Timing and Mechanism of the Opening of the Western Black Sea Basin*

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Abstract

The Black Sea consists of two main basins separated by a continental ridge. The western basin is oceanic in nature, while the eastern basin is believed to have a thinned continental basement. Data for the timing and mechanism of opening of both basins come mainly from the geology of the surrounding regions, but are very limited from the basins itself. In this presentation, the timing and the mechanism of the opening of the Western Black Sea Basin based on data from sedimentary basins of the Western Black Sea region, Turkey, will be discussed.

The southern passive margin of the oceanic Western Black Sea Basin consists of two tectonic units, the Istanbul Zone in the west and the Sakarya Zone in the east. These tectonic units are delimited by a fundamental, north-south Araç-Daday shear zone. The Istanbul Zone is covered by a sedimentary succession deposited in a southerly-deepening continental margin during the Early Cretaceous. This margin was bisected lengthwise during the Maastrichtian forming the Zonguldak Basin in the northwest and the Ulus Basin in the southeast. Both of these basins were deformed in the Early Cenozoic. To the east of the Araç-Daday shear zone, the northerly-deepening Sinop Basin dominates the architecture of the Pontides in the north, during the Early Cretaceous. It began forming by extension in the Barremian and was destroyed by a single phase but progressive north-south compression in the Late Eocene-Oligocene. After the juxtaposition of the Central Pontides and the Istanbul Zone during the Cenomanian, an E-W trending extensional magmatic arc has been established on these sedimentary basins in response to northward subducting Neo-Tethys to the south. Back-arc and intra-arc extension gave rise to extensive normal faulting period and thinning of the continental crust in the Western Black Sea region. During the Middle-Late Santonian, arc magmatism stopped and the entire region was covered by a deep marine. This period corresponds to the breaking-up of the continental crust and starting of sea-floor spreading in the Western Black Sea Basin.

The arc magmatism started again during the Campanian, and ceased at the beginning of the Maastrichtian. At the same time, the Neo-Tethys Ocean closed to the south. After the closing of this ocean, a compressional regime started to affect the Western Pontides. This compressional regime is still active in the eastern part of the Western Black Sea region while it was replaced by an extensional period during the Middle Miocene in the western part.

