

# **Eustasy Recording Potential of an Isolated Devonian to Pennsylvanian Carbonate Platform in a Foreland Basin Setting (Tengiz, Pricaspian Basin, Kazakhstan)\***

By  
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Search and Discovery Article #20047 (2008)  
Posted May 19, 2008

\*Abstract prepared for AAPG Annual Convention, San Antonio, Texas, April 20-23, 2008

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## **Abstract**

Research drilling of continental margins over the last decade has validated a significant number, as well as the timing, of EPR sea-level events for the past 100 My. However, for the older geological record diverging sea level estimates (EPR curve, continental flooding records, planktic evolutionary records) still exist and the extraction of reliable eustatic records remains problematic.

Tengiz field is an isolated carbonate buildup in the southeastern Pricaspian Basin, containing a complete Late Famennian to Early Bashkirian platform succession that was deposited in a relatively stable but rapidly subsiding foreland basin setting facing a thrust belt to the south. Since the Famennian, the platform aggraded and periodically back-stepped, resulting in approximately 1400 m (4480 ft) of relief above the Famennian platform, followed by up to 2 km (1.2 miles) of Serpukhovian progradation. Vertical trends in relative shoaling and deepening, recorded exposure and/or erosional events, and biostratigraphy provide a relative sea level record of punctuated sea level falls and rises that is made up of 2nd and 3rd order sequences which are superimposed by higher (4-5th order) frequency platform cycles.

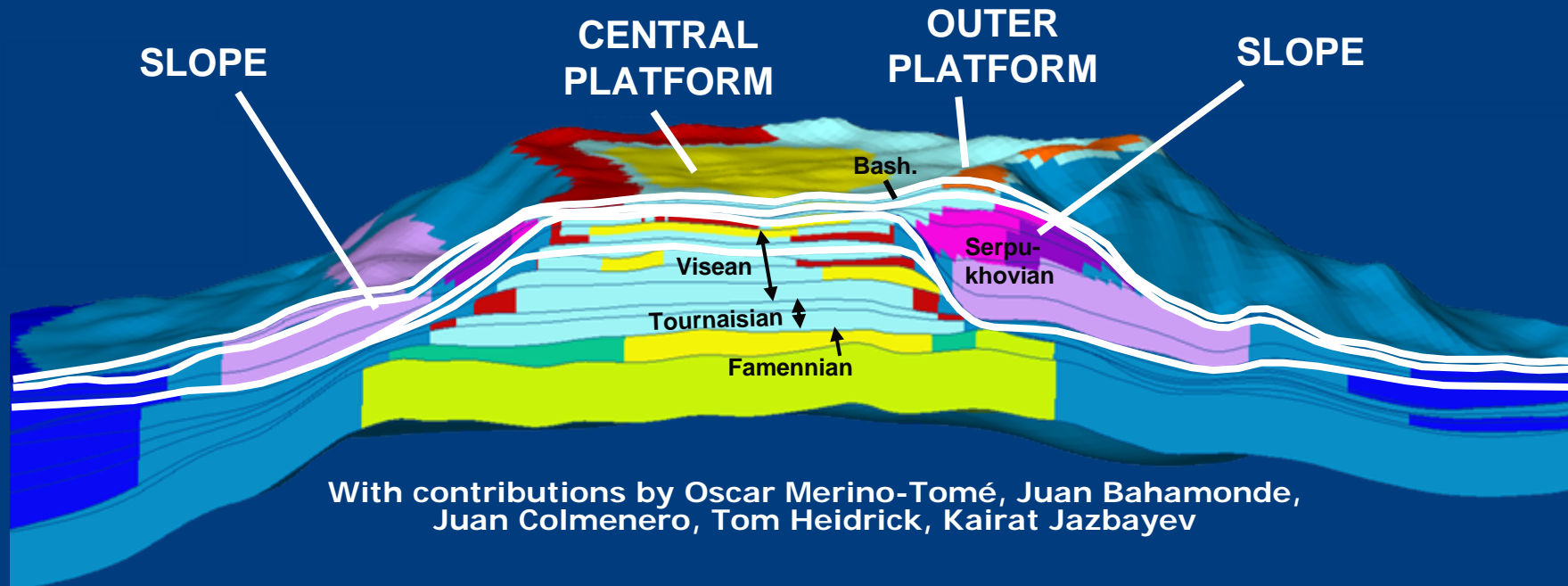
Though several of the observed sea level lowstands correspond to 3rd order eustatic sequences on the EPR curve, the influence of rapid changes in the paleobathymetry of the foreland basin, which caused significant thickening of sequences and drowning in the Late Devonian elsewhere in the basin, appears to have a strong influence on the regional sequence stratigraphic framework. This article addresses the interplay between subsidence and recorded sequences in such foreland basin settings.



# Paleozoic Carbonates in Foreland Basin Settings: Northern Pricaspian Basin (Kazakhstan) and Cantabrian Zone (Spain)

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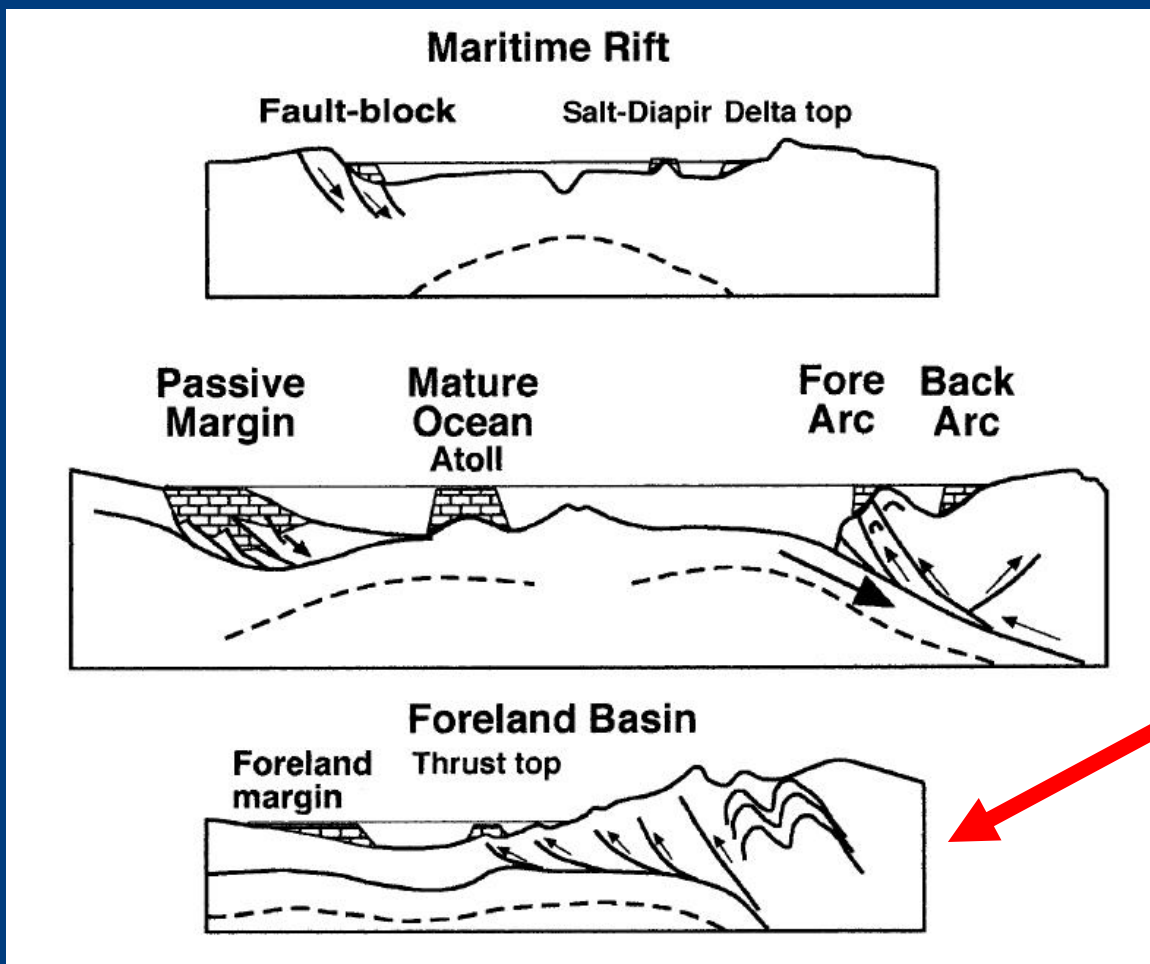
# Outline

