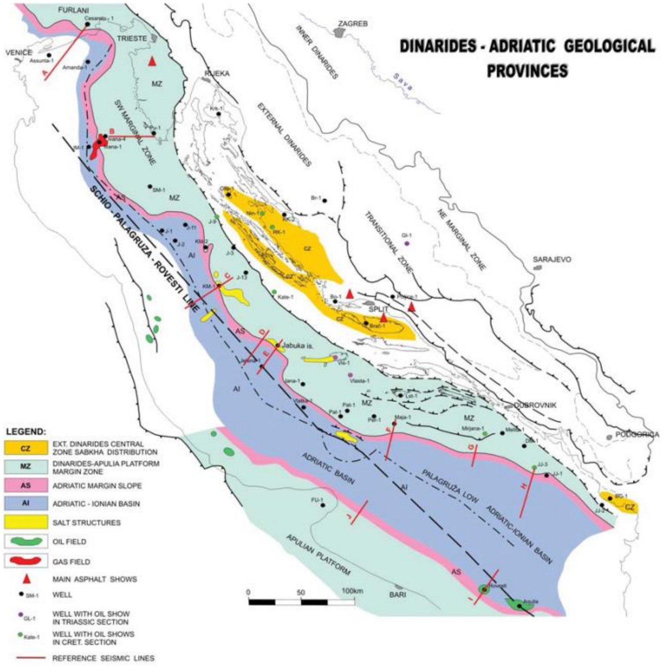
EXPLORATION in the CROATIAN OFFSHORE

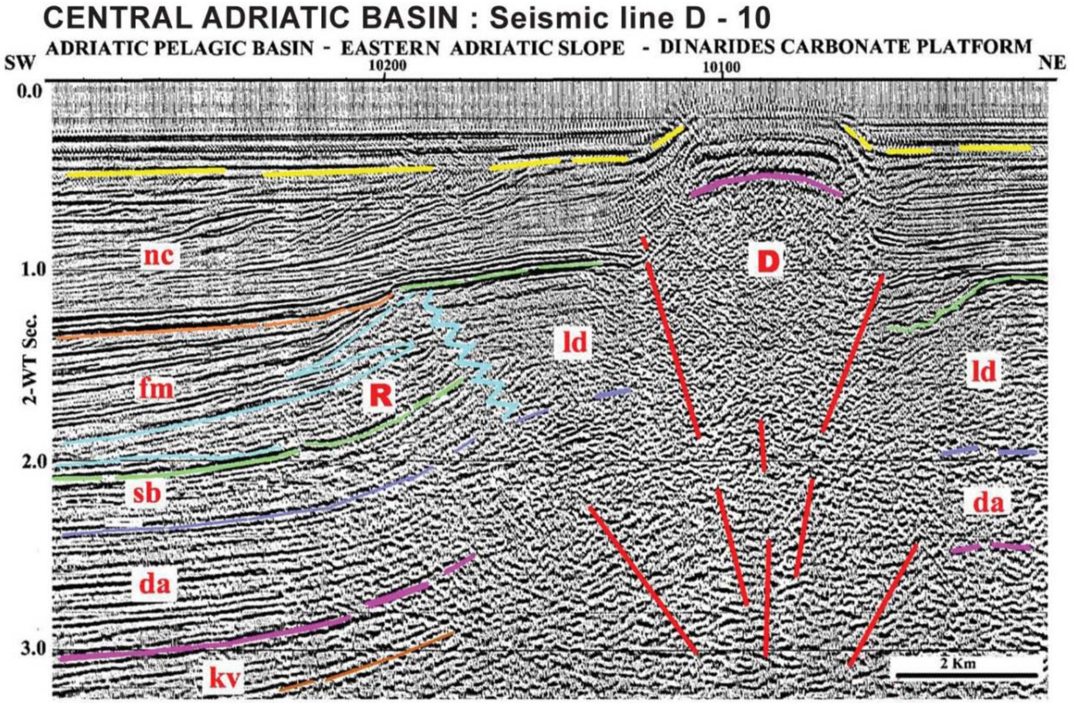



SEISMIC LINE EXAMPLE – SOUTH ADRIATIC


SEISMIC LINE I - 42 - 85


SEISMIC LINE PU - 74 - 89 - 90





LEGEND: **nc**	Neogene clastic Neogeni klastiti	**da**	Dolomite & Anhyd. seq. Dol. anhidritna sekvenca	**ld**	Lmst. & dolomite seq. Vap.-dol. sekvenca	**D**	Jabuka diapire Jabuka dijapir
fm	Flysch-Molasse Fliš i molasa	**sb**	Scaglia-Biancone fm. Scaglia-Biancone fm.	**vk**	Vlasta-Komiža bds. Vlasta-Komiža slojevi	**R**	Slope sedim. Sedim. padine

SEISMIC LINE : KV-63

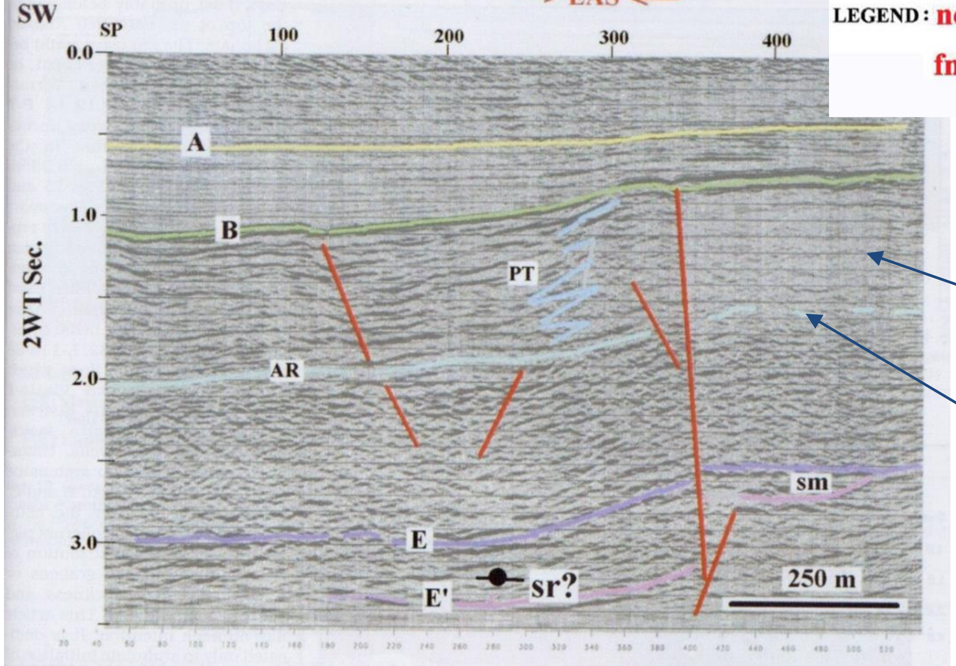


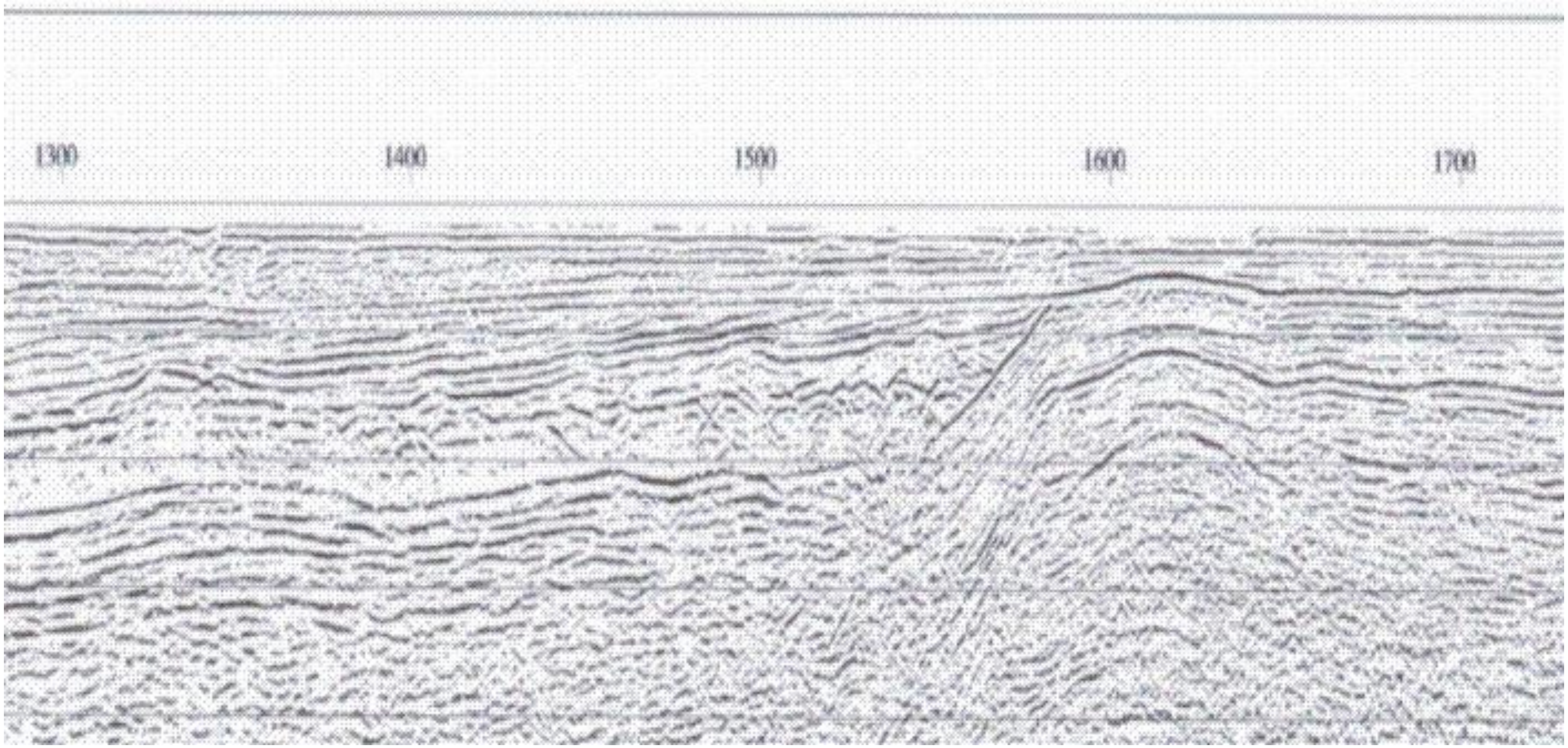
Fig. 9. Seismic line KV-63 represents configuration of the "EAS" zone. Symbols B and E indicate flexured "Top and Base Carbonate".

Carbonate platform:

-opaque seismic facies

-*velocity pull-up*

(Grandic, 1999)



Seismic profile crossing the Trieste Gulf. The margin of the Frulian/Istrian Carbonate Platform separates the pelagian basin to the west from the sw domain to the east.