Timing and Mechanism of the Opening of the Western Black Sea Basin

Data from the Pontide sedimentary basins

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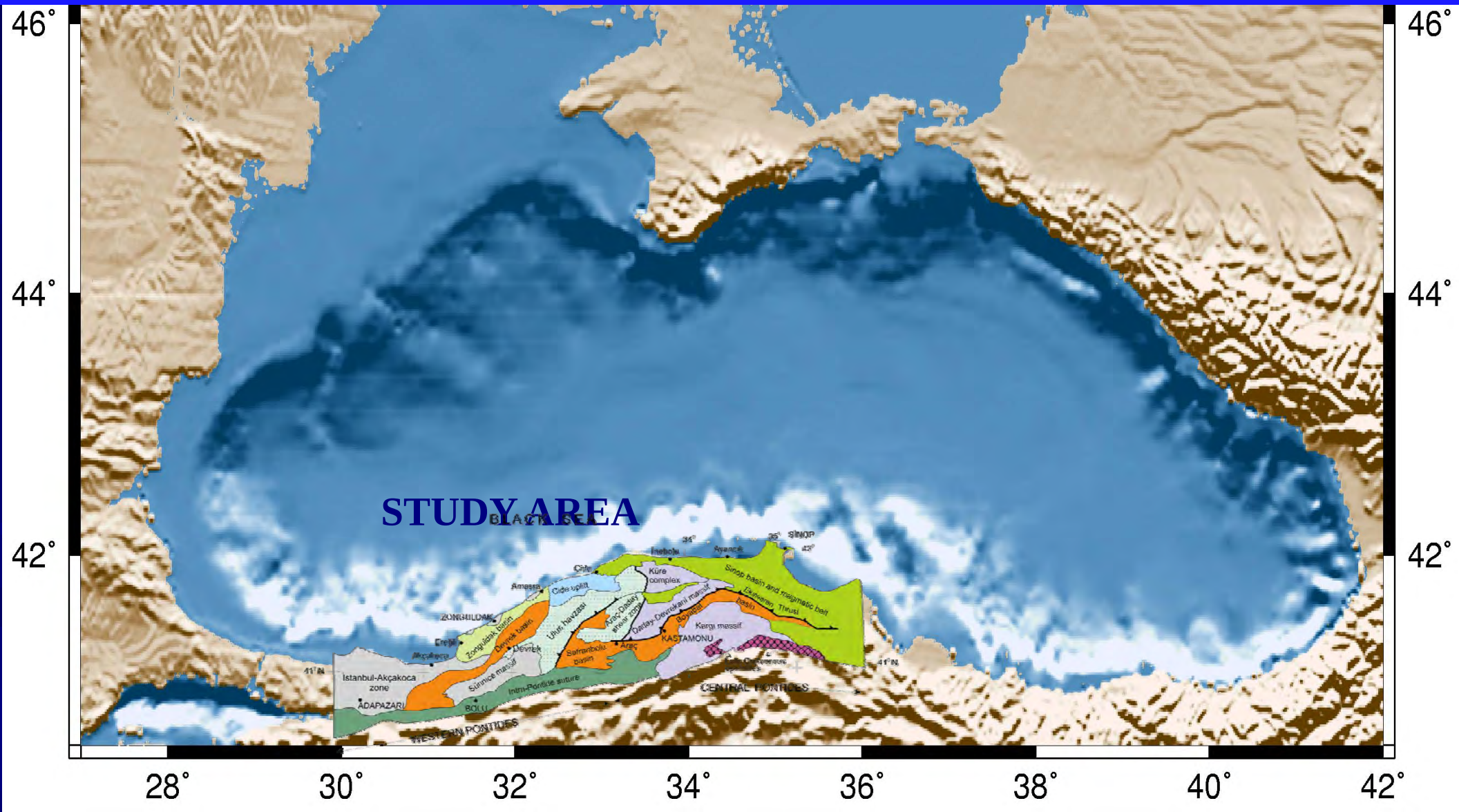
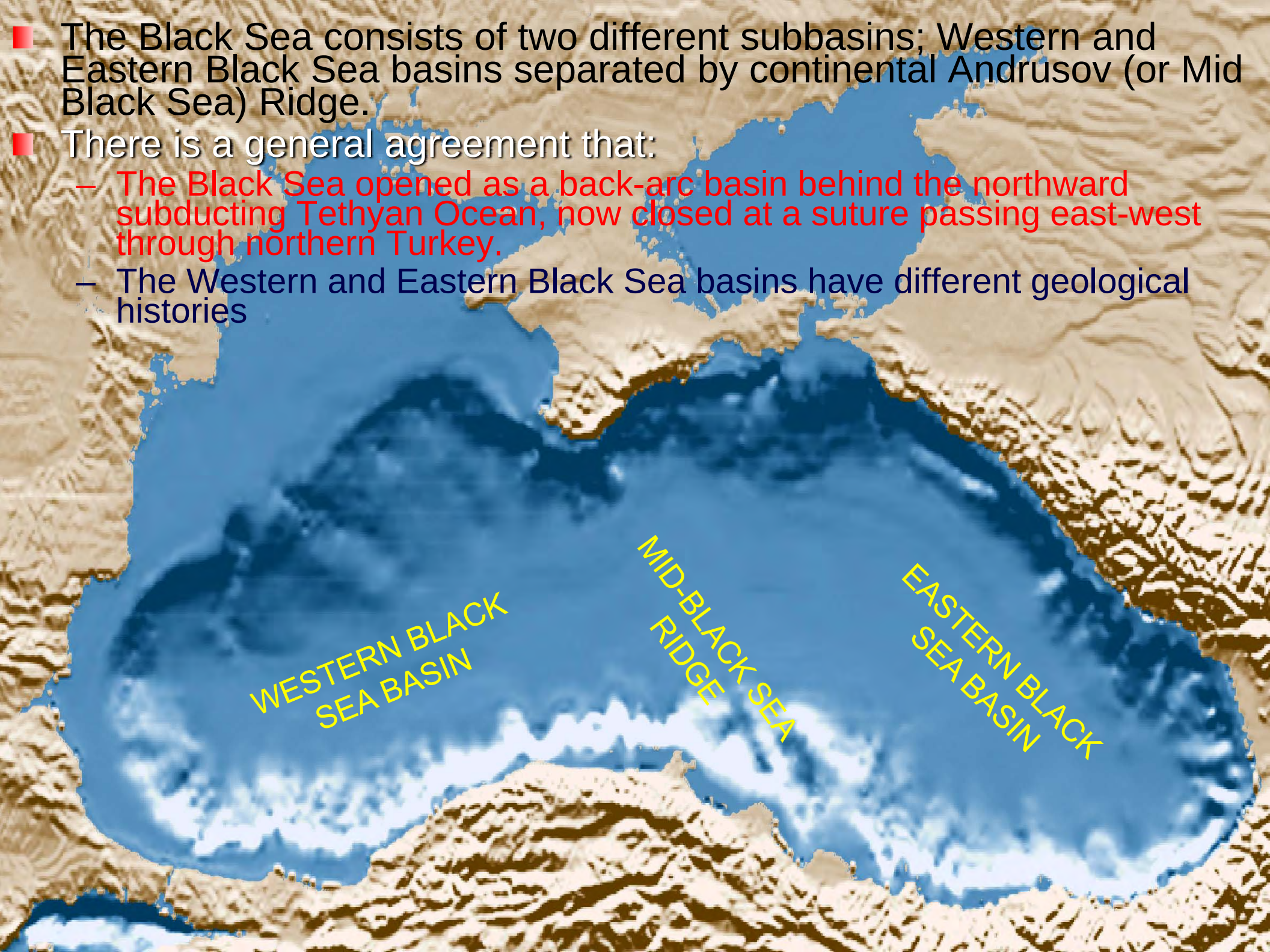
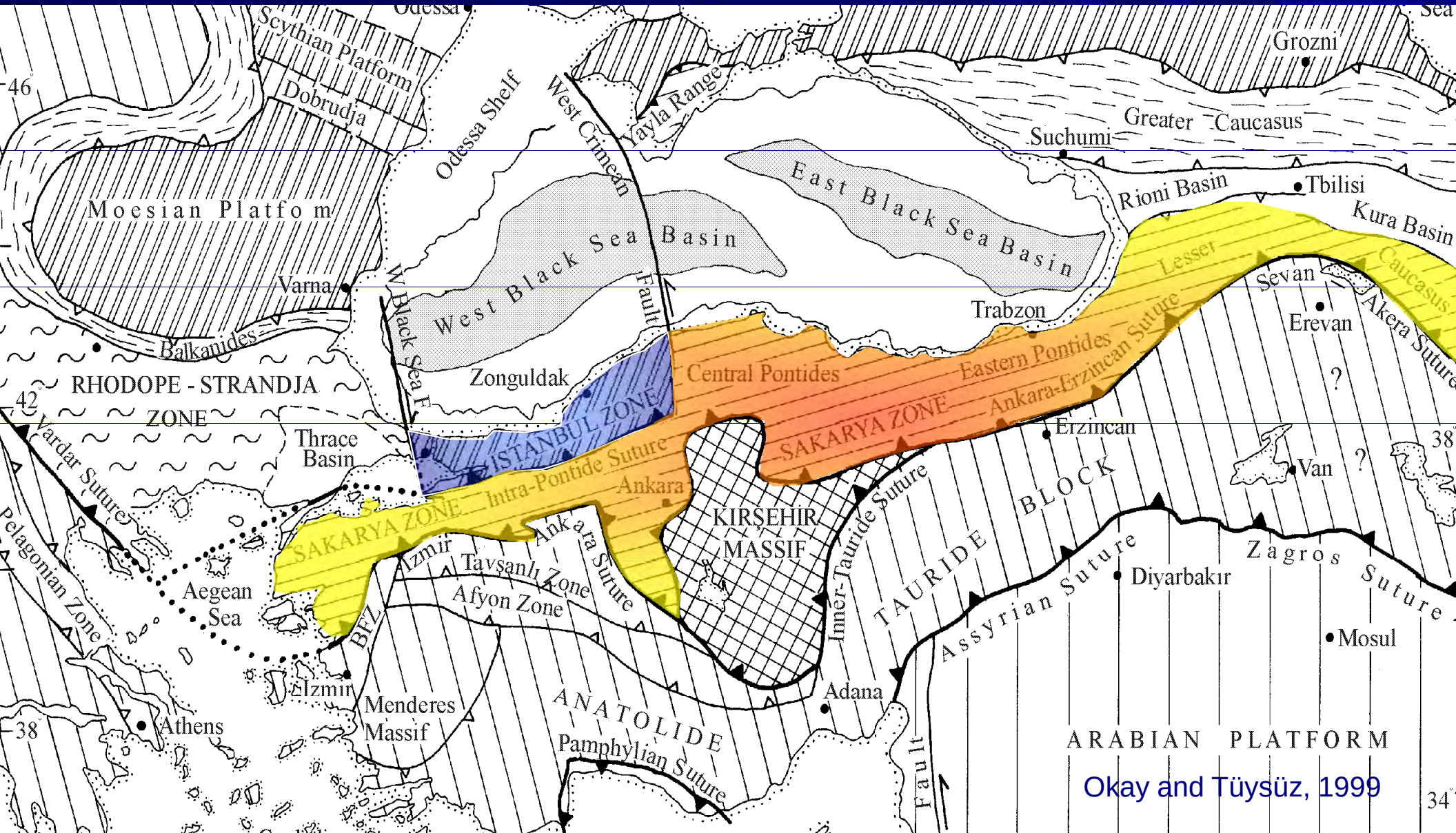
- Goal of this presentation:
  - Briefly describe tectonic settings of the Western Pontides
  - Present some stratigraphic data,
  - Discuss the timing and mechanism of opening of the Western Black Sea Basin