- Rationale
- Carbonate systems in foreland basin settings
- Tectonic setting Pricaspian Basin
- Tengiz Field accommodation history
- Outcrop analog from northern Spain: platforms and thrust-top buildups in a foreland basin setting
- Conclusions

# Rationale

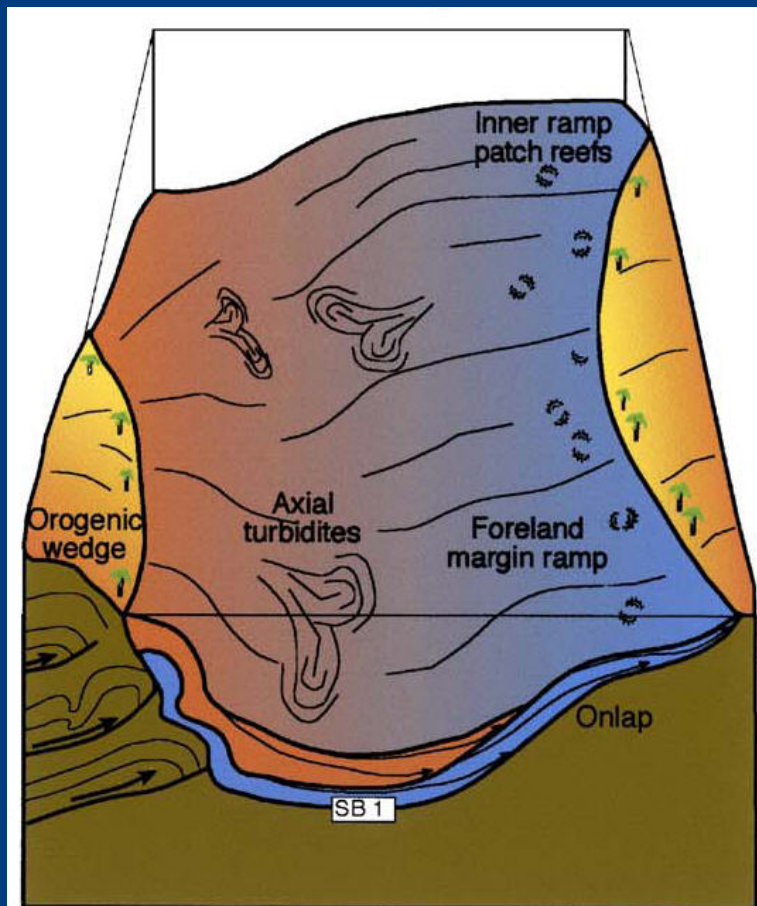
- Sedimentation in tectonically active settings controlled by 1) structural grain, 2) timing and rate of deformation, and 3) eustacy
- Many carbonate hydrocarbon reservoir systems formed in foreland basin settings
- Generally difficult to extract geometry and timing from outcrop BUT
- Outcrop analog from northern Spain shows variation of depositional style in time and space
- May assist understanding/interpretation of carbonate system evolution in such tectonic regimes and in Pricaspian in particular

# General tectonic settings of carbonate buildups



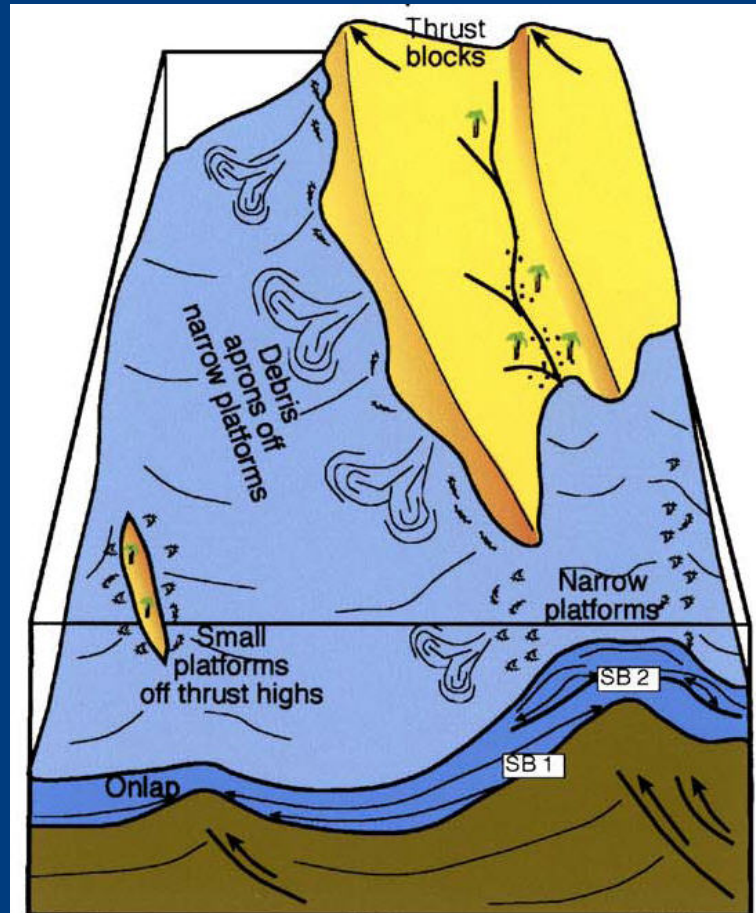
# Foreland basin and thrust-top buildups