Example of seismic profile in the in Adriatic Sea:

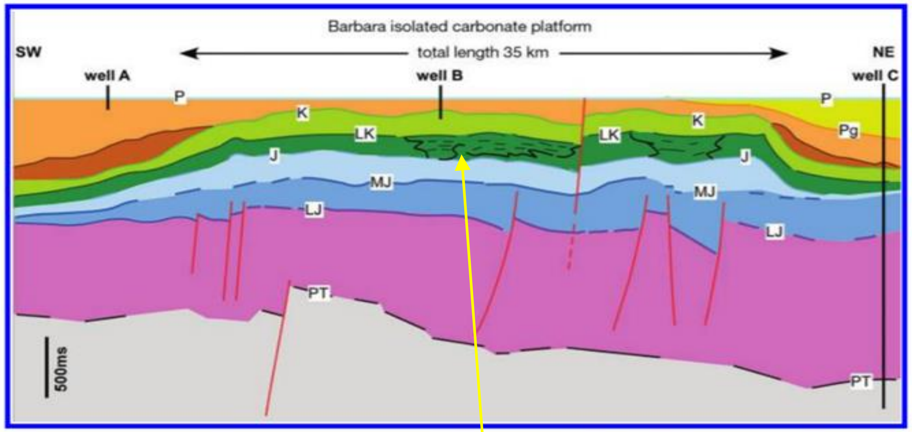
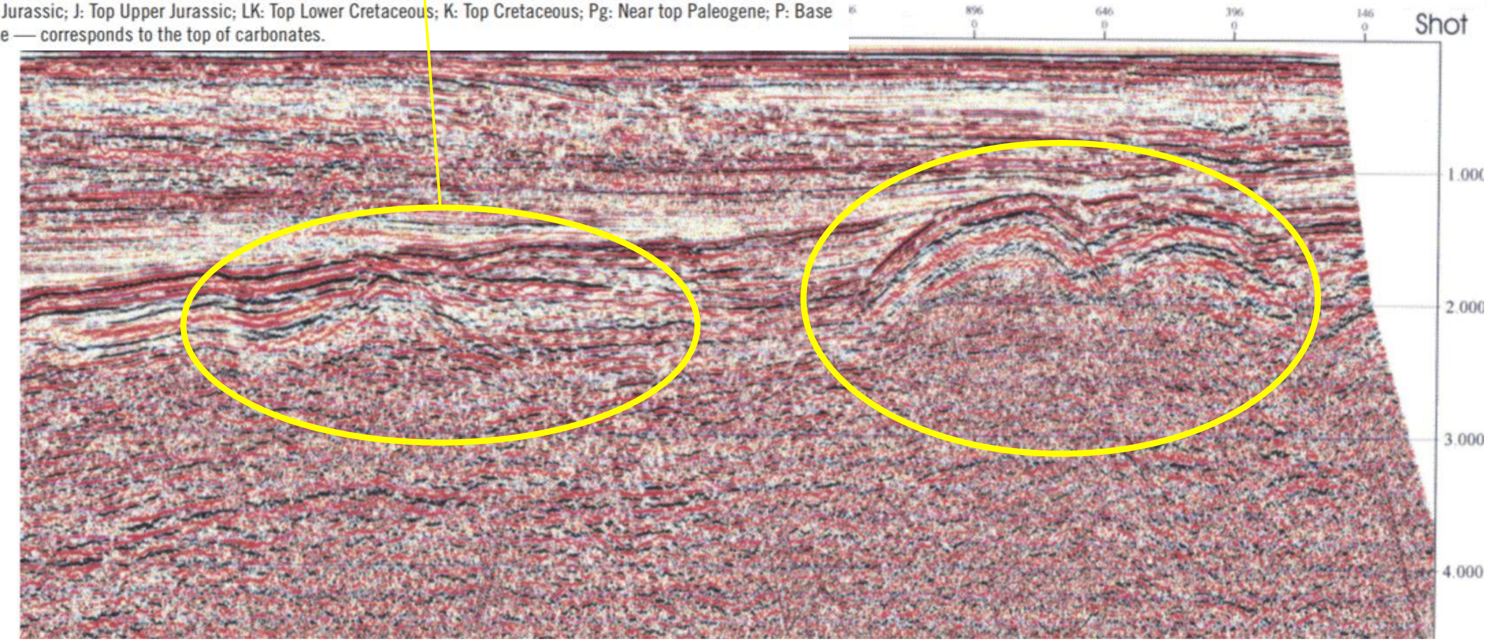
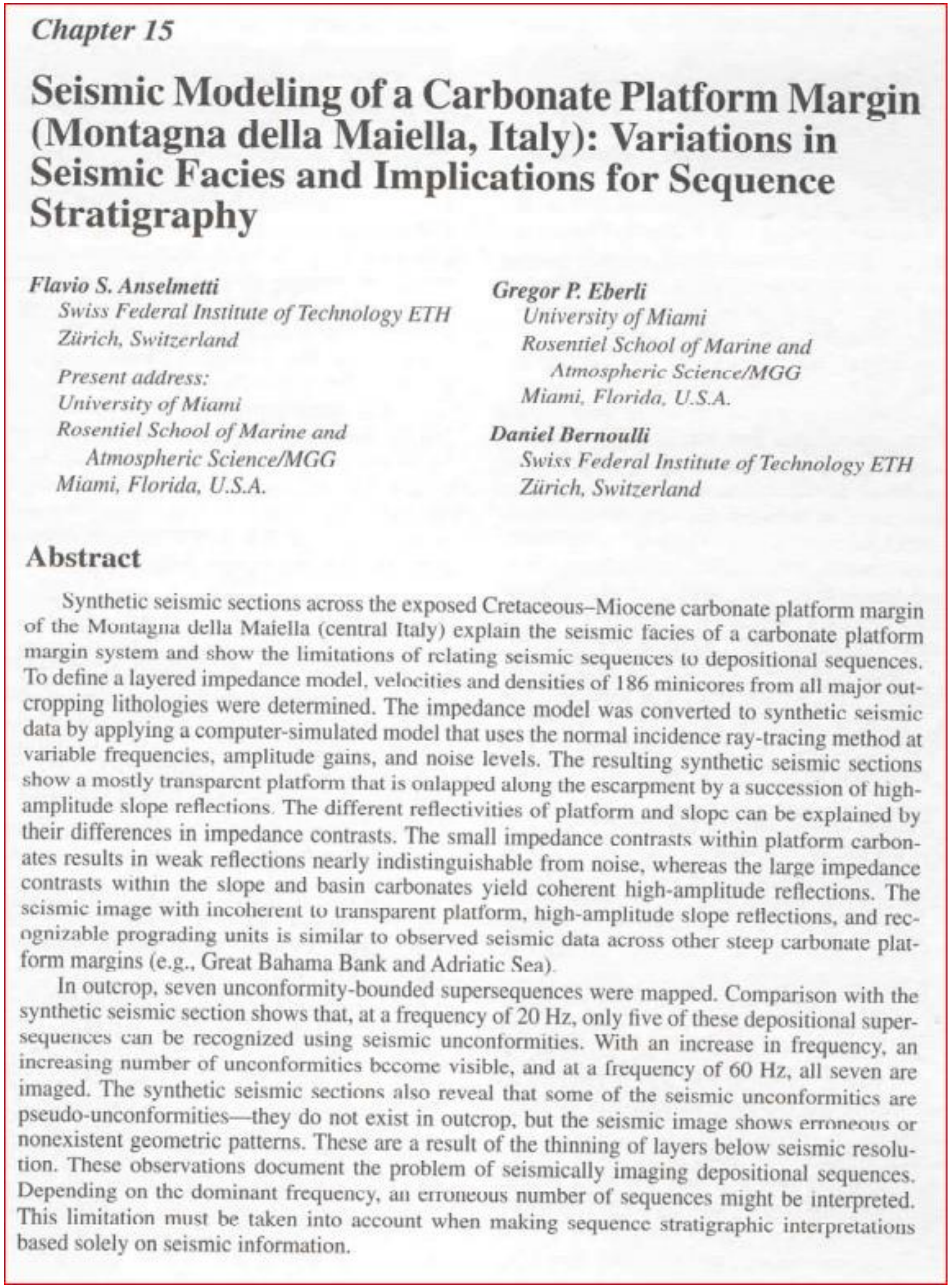


Figure 5. Line drawing of the Barbara Platform from the Central Adriatic showing the internal organization and the architecture of the margins of a well-preserved MICP. The platform is characterized by a transparent seismic facies, but between the J and LK reflectors, seismic facies variations are interpreted to be due to facies zonation with a reflective and stratified platform interior passing laterally into a chaotic to massive margin facies. Line drawing from line CROP M16, flattened on the base Pliocene. PT: Top Permo Triassic; LJ: Top Lower Jurassic; MJ: Top Middle Jurassic; J: Top Upper Jurassic; LK: Top Lower Cretaceous; K: Top Cretaceous; Pg: Near top Paleogene; P: Base Pliocene — corresponds to the top of carbonates.

Margin





Chapter 15

Seismic Modeling of a Carbonate Platform Margin (Montagna della Maiella, Italy): Variations in Seismic Facies and Implications for Sequence Stratigraphy

Flavio S. Anselmetti
Swiss Federal Institute of Technology ETH
Zürich, Switzerland

Present address:
University of Miami
Rosentiel School of Marine and
Atmospheric Science/MGG
Miami, Florida, U.S.A.

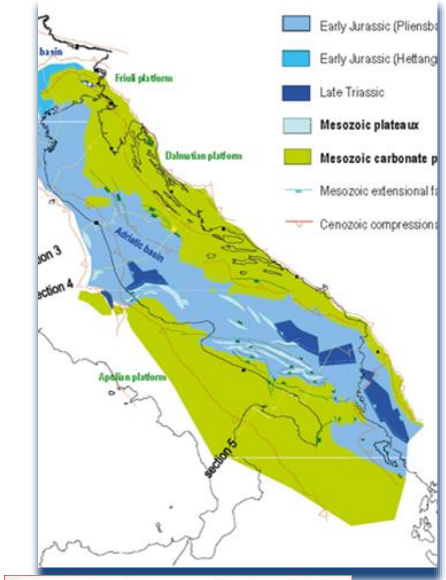
Gregor P. Eberli
University of Miami
Rosentiel School of Marine and
Atmospheric Science/MGG
Miami, Florida, U.S.A.

Daniel Bernoulli
Swiss Federal Institute of Technology ETH
Zürich, Switzerland

Abstract

Synthetic seismic sections across the exposed Cretaceous–Miocene carbonate platform margin of the Montagna della Maiella (central Italy) explain the seismic facies of a carbonate platform margin system and show the limitations of relating seismic sequences to depositional sequences. To define a layered impedance model, velocities and densities of 186 minicores from all major outcropping lithologies were determined. The impedance model was converted to synthetic seismic data by applying a computer-simulated model that uses the normal incidence ray-tracing method at variable frequencies, amplitude gains, and noise levels. The resulting synthetic seismic sections show a mostly transparent platform that is onlapped along the escarpment by a succession of high-amplitude slope reflections. The different reflectivities of platform and slope can be explained by their differences in impedance contrasts. The small impedance contrasts within platform carbonates results in weak reflections nearly indistinguishable from noise, whereas the large impedance contrasts within the slope and basin carbonates yield coherent high-amplitude reflections. The seismic image with incoherent to transparent platform, high-amplitude slope reflections, and recognizable prograding units is similar to observed seismic data across other steep carbonate platform margins (e.g., Great Bahama Bank and Adriatic Sea).

In outcrop, seven unconformity-bounded supersequences were mapped. Comparison with the synthetic seismic section shows that, at a frequency of 20 Hz, only five of these depositional supersequences can be recognized using seismic unconformities. With an increase in frequency, an increasing number of unconformities become visible, and at a frequency of 60 Hz, all seven are imaged. The synthetic seismic sections also reveal that some of the seismic unconformities are pseudo-unconformities—they do not exist in outcrop, but the seismic image shows erroneous or nonexistent geometric patterns. These are a result of the thinning of layers below seismic resolution. These observations document the problem of seismically imaging depositional sequences. Depending on the dominant frequency, an erroneous number of sequences might be interpreted. This limitation must be taken into account when making sequence stratigraphic interpretations based solely on seismic information.