- The Black Sea consists of two different subbasins; Western and Eastern Black Sea basins separated by continental Andrusov (or Mid Black Sea) Ridge.
- There is a general agreement that:
  - The Black Sea opened as a back-arc basin behind the northward subducting Tethyan Ocean, now closed at a suture passing east-west through northern Turkey.
  - The Western and Eastern Black Sea basins have different geological histories

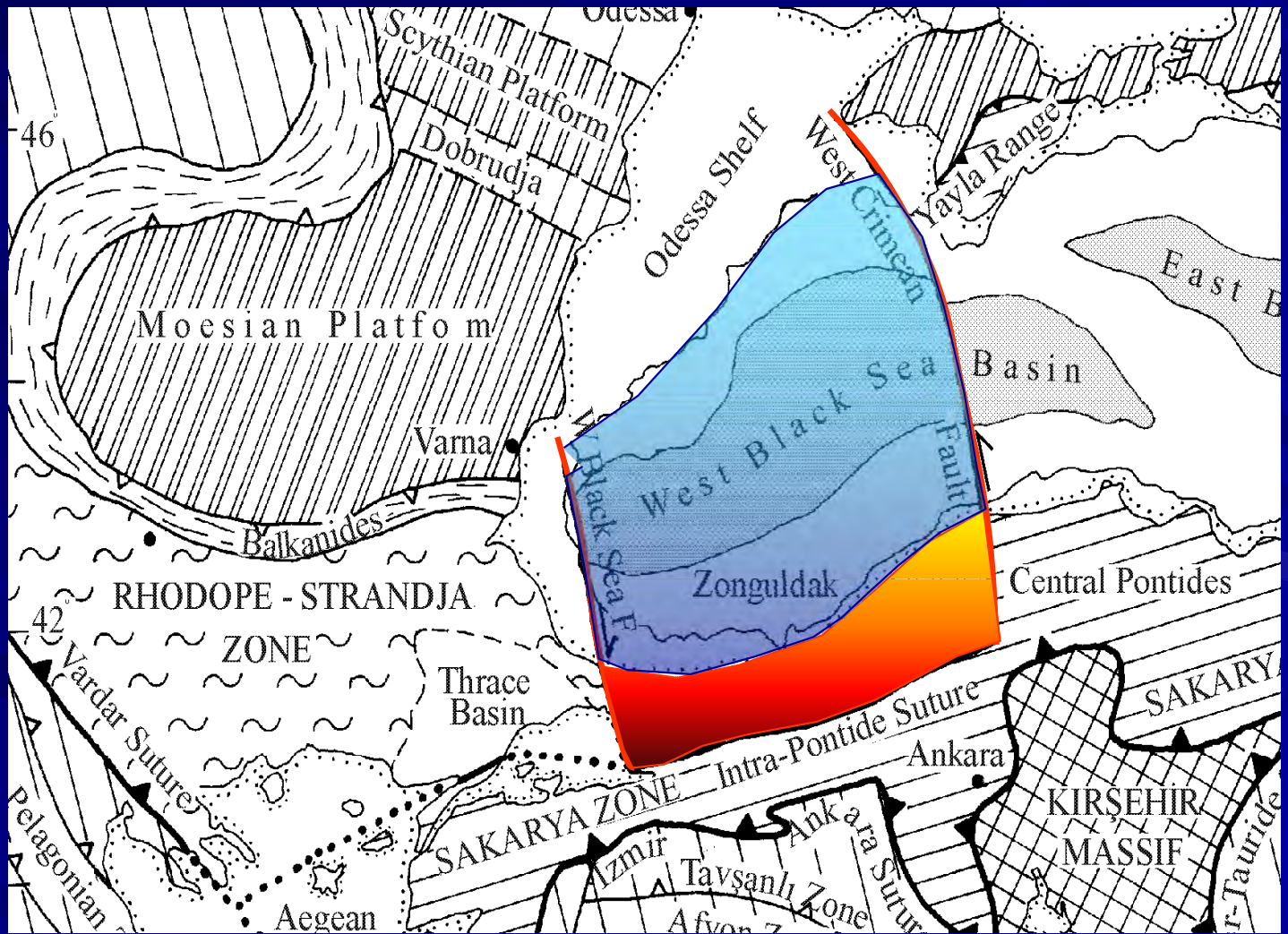


- The Pontides can be subdivided into two different parts:
  - The Istanbul Zone (Western Pontides)
  - The Sakarya Zone (Central and Eastern Pontides)