## Foreland margin buildups



—SB Sequence Boundary scale: kms-100s km across

## Thrust-top buildups

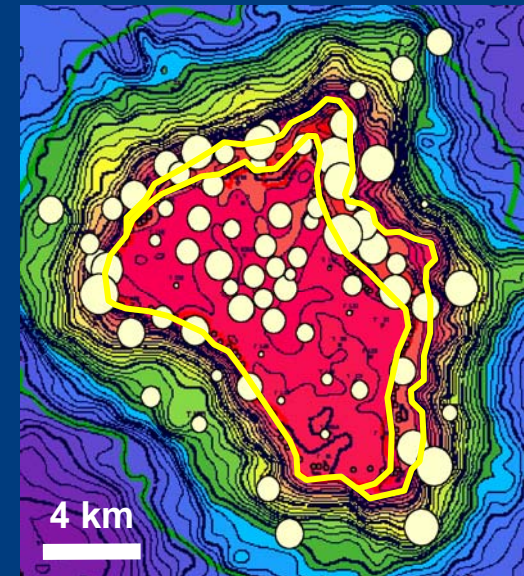


scale: kms-10s km across



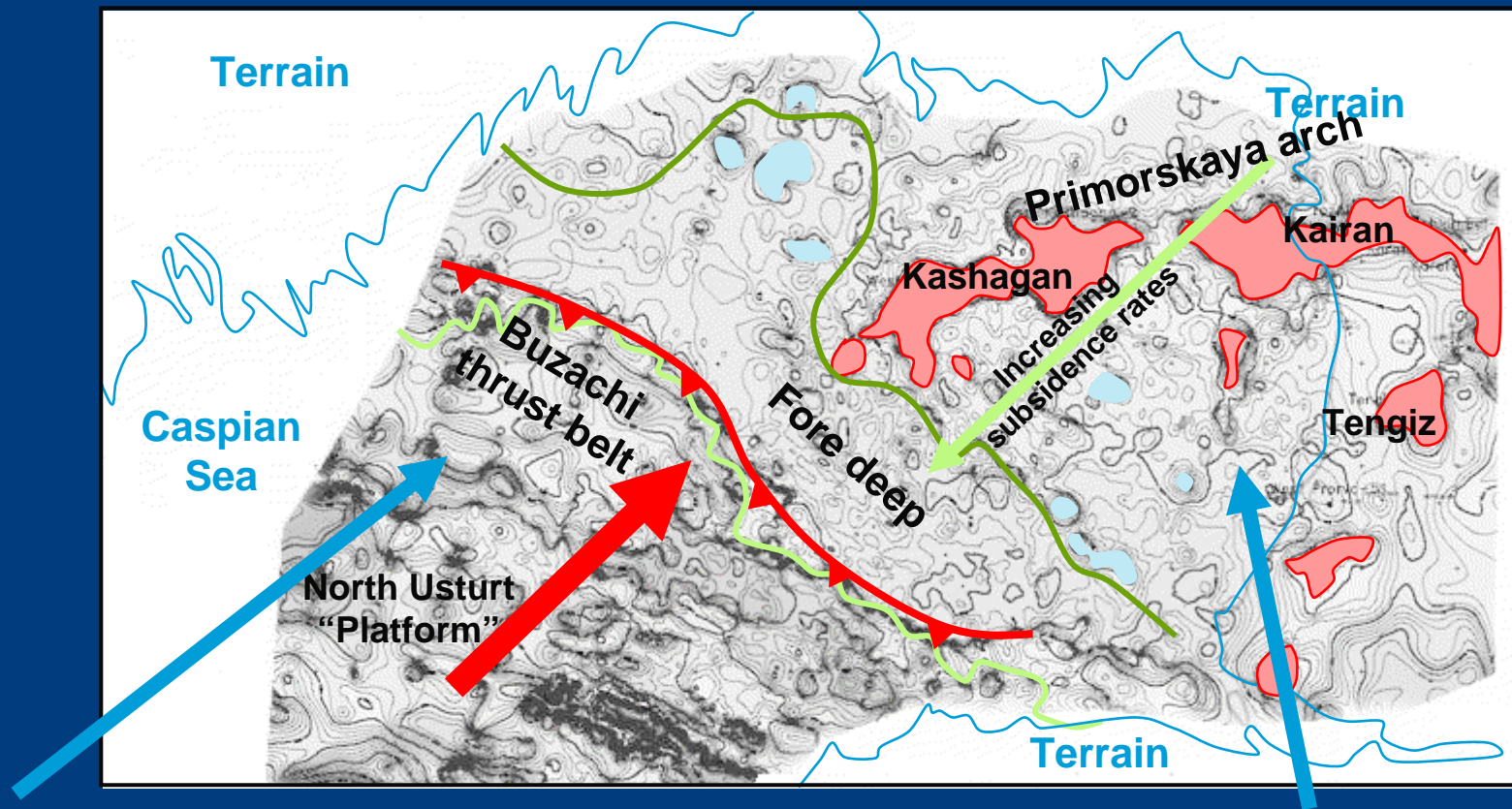
# North Caspian Basin – Background

- Produces oil from subsalt Devonian-Carboniferous carbonate platforms
- Pricaspian Basin holds 46 BBOE (56% gas)
- Four supergiant carbonate fields: Tengiz, Karachaganak, Astrakhan and Kashagan
- Complex tectonic history of
  - Thermal subsidence and rifting until late Carboniferous
  - Collision and thrusting starting in Permian
  - Separation from Tethys Ocean and formation of salt basin in Kungurian



Tengiz production bubbles

# Top Devonian (sketch) structure map



Thick isolated and thrust-top platforms?