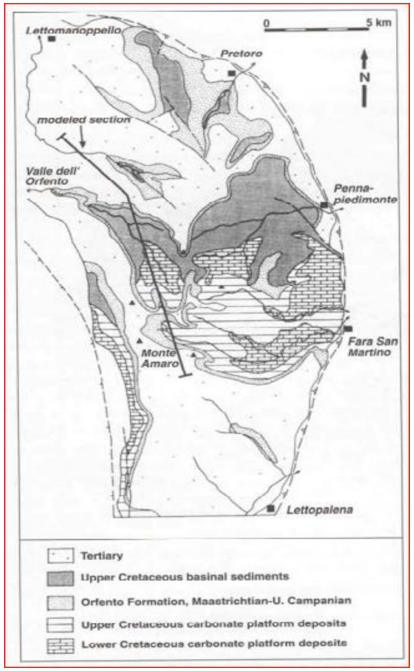


Fig. 3. Location map of the Montagna della Maiella in central Italy and the relative positions of the carbonate platforms of Apulia (A) and the Abruzzi–Campanian limestones of the southern Apennines (B). The Apulian platform is partially covered by foreland deposits and allochthonous units of the internal southern Apennines and only marginally involved in Tertiary thrusting in the Montagna della Maiella. The seismic section of the Adriatic subsurface images the continuation of the Maiella platform margin.

Fig. 18. Plot of synthetic seismic section (30 Hz, Figure 13c) over the modeled valley flank outcrop (Valle dell'Orfento, Figure 6). This overlay, distorted and plotted at approximately the same scale and position, show that all major elements of the geologic section (e.g., escarpment, megabreccias, and reefs) are well imaged. However, seismic resolution is not comparable to detailed geologic information obtained from outcrops.

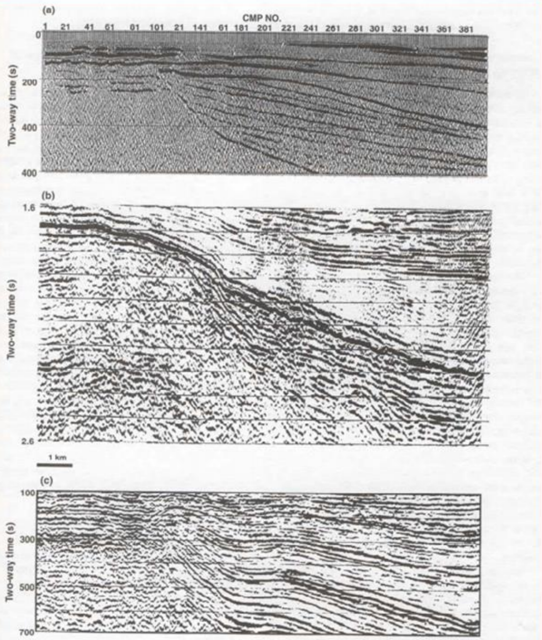


Fig. 15. Comparison of seismic sections from similar geologic environments plotted at equal horizontal and vertical scales (total width of sections is 14 km). (a) Synthetic seismic section across the platform-to-basin transition in the Montagna della Maiella (30 Hz). (b) Seismic section of the eastward continuation of the Maiella platform margin (Apulian platform) located ~40 km east of the Maiella where the margin plunges into the subsurface beneath the Adriatic Sea (Figure 3). The reflection pattern is characterized by a transparent platform onlapped by a wedge-like succession of high-amplitude reflections. (c) Part of the Western seismic line from Great Bahama Bank (Eberli and Ginsburg, 1989). The reflection pattern is similar to that above, confirming the differences in seismic facies of platform and slope.

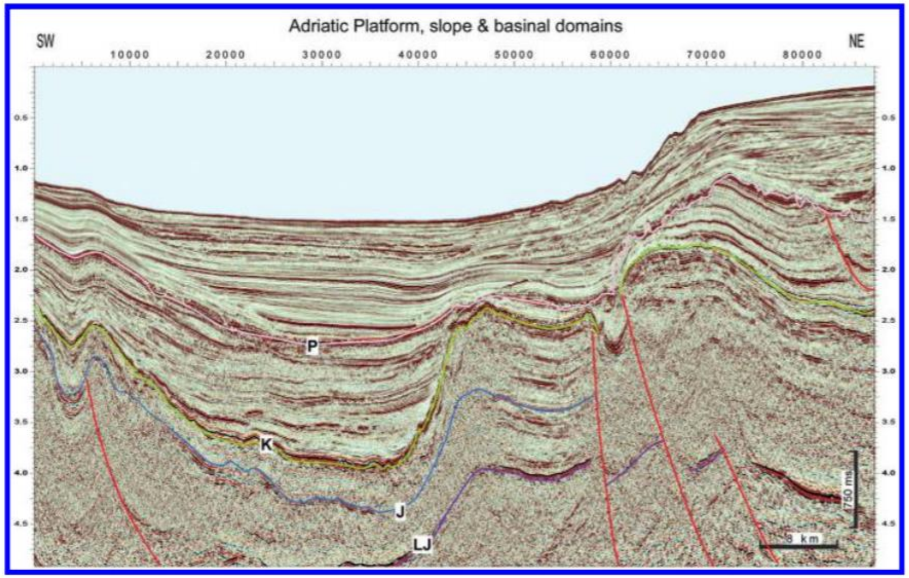
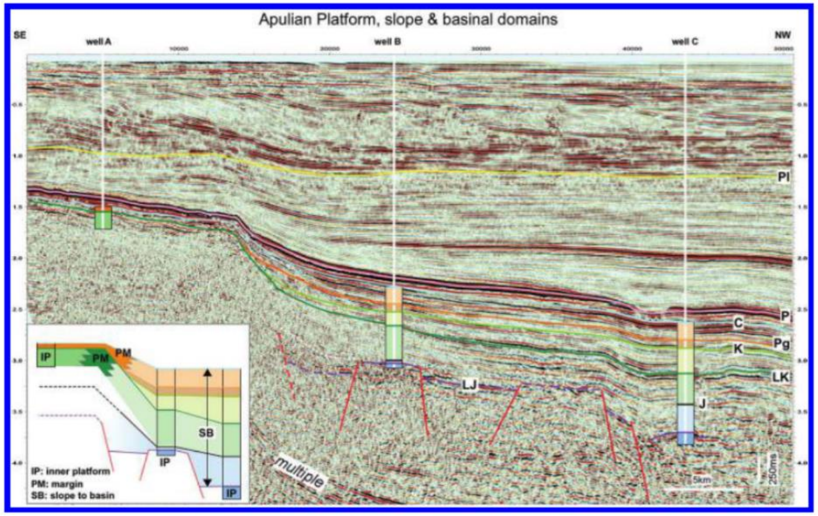


Figure 8. Seismic profile from offshore southeastern Adriatic showing the southwestern margin of the Adriatic Platform modified after Wrigley et al. (2015). The LJ reflector is the same event as in Figure 6 and represents the differentiation of the epeiric platform into ICPs and intervening basins and, on this more modern data, is continuous into the platform domain where it clearly defines the base of the MICP. Also on this data, the platform interior appears to be characterized by a parallel, continuous seismic facies, passing into a more massive, chaotic facies toward the margin. At this location, the margin is characterized by an aggradational slope with minor backstepping and present-day vertical relief of approximately 1750 m and a slope angle of approximately 15°. On the eastern end of the line, an inversion structure formed during Tertiary compression is clearly imaged. LJ: Top Lower Jurassic; J: Top Jurassic; K: Top Cretaceous (also top of carbonates); P: Base Pliocene.



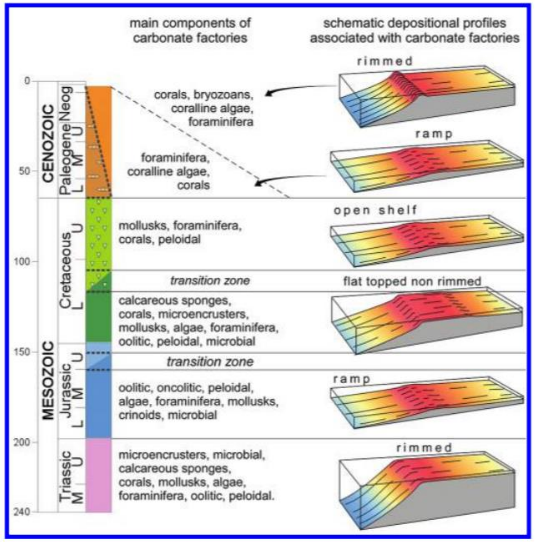


Figure 10. Stratigraphic distribution, main components, and schematic depositional profiles of carbonate factories of MICPs.