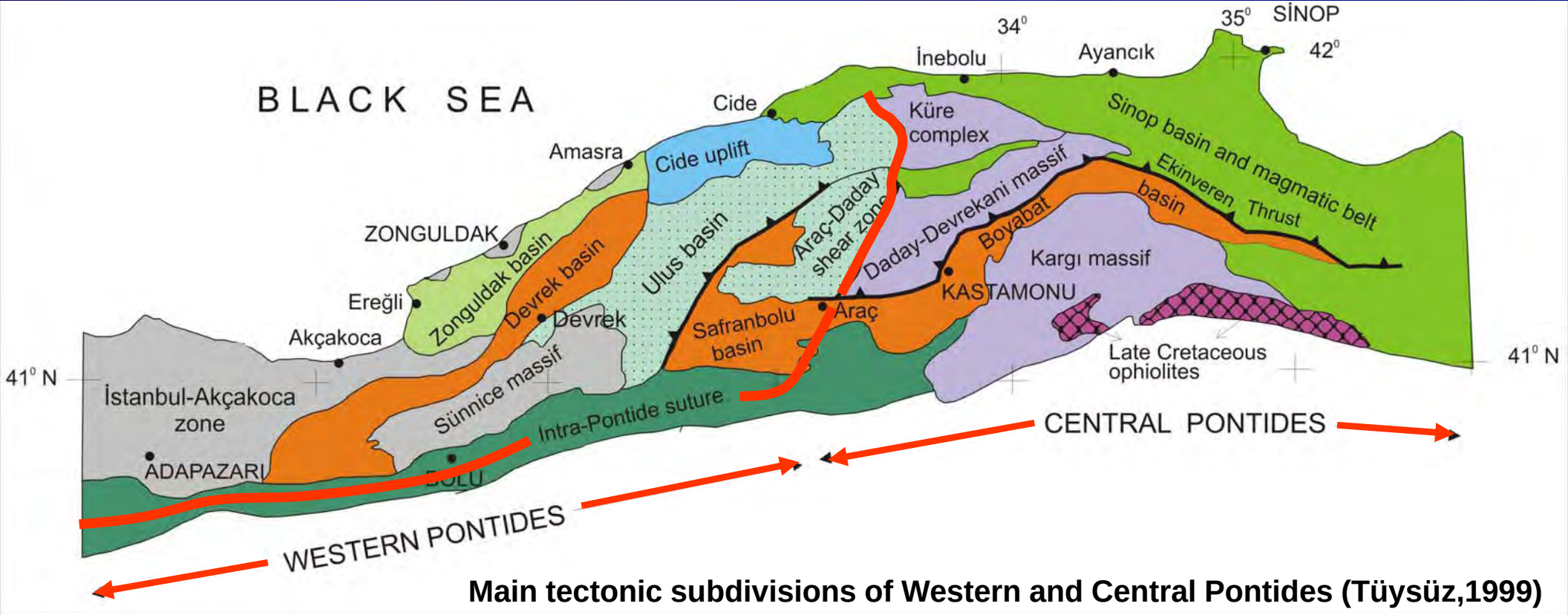


Okay and Tüysüz, 1999

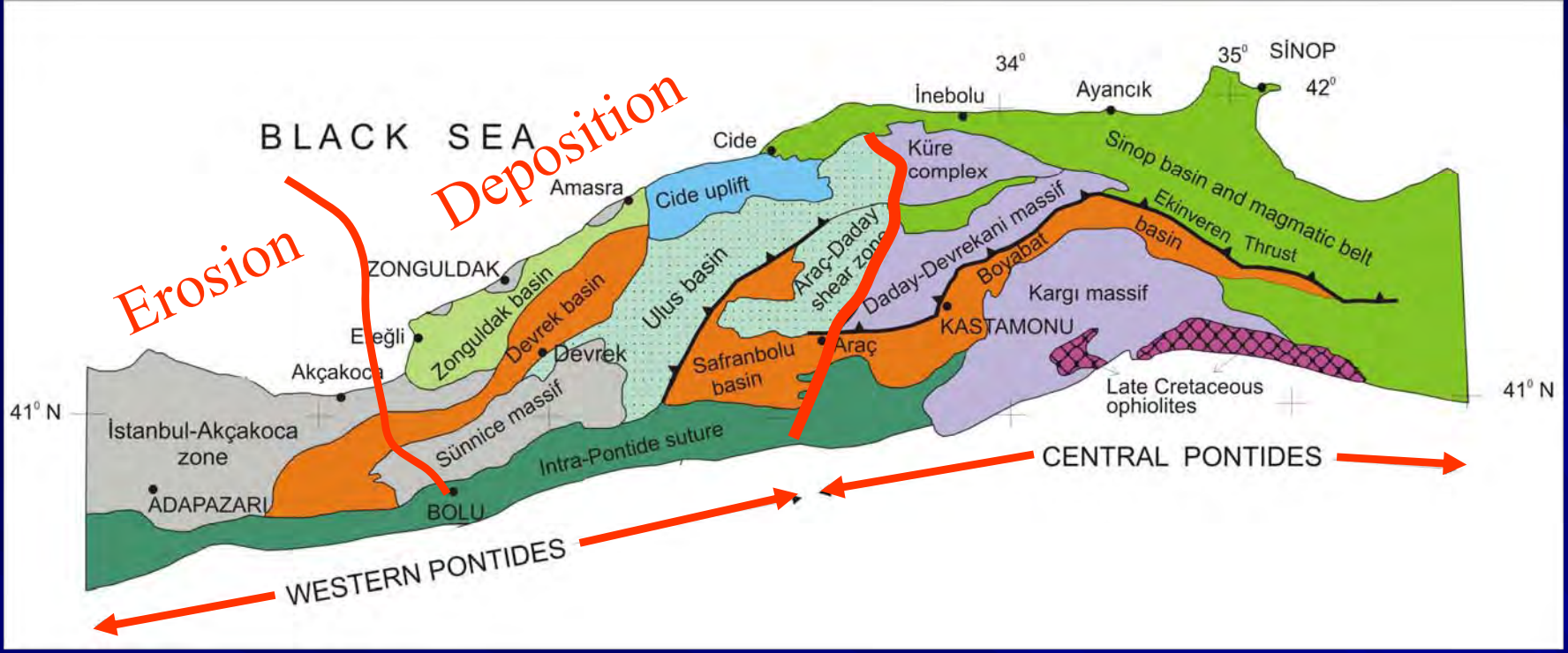
- Okay et al. (1994) proposed that the İstanbul Zone was located to the south of the Odessa Shelf until the Early Cretaceous.
- During the Early Cretaceous, this continental fragment rifted off from Eurasia and drifted southward along two transform faults, and placed its present position during the Early Eocene.
- The western basin opened behind this southward moving continental fragment.



- The Istanbul and the Sakarya zones have different Paleozoic-Jurassic units, showing different evolutionary trends
- These two zones are separated by the Intra-Pontide suture and its eastern continuation, the Araç-Daday shear zone
- Late Santonian and younger sediments commonly deposited on both zones indicating that these two zones juxtaposed just before the Santonian (Cenomanian ?).