Dev-Carb isolated platforms

Drowned Devonian? buildups

Southwards thickening (2.5 to 4.0 km) isolated platform archipelago



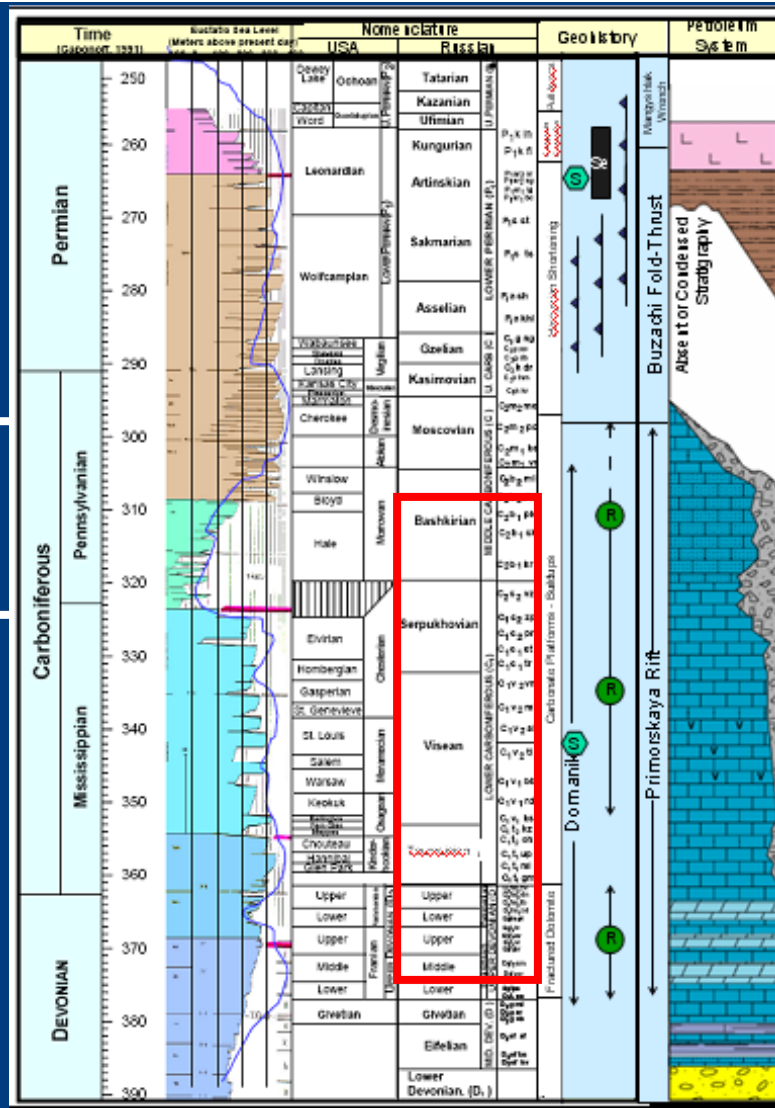
# Generalized Paleozoic stratigraphy and geohistory

## STYLE

Platforms in front and on top of thrustbelt



Platforms with variable thickness and internal geometries; drowning in foredeep



## TECTONICS

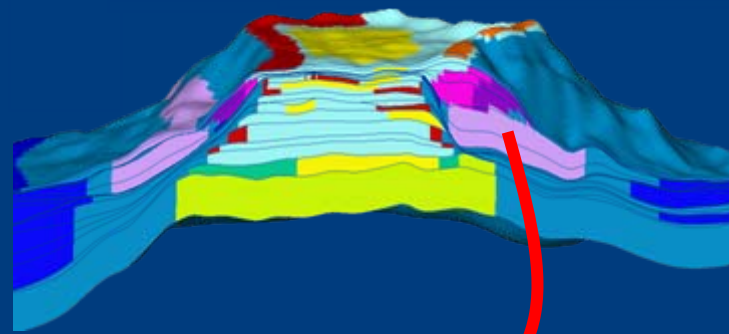
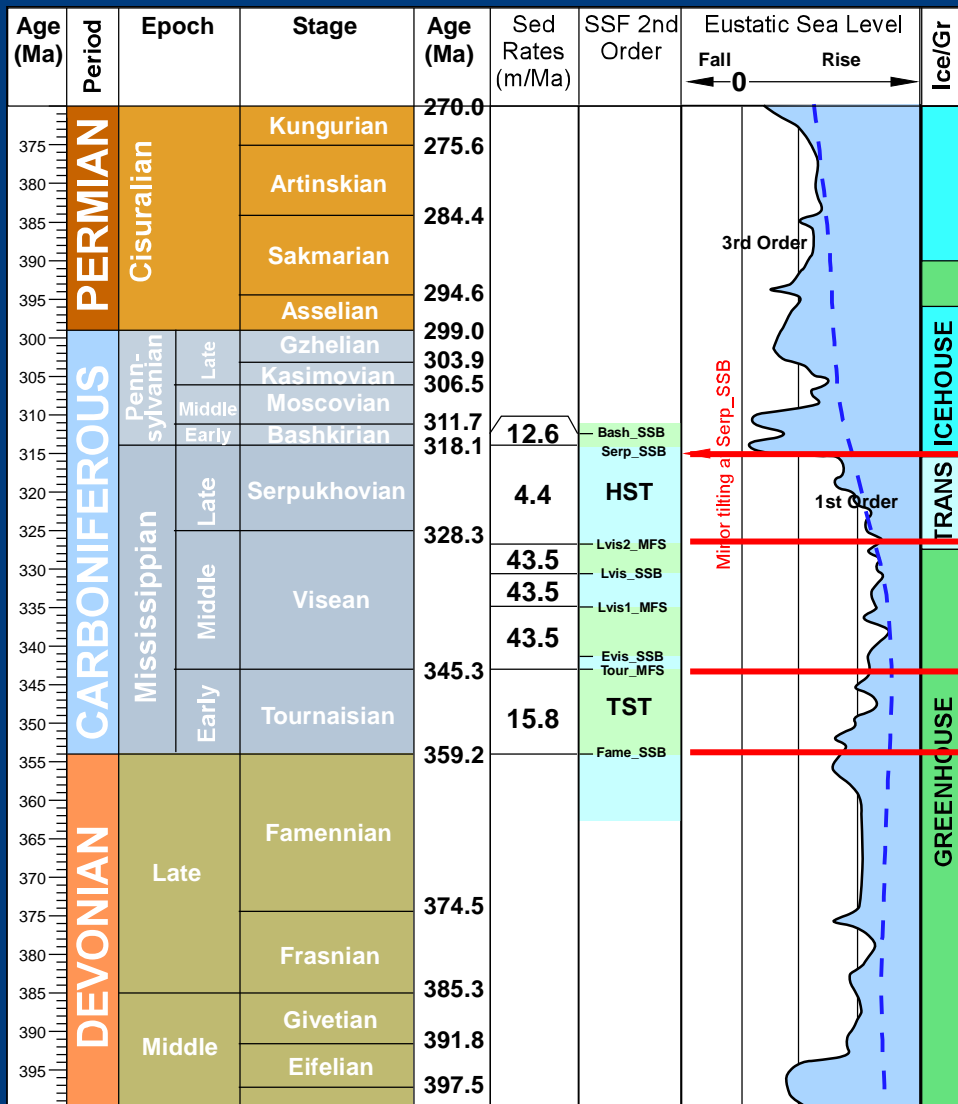
Isolation from Tethys Ocean and evaporite fill

Buzachi compressional phase (Hercynian)



Primorskaya rift phase with variable and increasing subsidence rates towards south