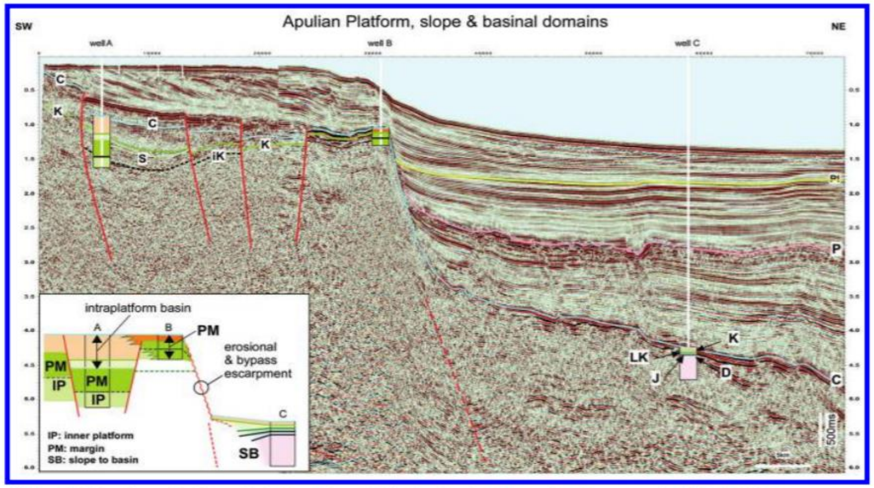
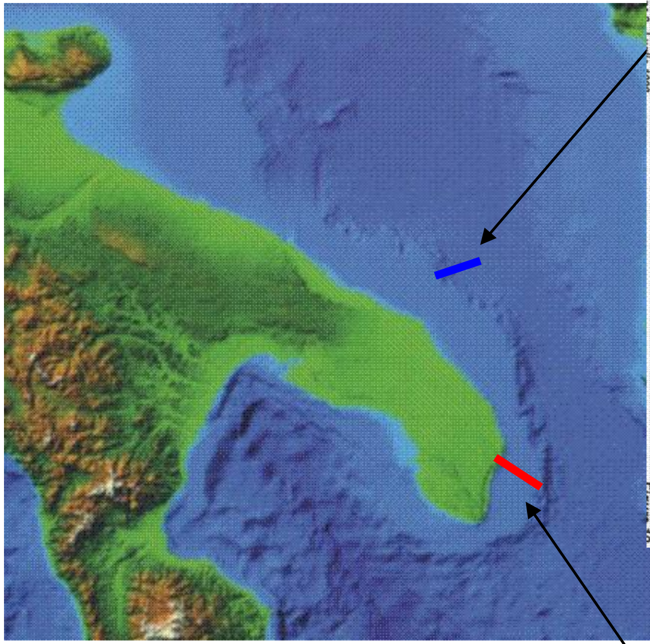
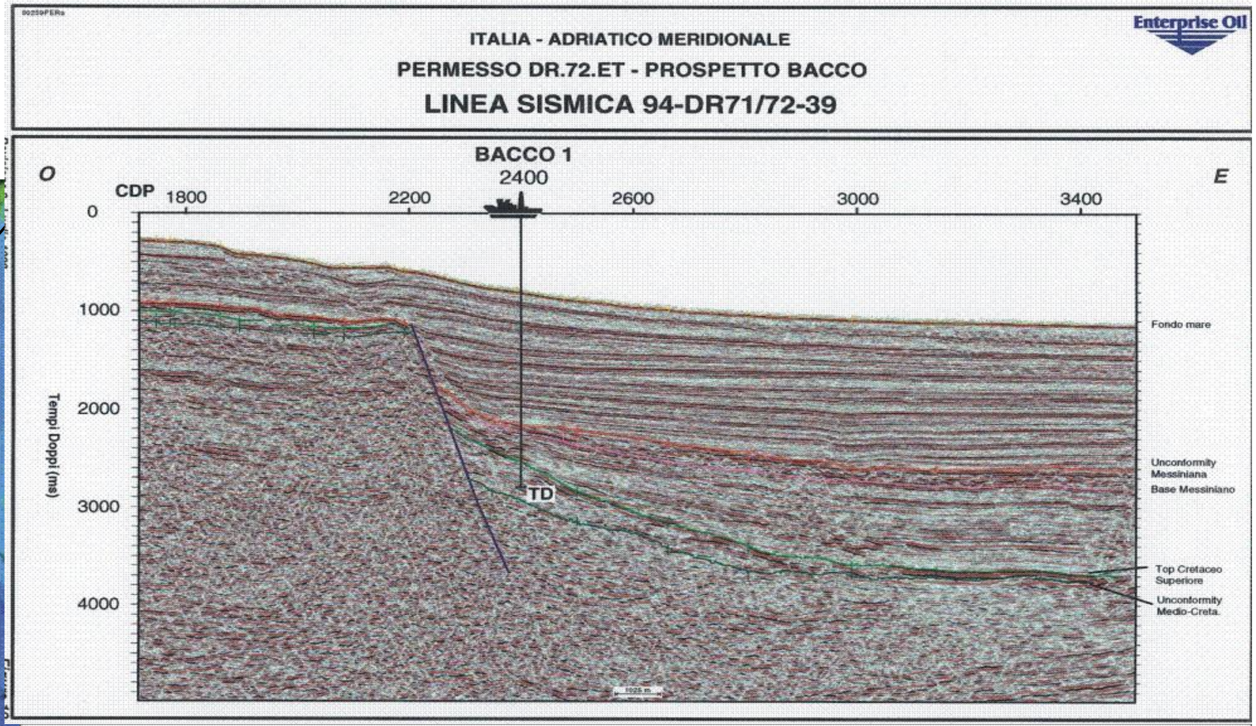
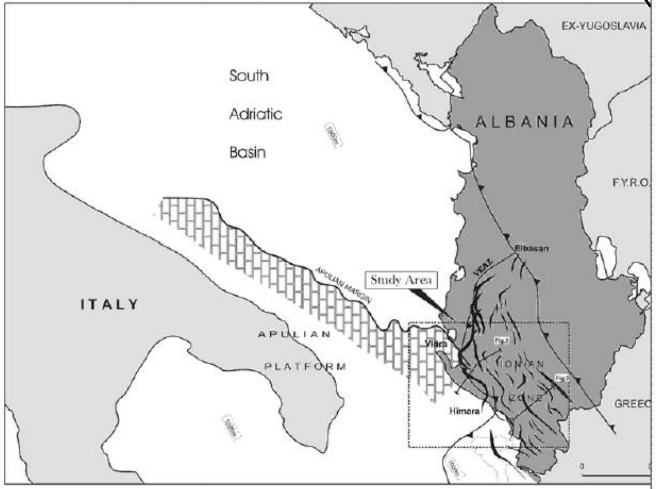


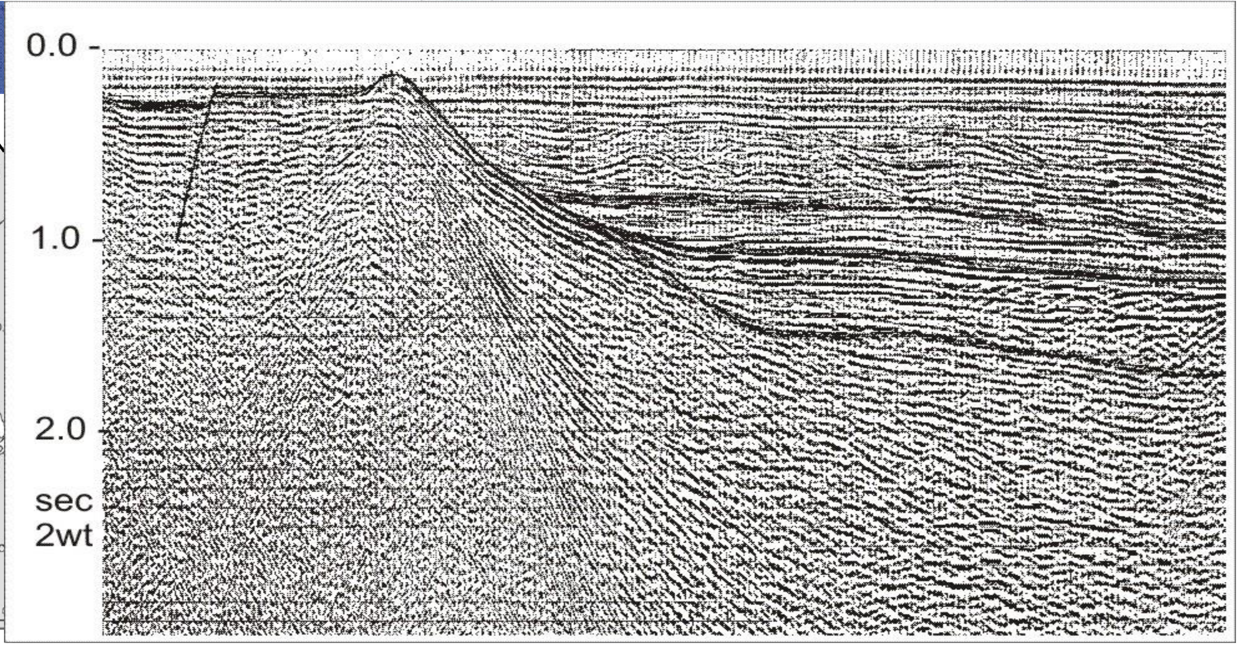
Figure 7. Seismic profile from offshore southern Adriatic showing the northeastern margin of the Apulian Platform. The C reflector corresponds to the top of the carbonates, while base carbonate is difficult to interpret in both platformal and basinal domains. This line shows evidence of Cretaceous tectonic activity that created localized deeper water basins within the platform, as evidenced by the presence of a thin interval of pelagic Upper Cretaceous sediments overlying shallow marine carbonates in well A. Shallow marine carbonate sedimentation lasted until the end of the Lower Miocene in well B. At this location, the margin is characterized by a bypass slope with a toe-of-slope apron and present-day vertical relief of approximately 2750 m and an escarpment angle of approximately 30°. Seismic line courtesy of Spectrum Geo Inc. with reprocessing as described by Nicholls et al. (2015). D: Top Dolostones; J: Top Upper Jurassic; LK: Top Lower Cretaceous; iK: infra Upper Cretaceous; S: Top Lower Senonian; K: Top Cretaceous; C: Top Carbonates (infra Miocene in the platform [left]; Top Paleogene in the basin [right]); P: Base Pliocene; Pl: Top Pliocene.

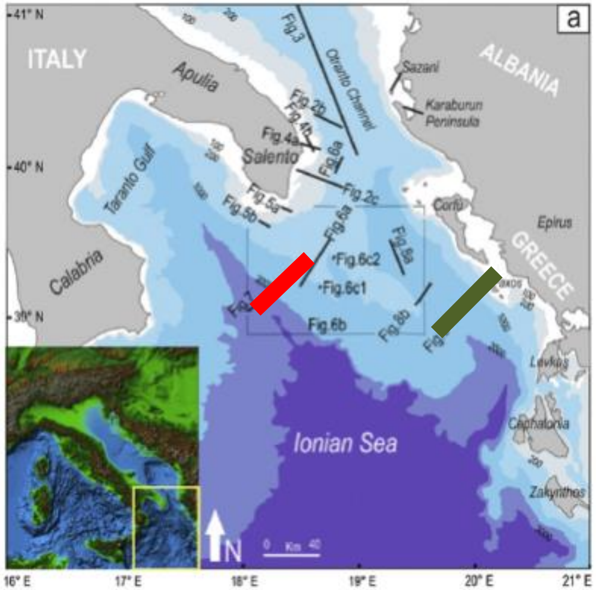
MARGINS OF THE APULIA CARBONATE PLATFORM (OTRANTO CHANNEL)