Main tectonic subdivisions of Western and Central Pontides (Tüysüz,1999)



- Western part of the Istanbul Zone was an erosional area during the Jurassic-Early Cretaceous period.
- The Zonguldak and the Ulus basins developed on the eastern part of the Western Pontides.
- Late Barremian-Cenomanian sediments of these basins reflect the geological records of opening of the Western Black Sea Basin
- Turonian-Campanian units of these basins reflects the development of the oceanic spreading in the Western Black Sea Basin

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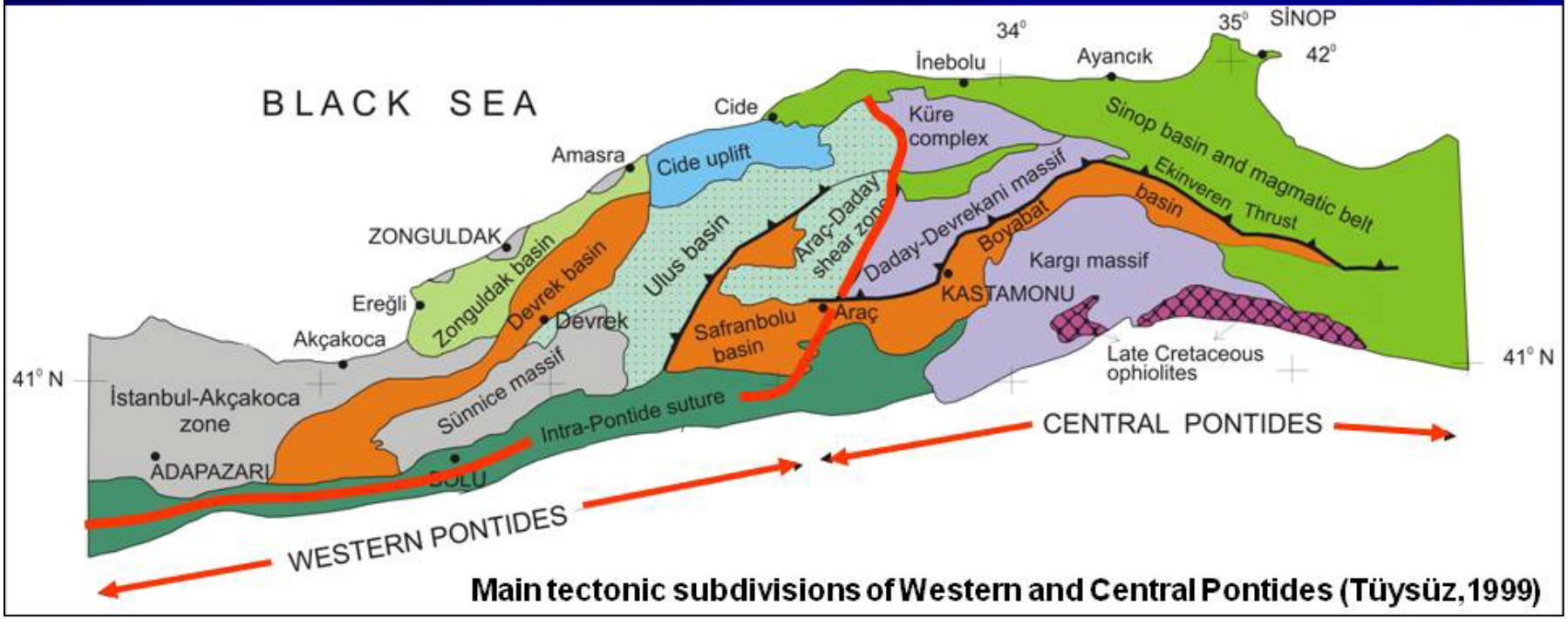
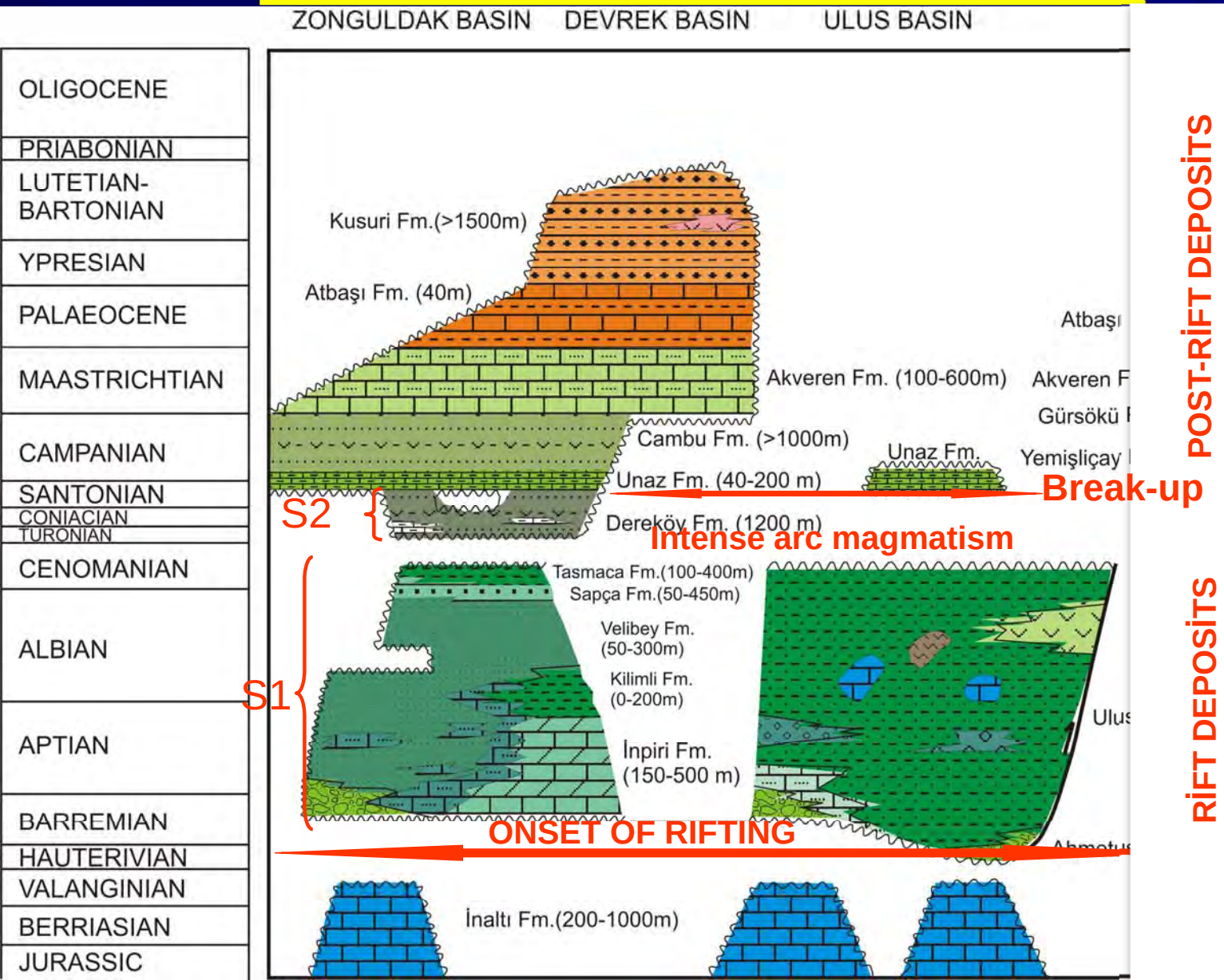