# Tengiz sequence stratigraphy framework and accommodation history



Aggradation

Predominantly progradation

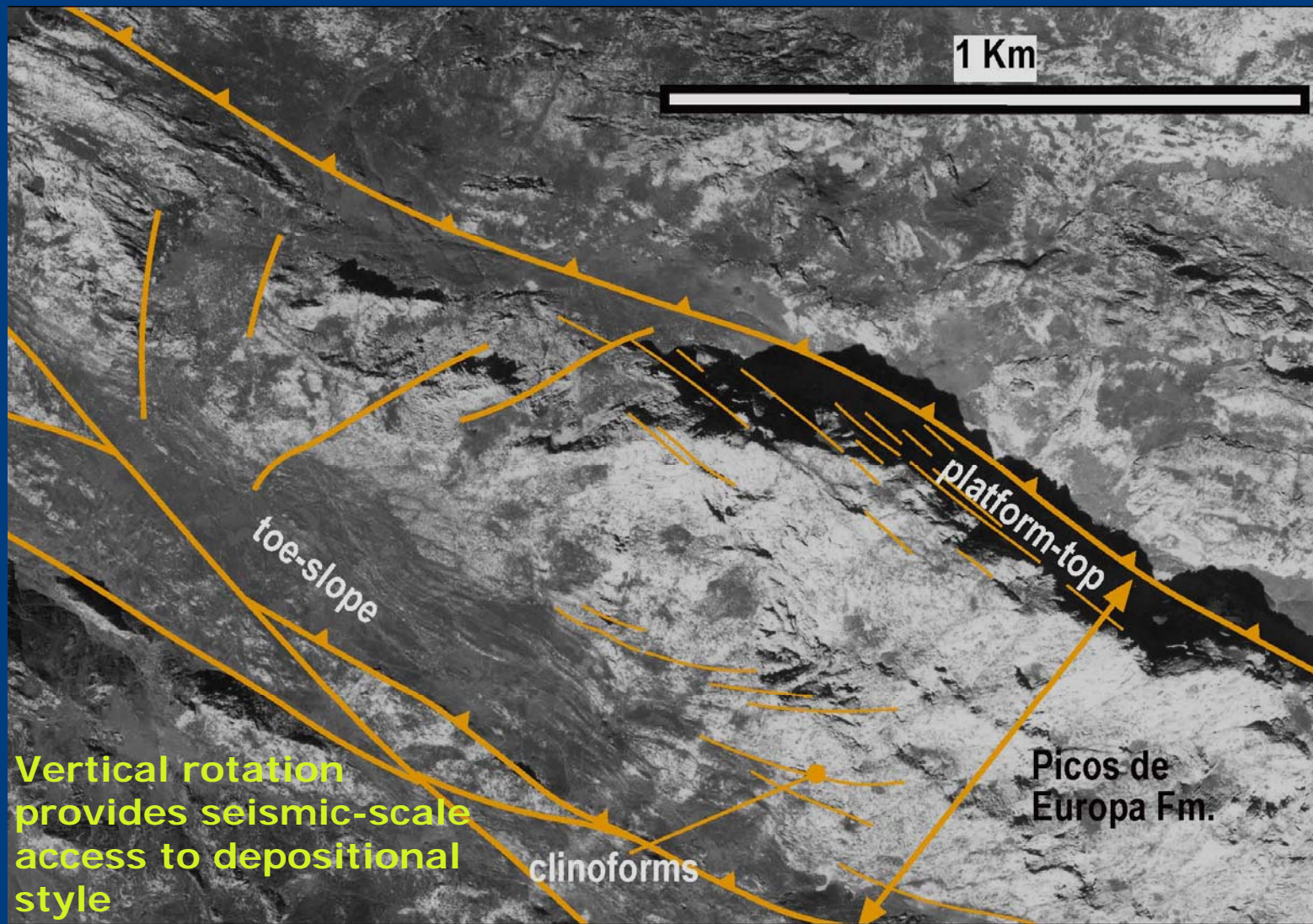
Rapid aggradation and backstepping

Moderate aggradation and backstepping

Mostly aggradation and minor backstepping

3<sup>rd</sup> order sequences with duration ~ 1 ma; 4/5<sup>th</sup> order parasequences with duration of ~0.2-0.4 ma