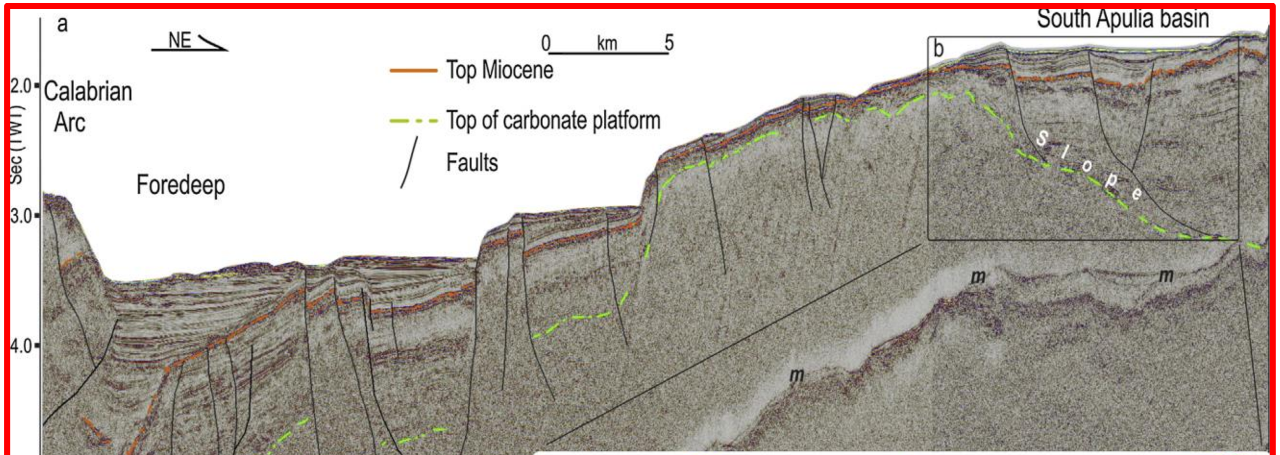


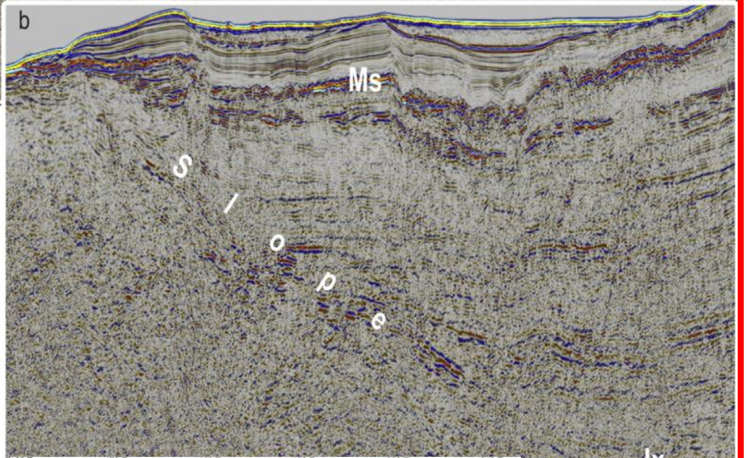


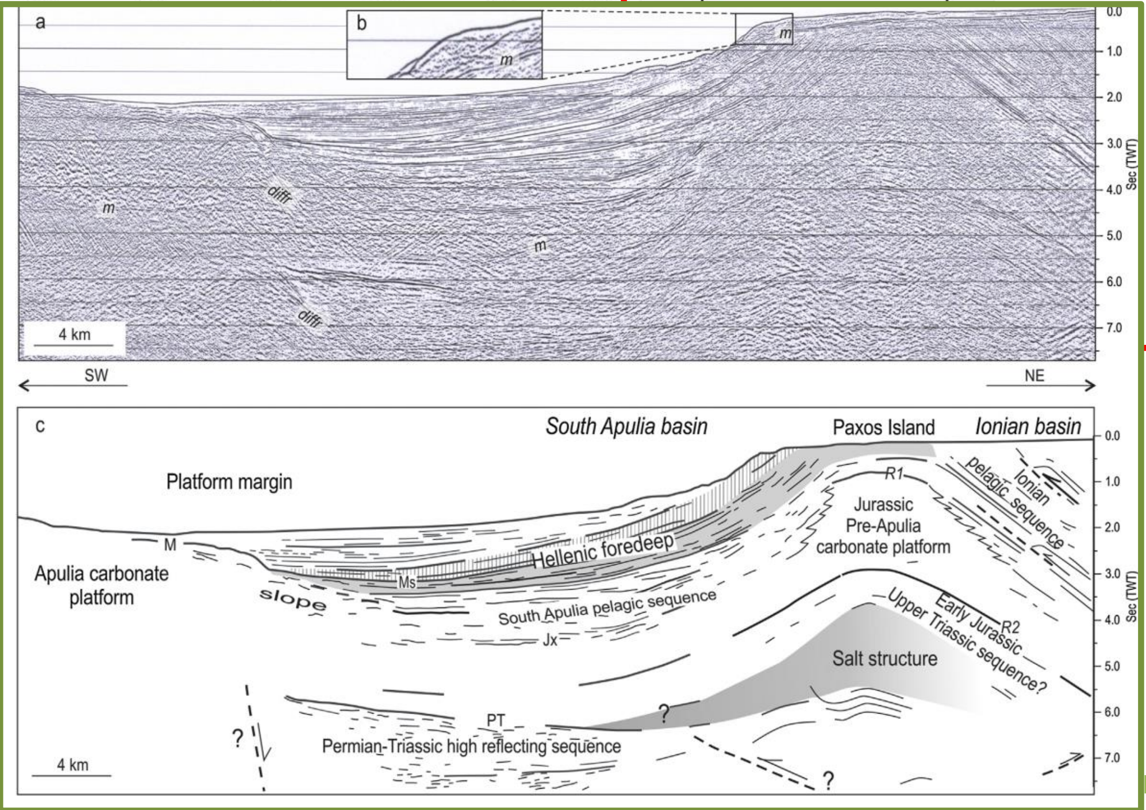


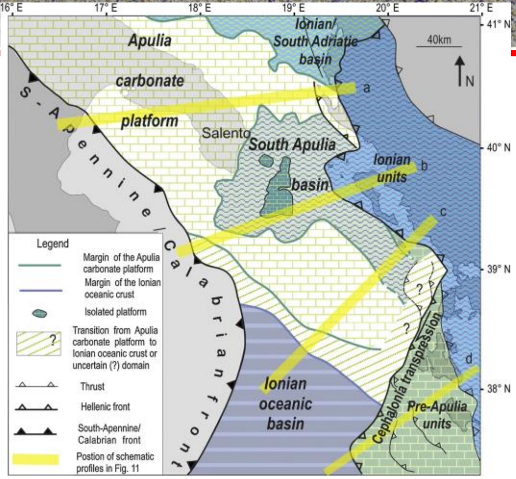



a
ITALY
Apulia
Salento
Taranto Gulf
Calabria
Ionian Sea
ALBANIA
GREECE
Sazani
Karaburun Peninsula
Otranto Channel
Corfu
Epirus
Paxos
Levkas
Cephalonia
Zakynthos
Fig.3
Fig.2b
Fig.4b
Fig.4a
Fig.6a
Fig.2c
Fig.5a
Fig.5b
Fig.6c2
Fig.6c1
Fig.6b
Fig.8b
Fig.7
N
0 Km 40
41° N
40° N
39° N
16° E
17° E
18° E
19° E
20° E
21° E

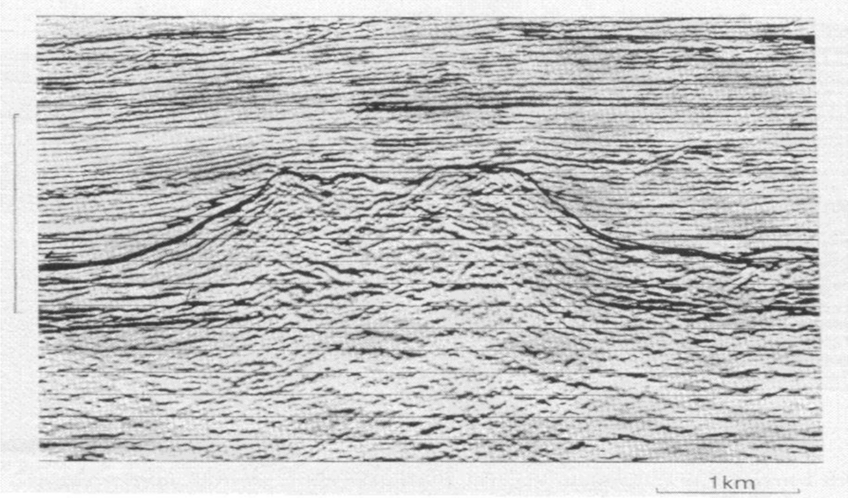

a
NE
0 km 5
Top Miocene
Top of carbonate platform
Faults
South Apulia basin
Calabrian Arc
Foredeep
Sec (TWT)
2.0
3.0
4.0
5.0
b
Slope
m
m
m
c
18° E
19° E


b
Ms
Slope
Jx


a
b
m
m
diffr
m
diffr
m
4 km
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Sec (TWT)
SW
NE
c
South Apulia basin
Paxos Island
Ionian basin
Platform margin
Apulia carbonate platform
M
slope
Ms
Hellenic foredeep
South Apulia pelagic sequence
Jx
R1
Jurassic Pre-Apulia carbonate platform
Ionian pelagic sequence
Early Jurassic
R2
Upper Triassic sequence?
Salt structure
PT
Permian-Triassic high reflecting sequence
?
4 km

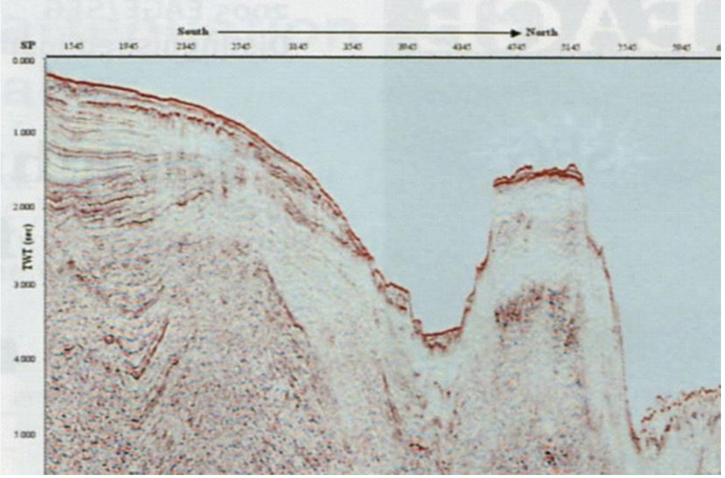

16° E
17° E
18° E
19° E
20° E
21° E
41° N
40° N
39° N
38° N
40km
N
Apulia carbonate platform
Ionian/ South Adriatic basin
Salento
South Apulia basin
Ionian units
S.-Apennine-Calabrian front
Ionian oceanic basin
Cephalonia transpression
Pre-Apulia units
a
b
c
d
?
Legend
Margin of the Apulia carbonate platform
Margin of the Ionian oceanic crust
Isolated platform
Transition from Apulia carbonate platform to Ionian oceanic crust or uncertain (?) domain
Thrust
Hellenic front
South-Apennine/ Calabrian front
Postion of schematic profiles in Fig. 11