Main tectonic subdivisions of Western and Central Pontides (Tüysüz,1999)

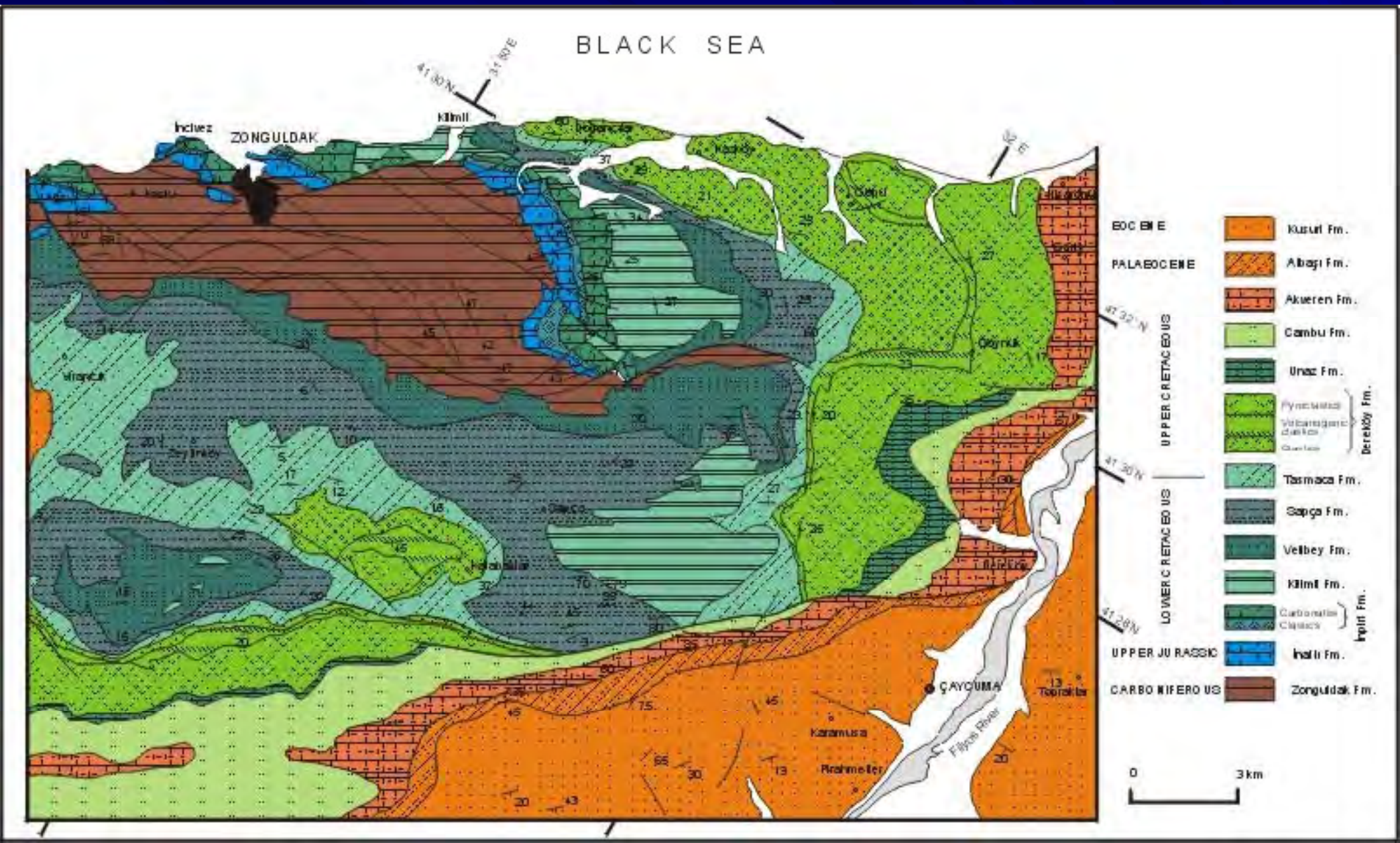
Notes by Presenter: The mechanism of this juxtaposition is out of scope of this presentation