# Northern Spain: “intact” and thrust-top systems in a foreland basin setting

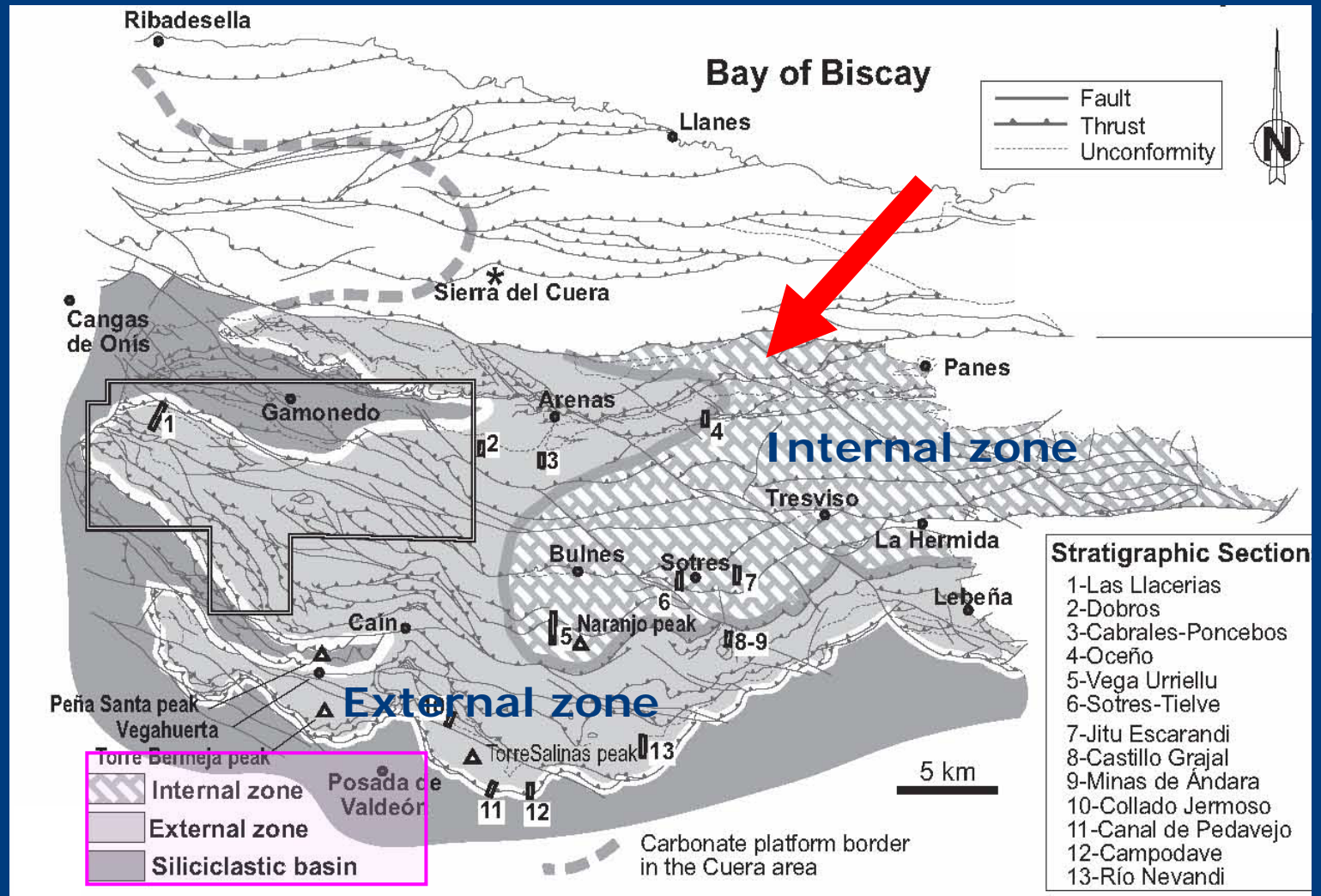


## Cantabrian Zone: Marine foreland basin

- Complex arc-shaped collision/deformation system
- Nucleation of Serpukhovian to Moscovian isolated platforms in foreland basin
- Highly variable subsidence rates caused by advancing thrust belt
- As a result, local drowning of buildups and variable depositional styles and internal geometries across basin
- Development of local basins at – and on top of frontal part of thrust belt
- Filled by (Moscovian-Ghzelian) alternating clastics and carbonate ramps and low relief platforms
- Angular unconformities and thickness variations reflect tectonic deformation rates but 3<sup>rd</sup> order (and higher) eustatic SL signal preserved