ISOLATED PLATFORM

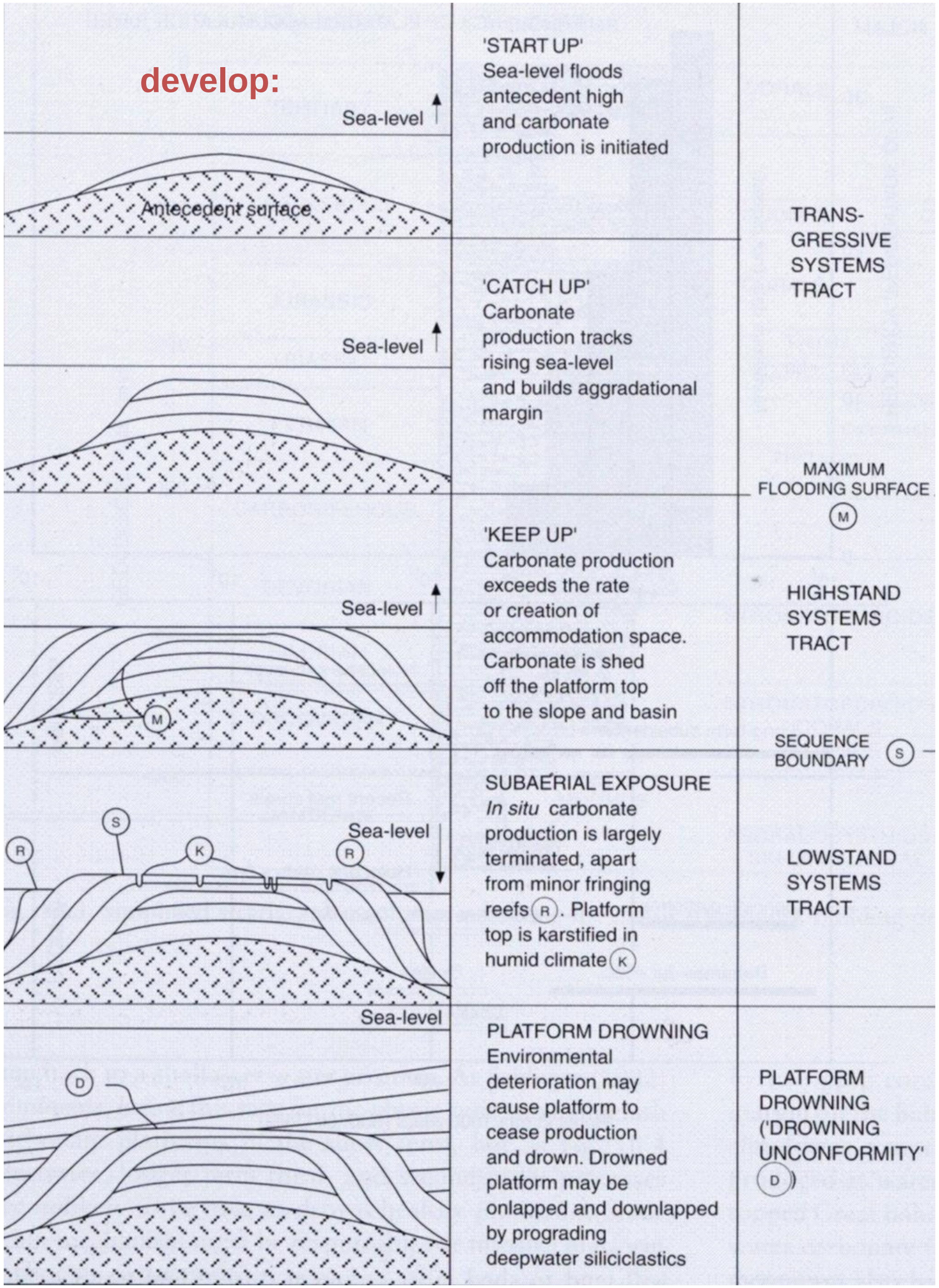


Examples of profiles crossing isolated platforms

offshore Libia



develop:



'START UP'
Sea-level floods antecedent high and carbonate production is initiated

'CATCH UP'
Carbonate production tracks rising sea-level and builds aggradational margin

TRANS-GRESSIVE SYSTEMS TRACT

MAXIMUM FLOODING SURFACE (M)

'KEEP UP'
Carbonate production exceeds the rate or creation of accommodation space. Carbonate is shed off the platform top to the slope and basin

HIGHSTAND SYSTEMS TRACT

SEQUENCE BOUNDARY (S)

SUBAERIAL EXPOSURE
In situ carbonate production is largely terminated, apart from minor fringing reefs (R). Platform top is karstified in humid climate (K)

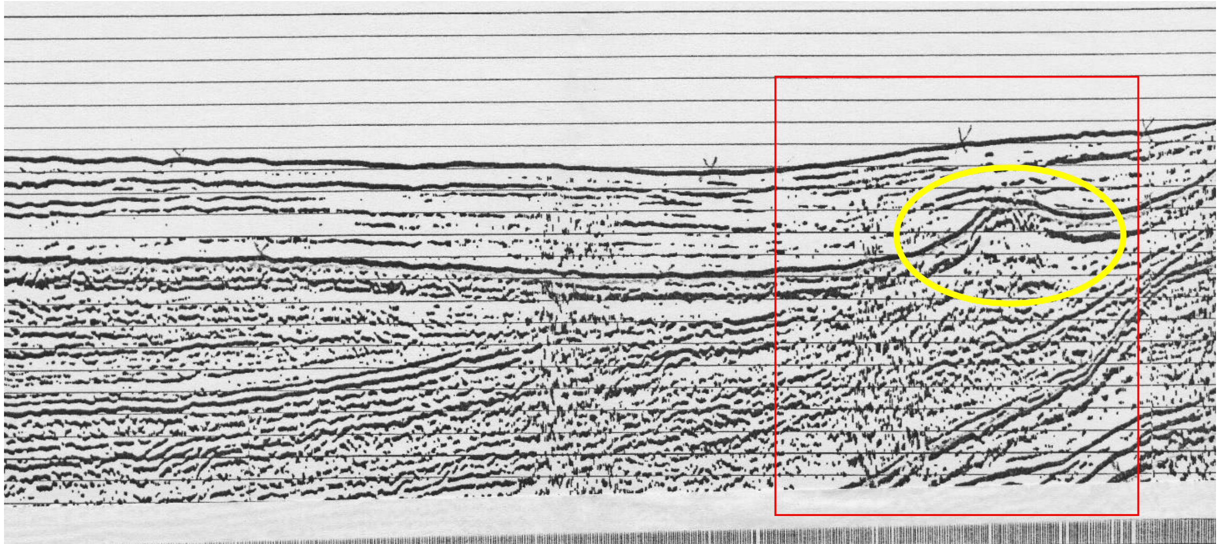
LOWSTAND SYSTEMS TRACT

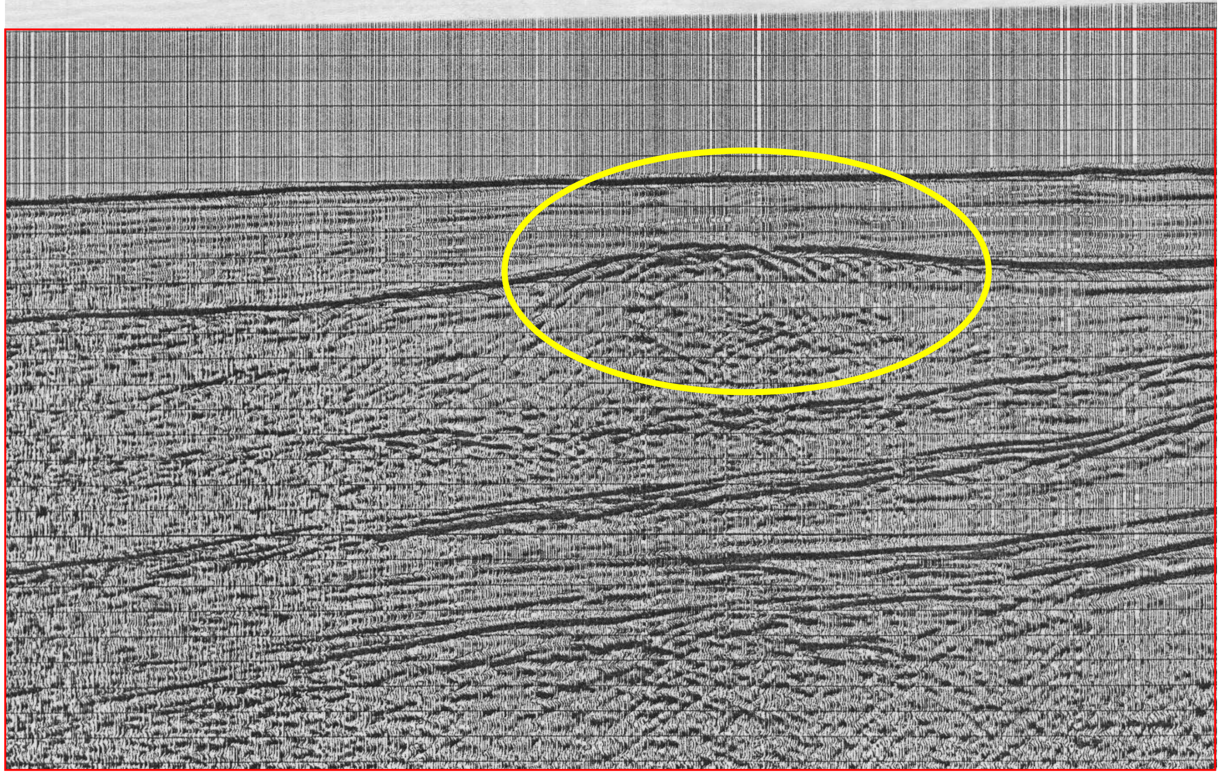
PLATFORM DROWNING
Environmental deterioration may cause platform to cease production and drown. Drowned platform may be onlapped and downlapped by prograding deepwater siliciclastics

PLATFORM DROWNING ('DROWNING UNCONFORMITY' (D))

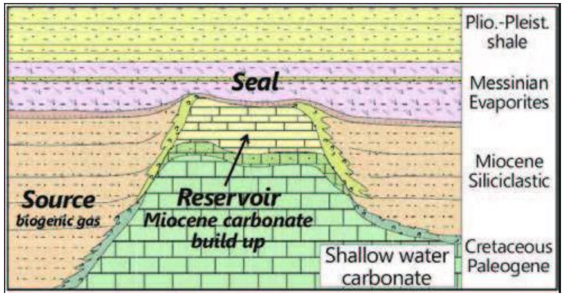
Example of an isolated *build-up* in the *Falkland Plateau*, southern Atlantic margin:

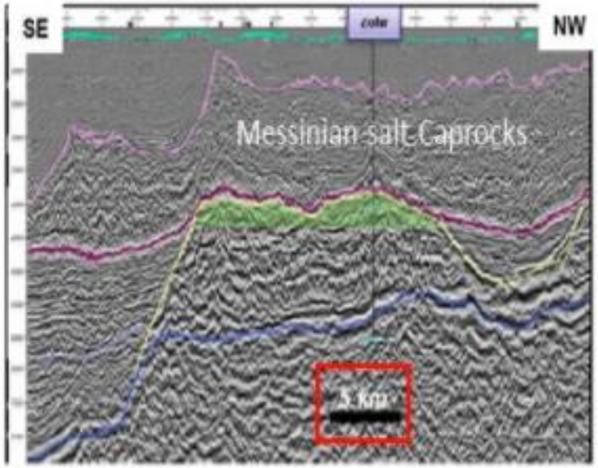
figure below represents a detail of the same profile above, with different scale