STRATIGRAPHY of the WESTERN PONTIDE BASINS

WESTERN PONTIDES



GEOLOGY MAP OF THE ZONGULDAK BASIN

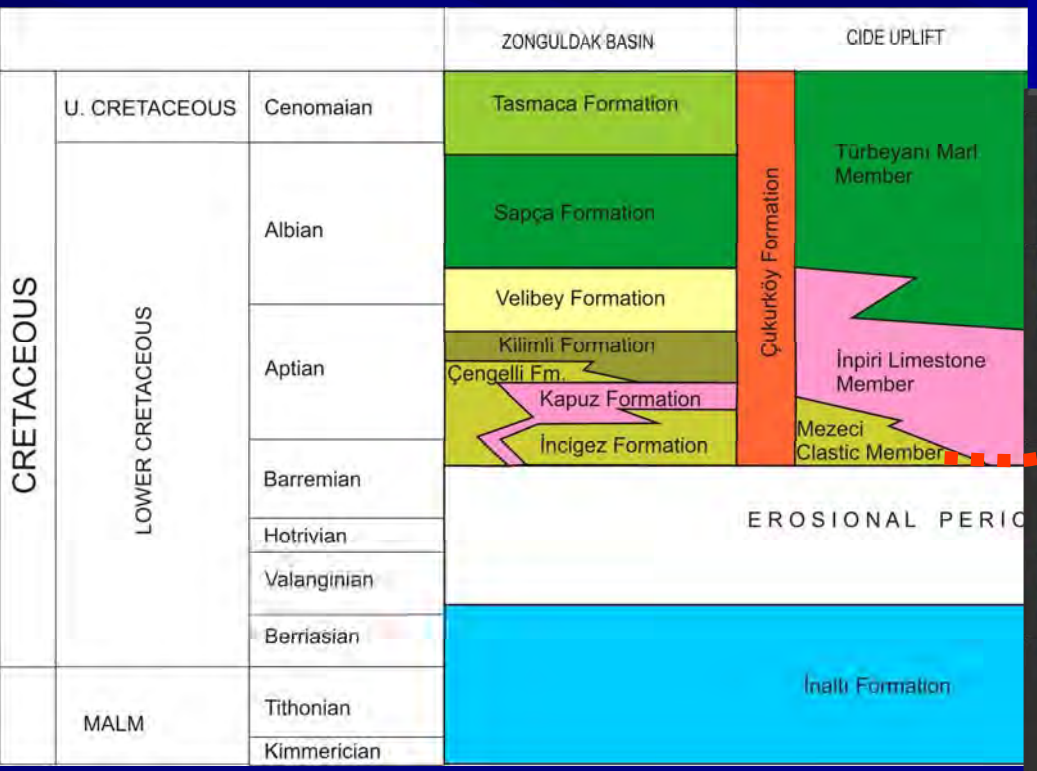


STRATIGRAPHY OF THE ZONGULDAK BASIN and THE CIDE UPLIFT

- Basin stratigraphy consist of;
  - Late Barremian-Cenomanian sediments :
    a) Opening of the basin
    b) Establisment of a short-lived carbonate platform
    c) Downwarping of the Platform
  - Upper Cretaceous volcanics and volcanoclastics:
    a) Establishment of a magmatic arc
    b) Rifting of the magmatic arc
    c) Beginning of the oceanic spreading in the Western Black Sea Basin

THE ZONGULDAK BASIN

The basin sequence starts with an Upper Barremian-Lower Albian continental-shallow marine clastics (Mezeci-Incigez) and grades upward into a carbonate succession (İnpiri-Kapuz fms).



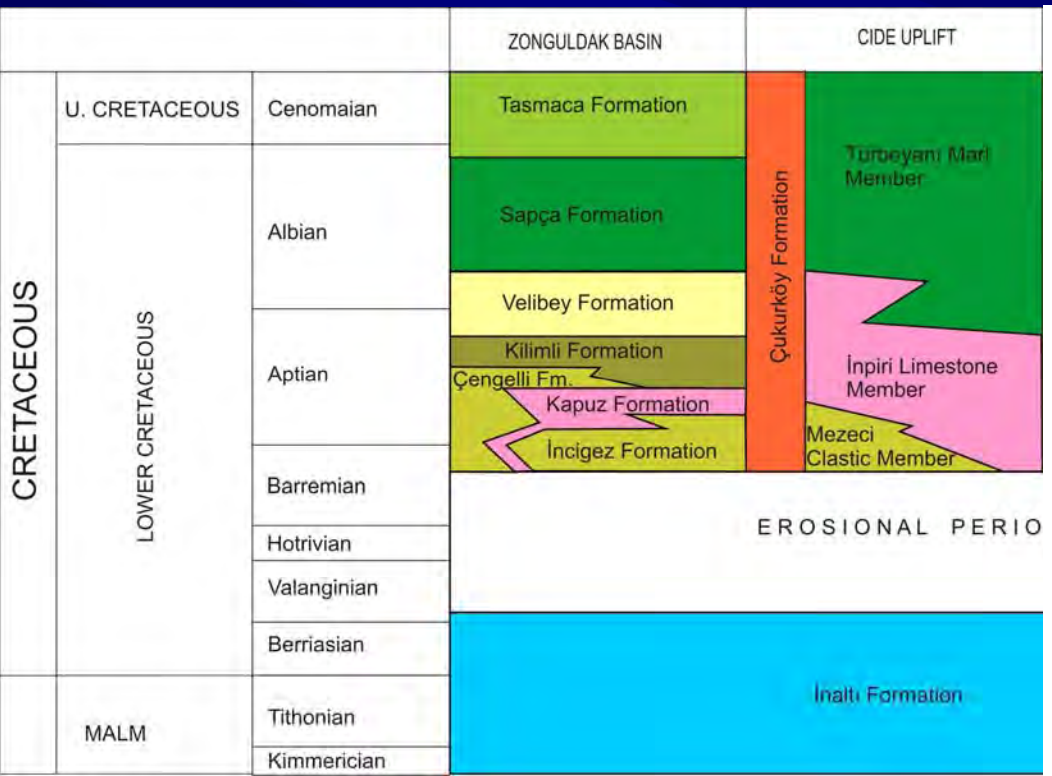
- Deposition of the basal part of the basin fill was mainly controlled by normal faults, which probably indicate the opening of the basin during the Late Barremian.

- Clasts within this basal part indicate that erosion started from the Upper Jurassic platform carbonates at the base and reached down to the Palaeozoic substratum.

- These stratigraphic data also support the fault-controlled depositional model owing to progressive downward erosional destruction of uplifted block edges.

Establishment of the Carbonate Platform

- During the Late Barremian- Early Aptian (Bedoulian), a carbonate plaform established between Zonguldak and Kurucaşile
- Facies properties indicate that this platform was facing to the Western Black Sea Basin in the north
- During the Late Bedoulian this platform drowned and deepened in the north and the shallow water carbonates are replaced by ammonite-bearing marly sediments
- In the southern part of the plaform the shallow carbonates first replaced by fluvio-deltaic deposits then by siliciclastic turbidites.