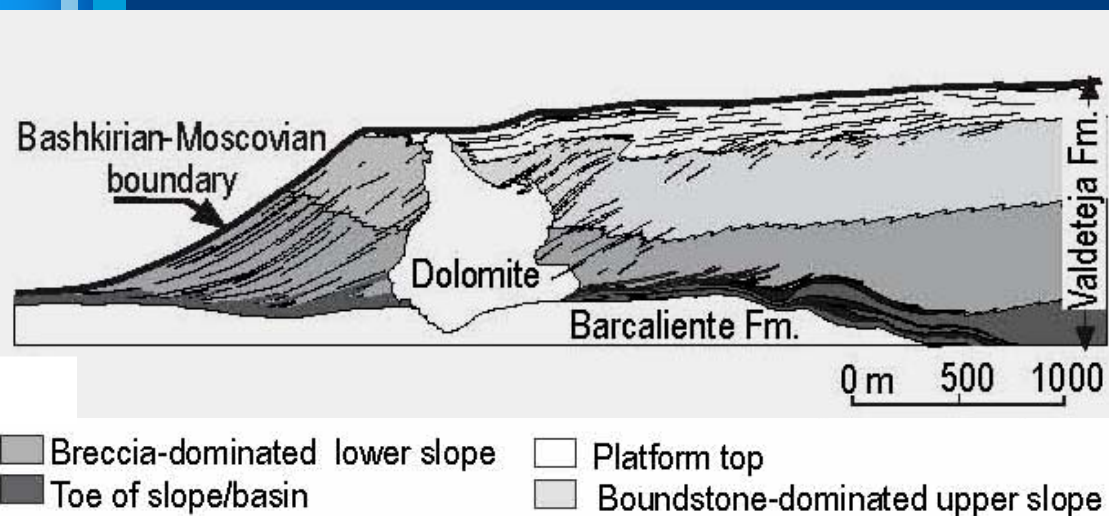


# Internal (proximal) vs External (distal) zones

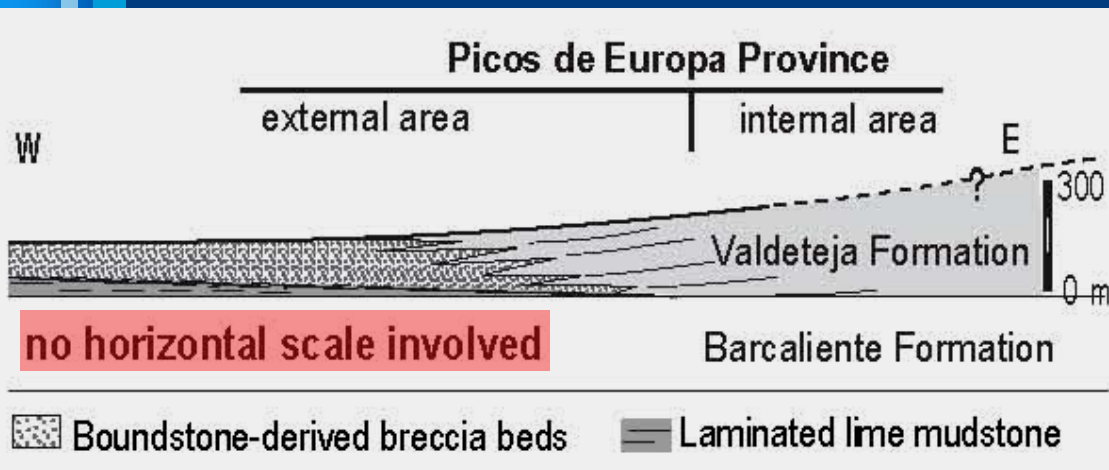




# Bashkirian

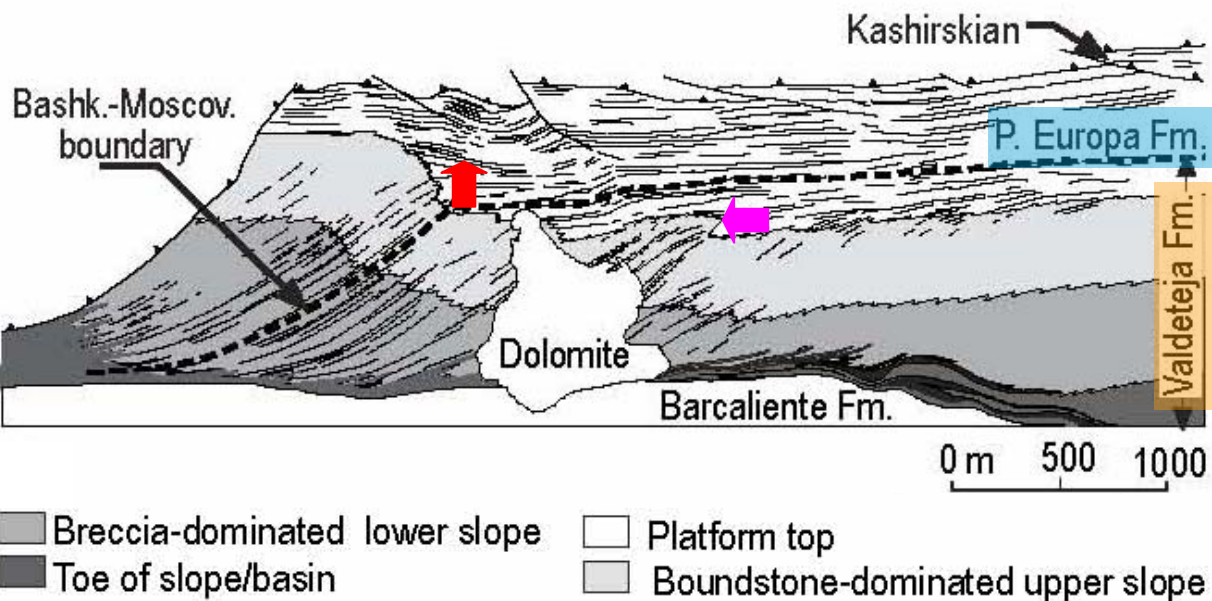


**Internal Zone:**  
 Evolution low- to high angle and high relief progradation (>10 km); no basinal input - starved

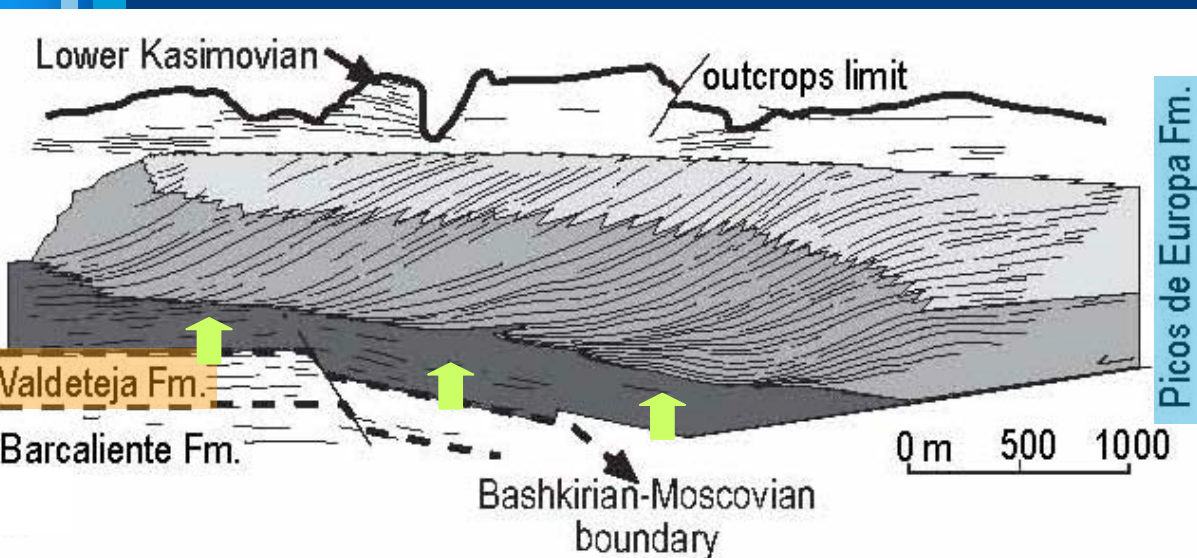


**External Zone:**  
 Low relief platforms and ramps

# Bashkirian-Moscovian transition

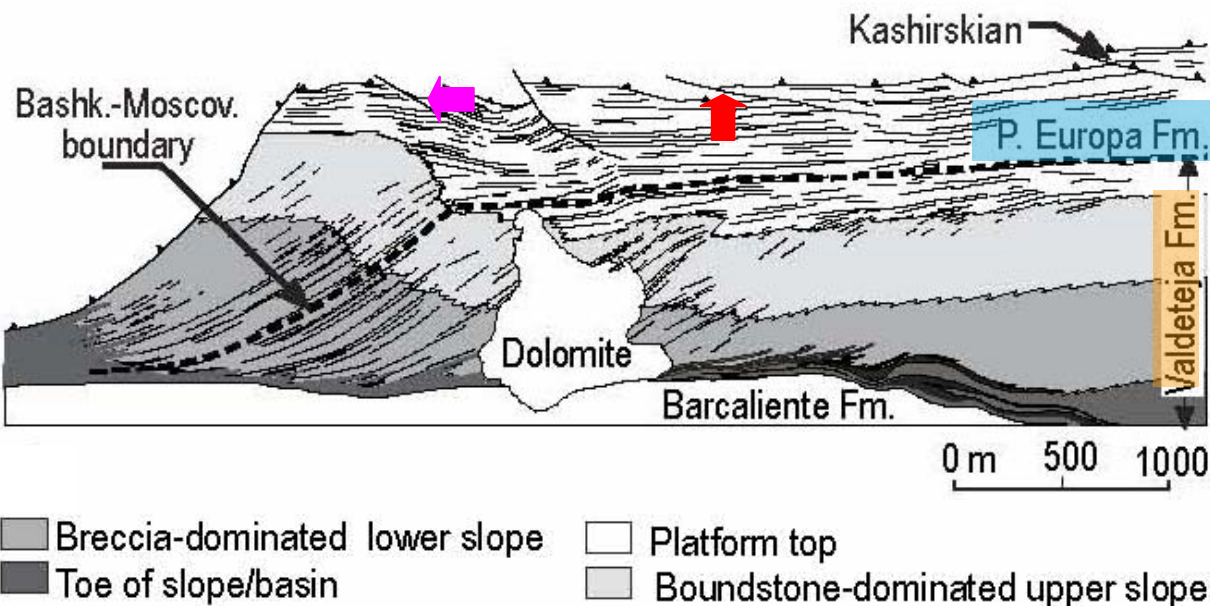


**Internal Zone:**  
Clastics partially fill starved basin modifying progradation from horizontal [←] to climbing [↑]

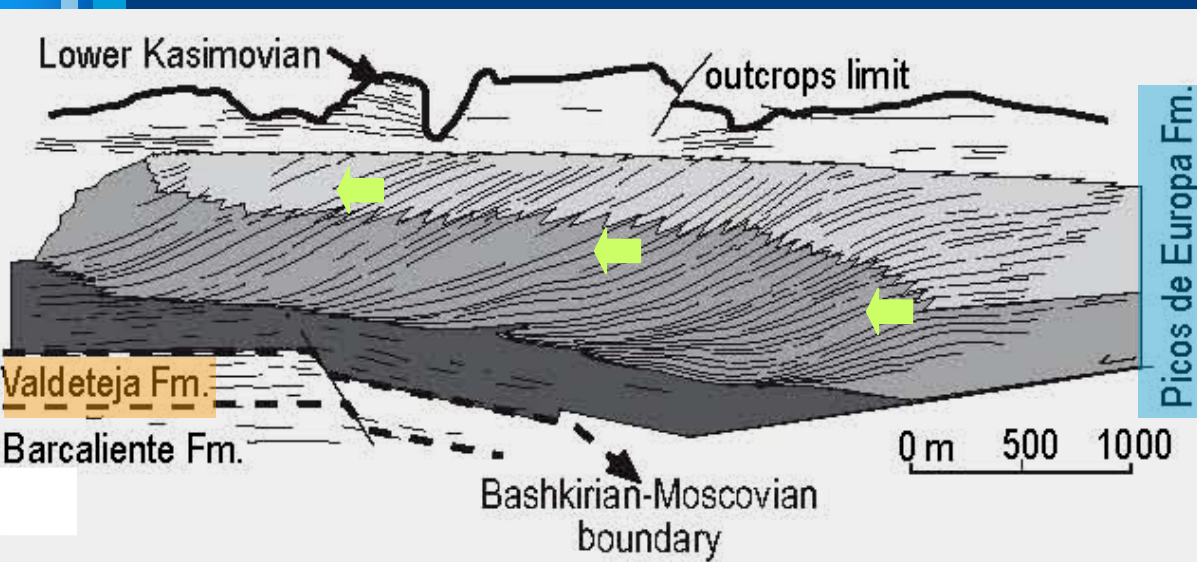


**External Zone:**  
Clastics draping low relief ramp [↑]

# Moscovian



**Internal Zone:**  
General aggradational growth style [↑] with minor progradational pulses [←]



**External Zone:**  
Formation of buildups; high rates (> 2 km/Ma) of platform progradation [←]

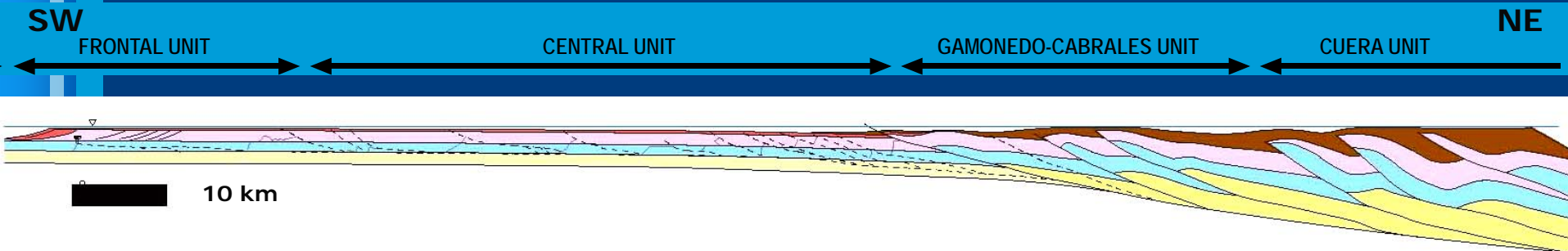
# Late Moscovian - Early Kasimovian

## ■ Internal Zone:

- Migration of thrust front towards the foreland incorporates carbonate platforms
- Rapidly subsiding basins develop in front and on top of the thrust wedge (thrust-top platforms)