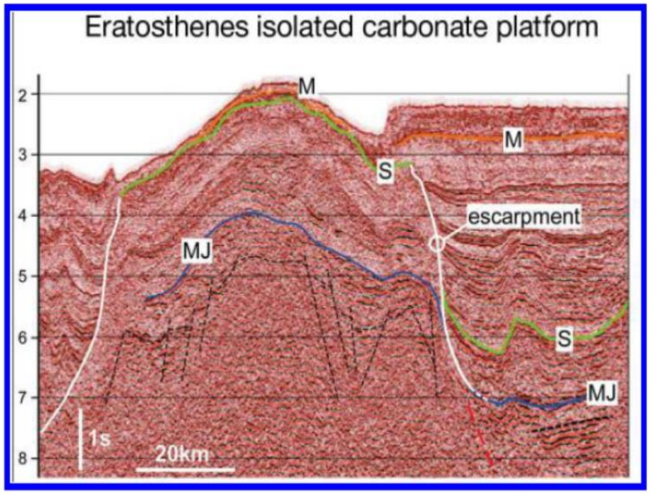




A giant discovery: the Zohr Field







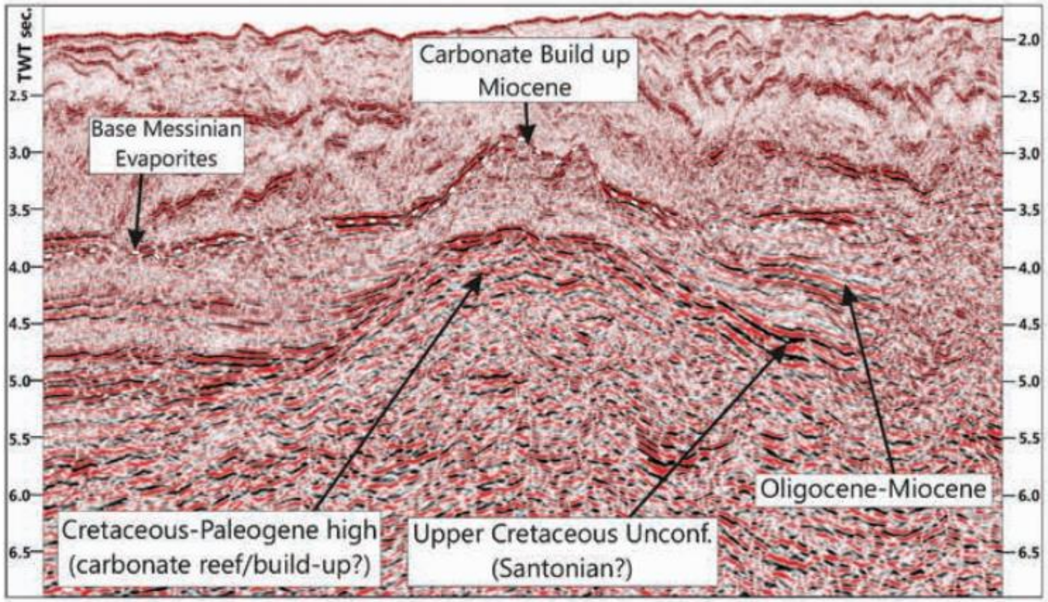
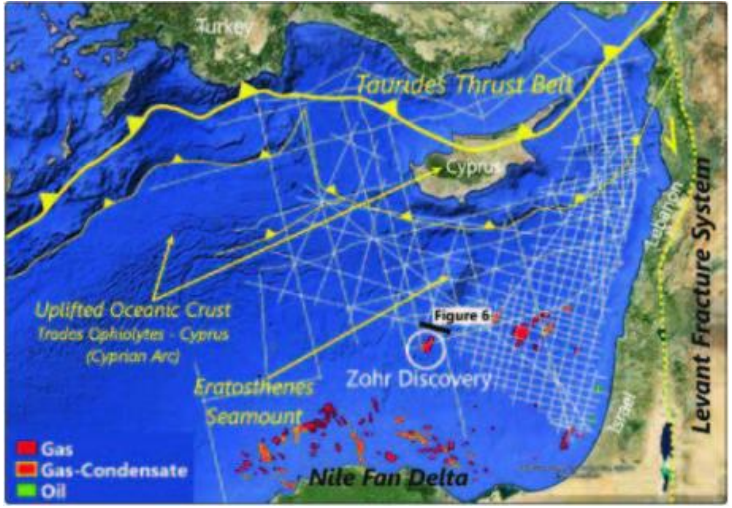


Figure 6 *TWT section across a Miocene carbonate build-up along the margins of the Eratosthenes Platform. The section is located in Figure 1.*



Isolated carbonate platforms of the Mediterranean and their seismic expression — Searching for a paradigm

Giovanni Rusciadelli[1] and Peter Shiner[2]

https://doi.org/10.1190/tle37070492.1.

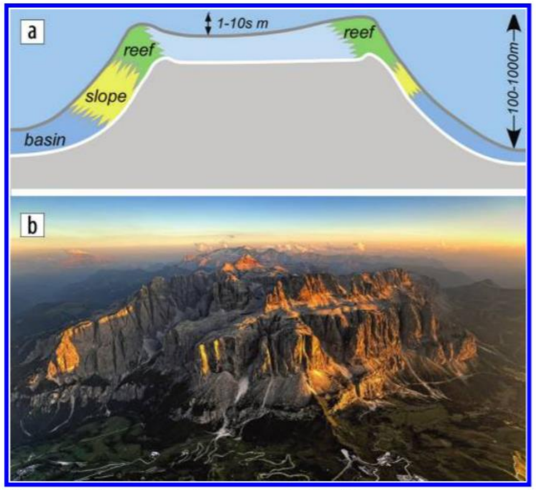


Figure 1. (a) Illustration showing the geometry of an ICP and its internal subdivision into gross depositional environments. (b) Example of a Triassic ICP (Sella Group, Dolomites) in which erosion of softer and younger basinal sediments has resulted in exposure of the paleotopography of the ICP.

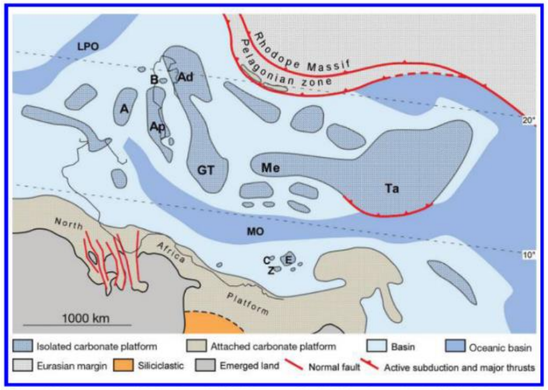


Figure 4. Paleogeography of Tethys during the Mid-Cretaceous. Modified after Dercourt et al. (2000); Barrier et al. (2008). A: Apenninic Platform; Ad: Adriatic Platform; Ap: Apulian Platform; B: Barbara Platform; C: Calypso Platform; E: Eartosthenes Platform; GT: Gavrovo-Tripolitza Platform; LPO: Ligure-Piemontese Ocean; Me: Menderes Platform; MO: Mesogean Ocean; Ta: Taurus Platform; Z: Zohr Platform.

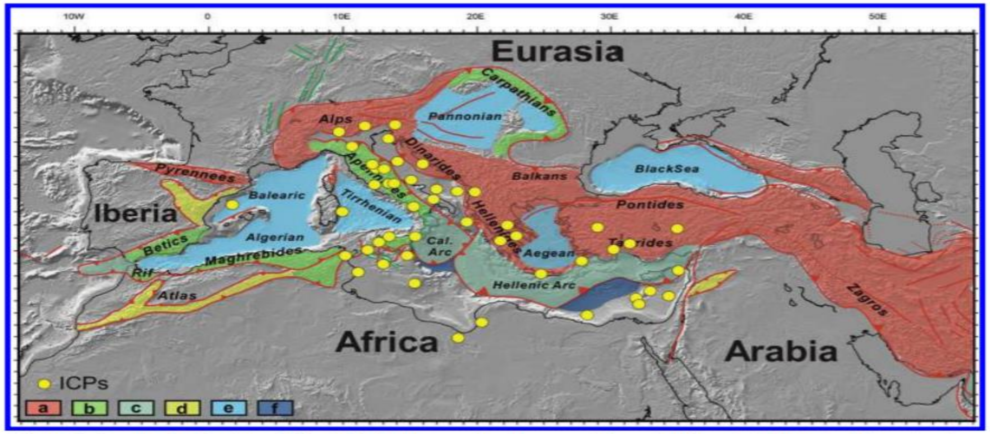
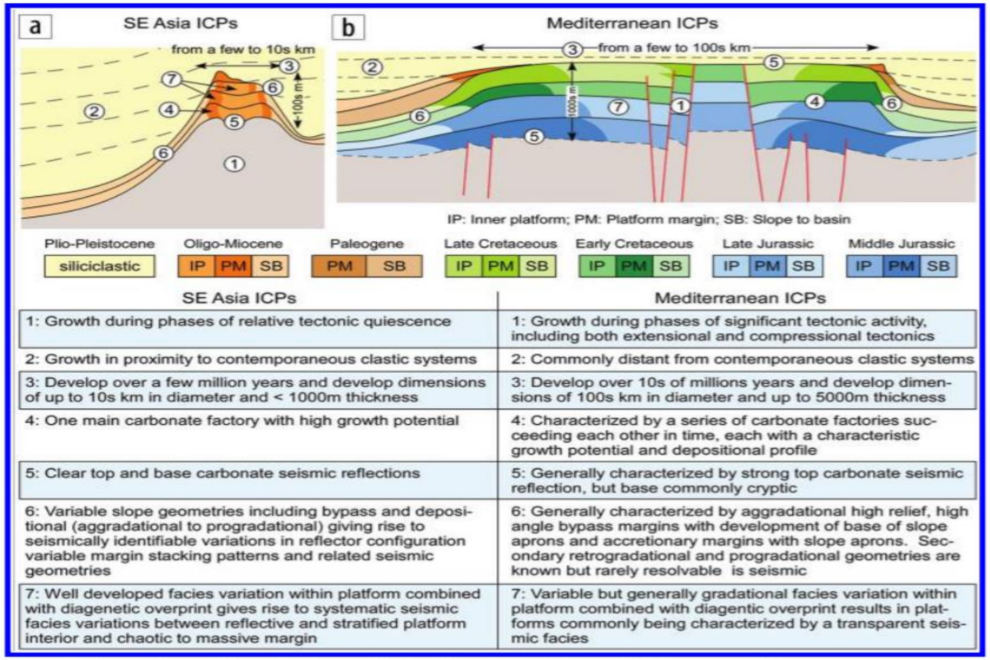


Figure 2. Present distribution of ICPs in Mediterranean in outcrop and the subsurface. (a) Mountain belts related to continental collision. (b) Fold-and-thrust belts related to back-arc opening. (c) Accretionary complexes related to oceanic subduction. (d) Intracontinental belts. (e) Back-arc basins. (f) Residual (Mesozoic) Tethyan ocean.

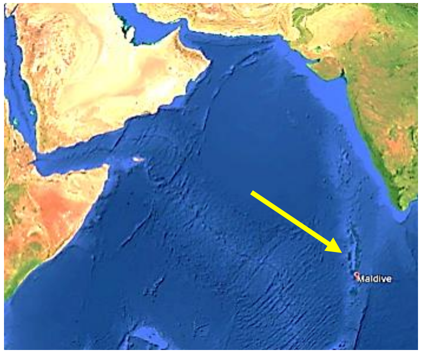


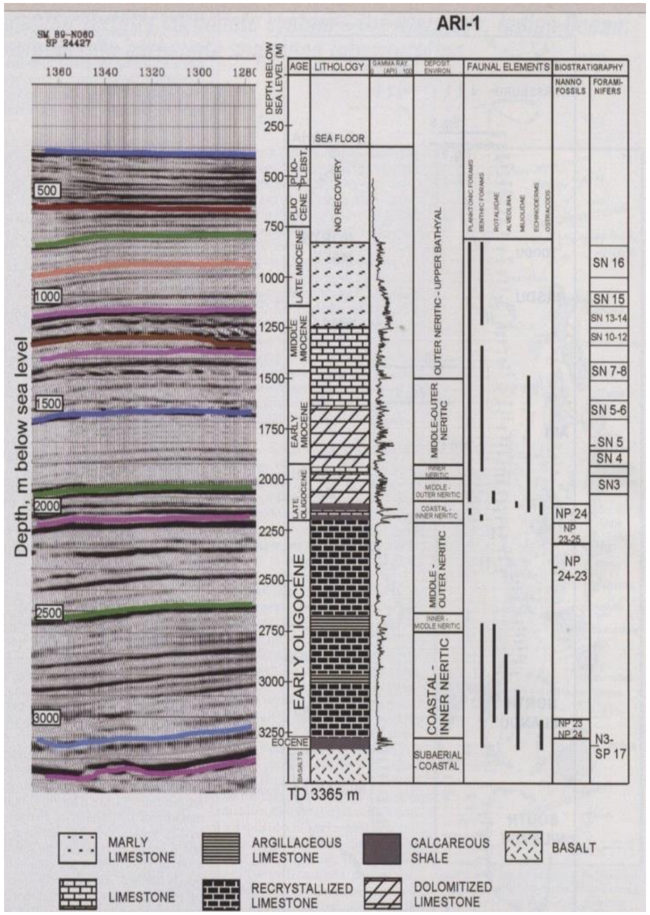
SE Asia ICPs	Mediterranean ICPs
1: Growth during phases of relative tectonic quiescence	1: Growth during phases of significant tectonic activity, including both extensional and compressional tectonics
2: Growth in proximity to contemporaneous clastic systems	2: Commonly distant from contemporaneous clastic systems
3: Develop over a few million years and develop dimensions of up to 10s km in diameter and < 1000m thickness	3: Develop over 10s of millions years and develop dimensions of 100s km in diameter and up to 5000m thickness
4: One main carbonate factory with high growth potential	4: Characterized by a series of carbonate factories succeeding each other in time, each with a characteristic growth potential and depositional profile
5: Clear top and base carbonate seismic reflections	5: Generally characterized by strong top carbonate seismic reflection, but base commonly cryptic
6: Variable slope geometries including bypass and depositional (aggradational to progradational) giving rise to seismically identifiable variations in reflector configuration variable margin stacking patterns and related seismic geometries	6: Generally characterized by aggradational high relief, high angle bypass margins with development of base of slope aprons and accretionary margins with slope aprons. Secondary retrogradational and progradational geometries are known but rarely resolvable is seismic
7: Well developed facies variation within platform combined with diagenetic overprint gives rise to systematic seismic facies variations between reflective and stratified platform interior and chaotic to massive margin	7: Variable but generally gradational facies variation within platform combined with diagentic overprint results in platforms commonly being characterized by a transparent seismic facies

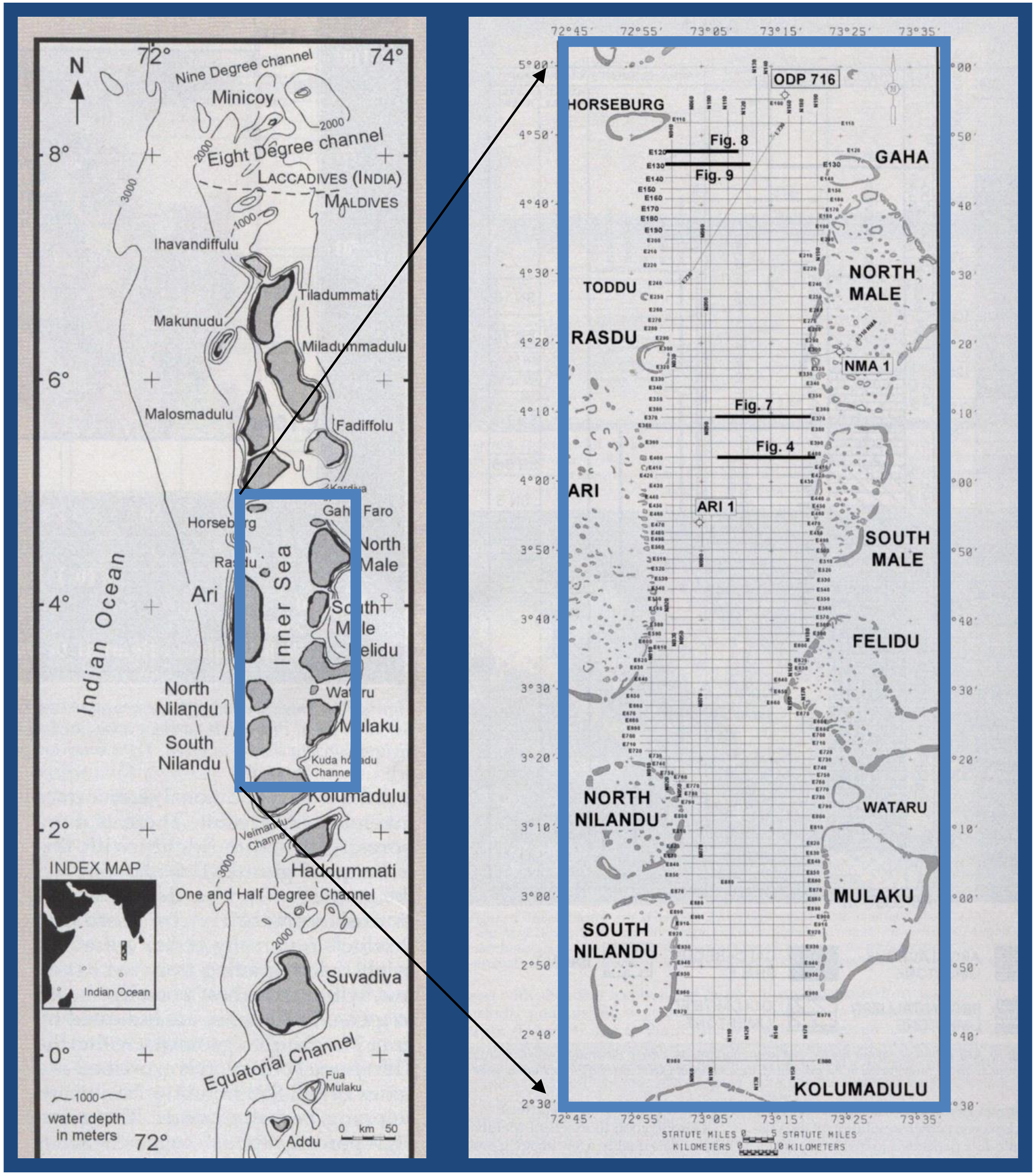
Figure 3. Comparison of the main characteristics of Southeast Asian and Mediterranean ICPs.

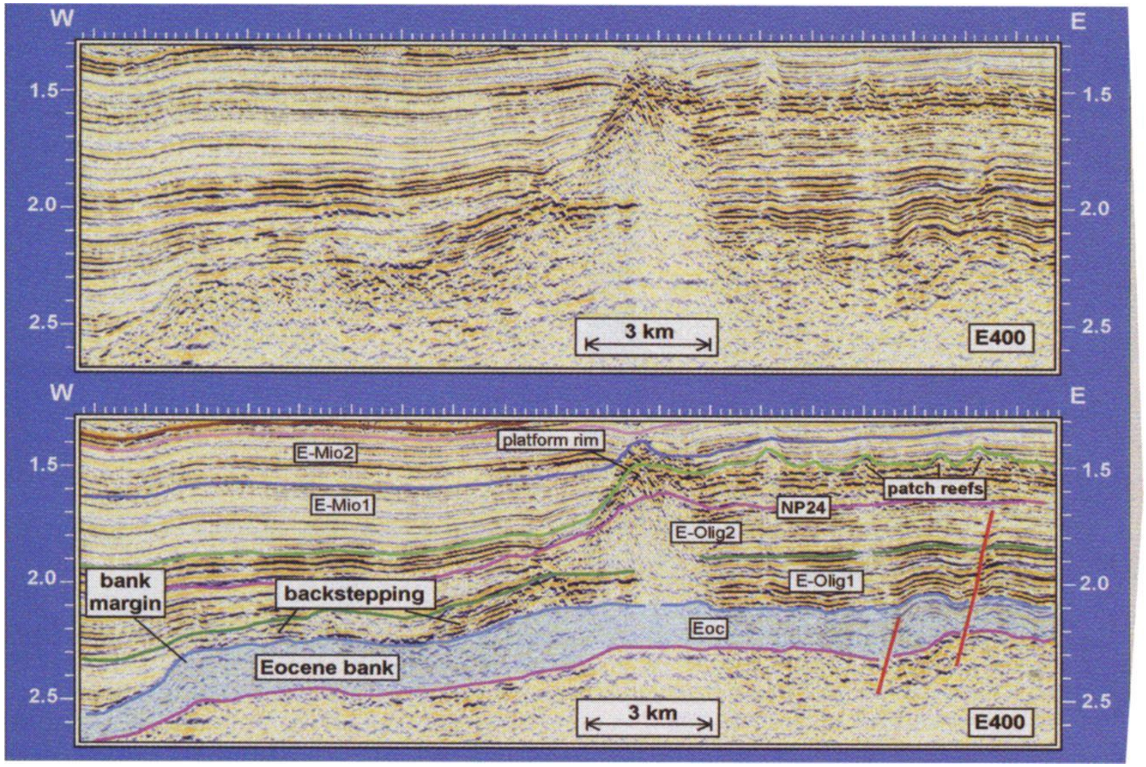
MALDIVE

Example of carbonate platform developed since the end of Eocene until the Present









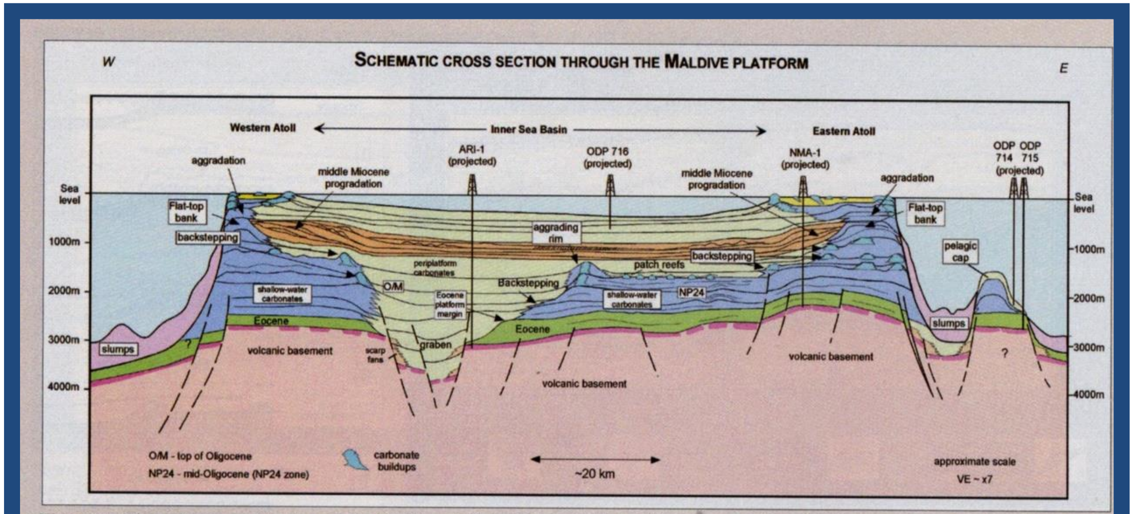
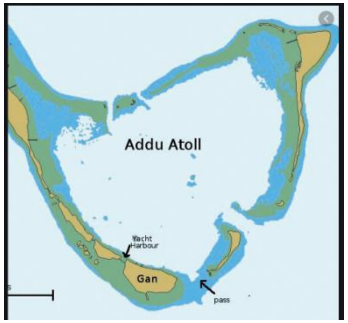


Figure 11. *Schematic cross-section through the Maldives platform. Substantially modified from van Gils and Rubbens (1992).*



Data show that the margins of the Maldive platform migrated during the time: some sectors subsided and were buried below pelagic sediments, other sectors outcropped were eroded. Eventually, after erosion, new building could develop.

Int J Earth Sci (Geol Rundsch) (2018) 107:481–504
https://doi.org/10.1007/s00531-017-1504-7

ORIGINAL PAPER

Growth and demise of a Paleogene isolated carbonate platform of the Offshore Indus Basin, Pakistan: effects of regional and local controlling factors

Khurram Shahzad[1] · Christian Betzler[1] · Nadeem Ahmed[2] · Farrukh Qayyum[1] ·
Silvia Spezzaferri[3] · Anwar Qadir[4]