## ■ External zone

- Carbonate sedimentation continuous





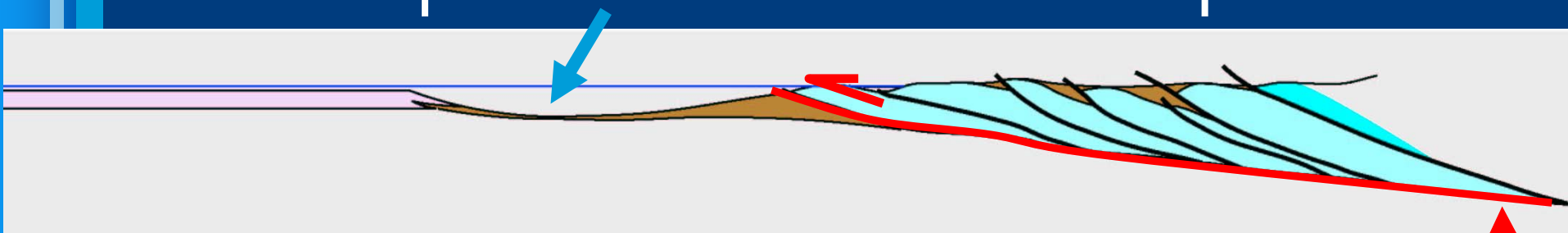
# Frontal basins and thrust-top platforms

## Mid-late Myachkovskian (late Moscovian)

External Zone:  
active platform  
growth

Basins developed at the frontal part of the  
thrust wedge

Internal Zone:  
deformation and  
uplifting of the  
carbonate shelf

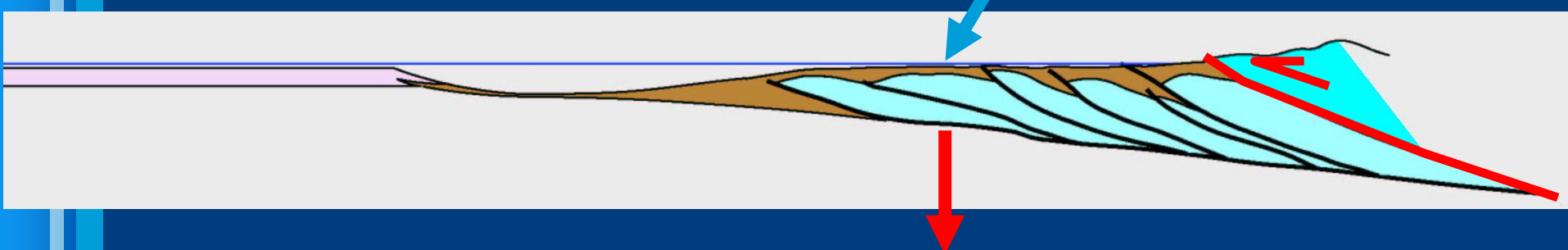


## Early Krevyakian (early Kasimovian)

External Zone:  
active platform  
growth

Flexural warping generated subsiding basins  
developed on top of the frontal part of the  
thrust wedge

Internal Zone:  
Continued  
thrusting





## Summary and Conclusions

- Northern Pricaspian has 46 BBOE and 4 supergiant isolated platforms in Paleozoic foreland basin settings
- Highly complex and variable system
- Both un- and deformed isolated buildups and thrust-top platforms have reservoir potential
- Cantabrian Zone (Spain) provides well-studied outcrop analogs of arc-shaped system
- Spain provides mosaic of carbonate buildup styles in space and time and as a result of tectonic deformation and eustatic sea level