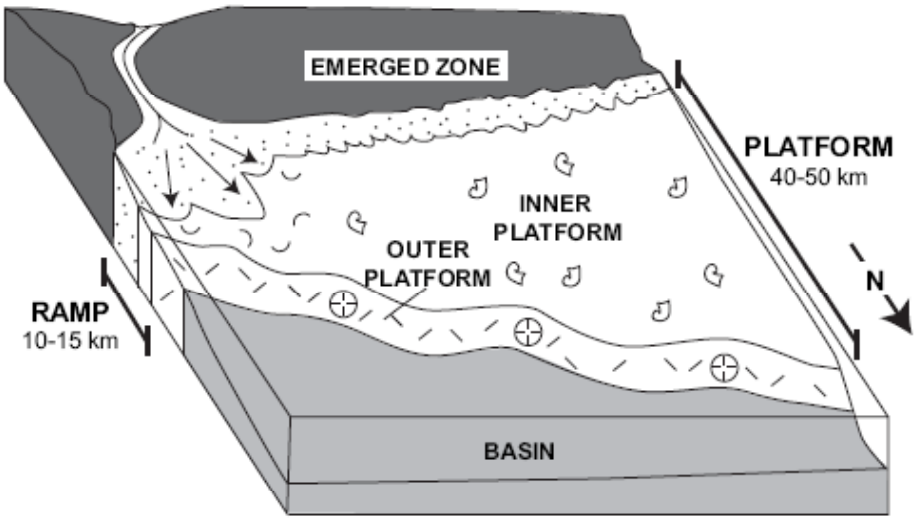
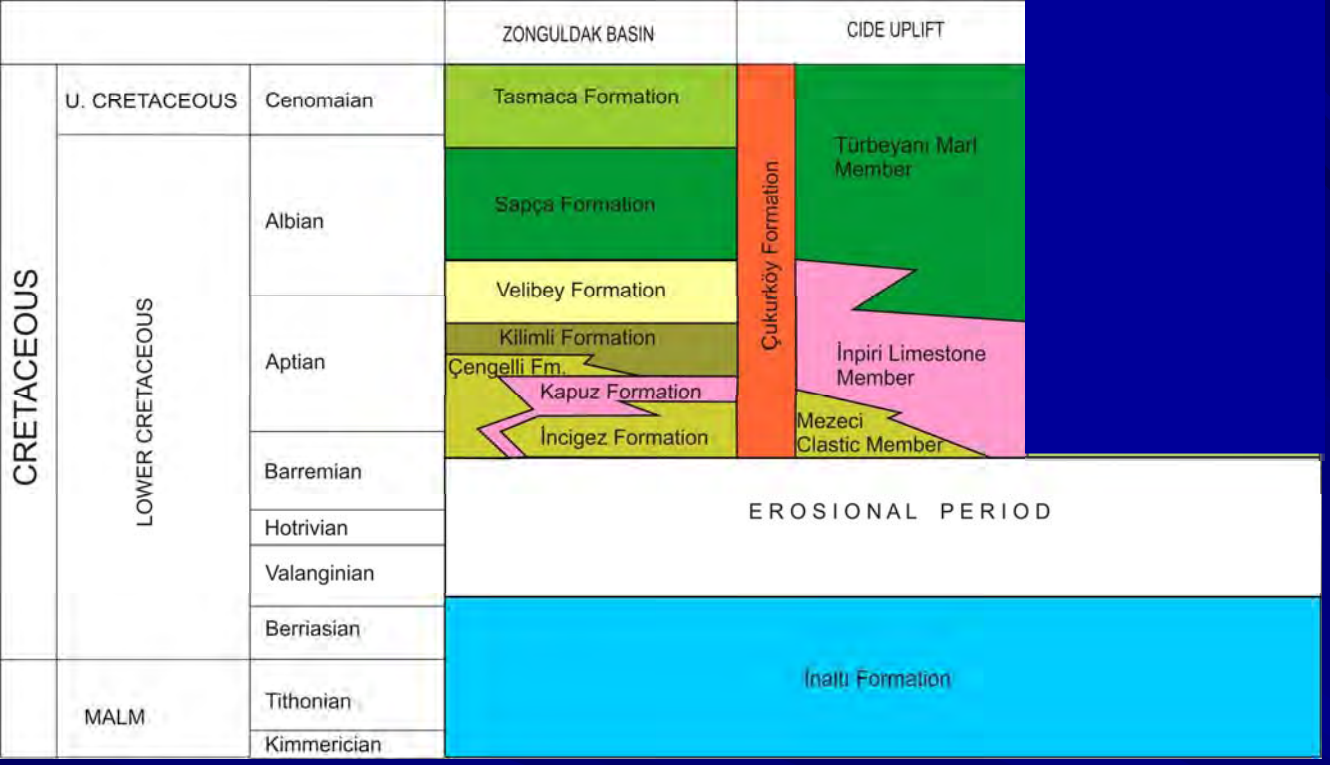


Fig. 7. Palaeogeographic regional reconstruction of the Zonguldak-Amasra area showing the spatial reduction of the western carbonate platform grading to the eastern ramp flanking an emerged zone, and the inferred location of the adjacent basin.



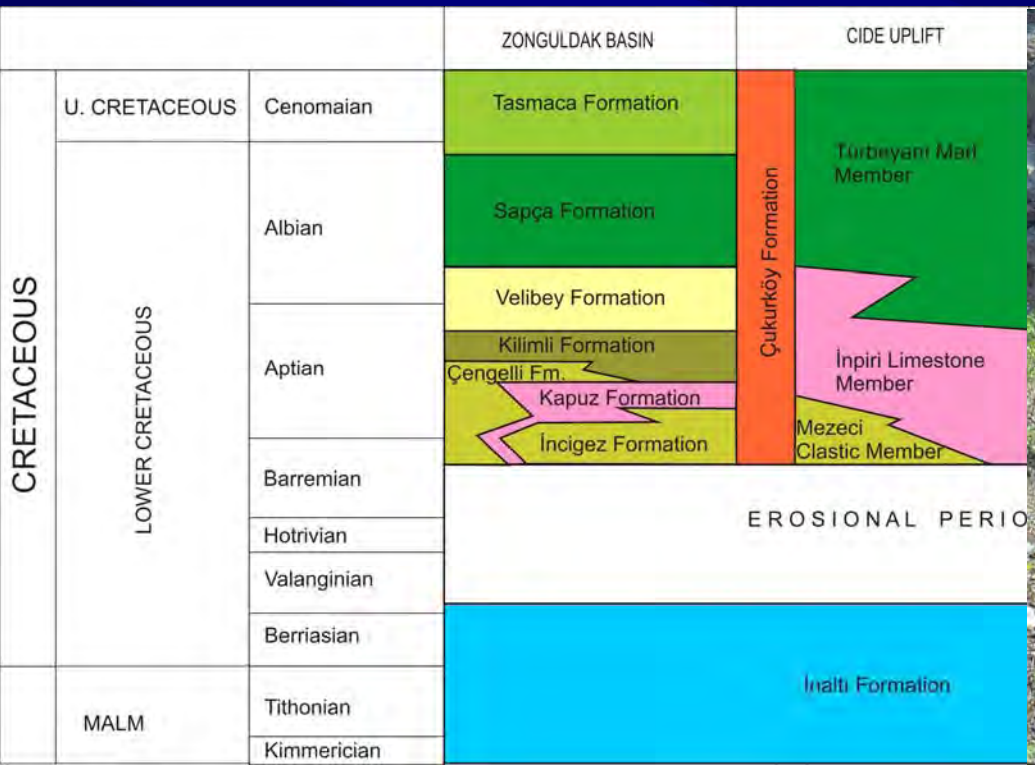
Between Amasra and Cide platform carbonates grade upward into dark Ammonite-bearing Türbeyani marls, Aptian-Albian in age

In the south of Zonguldak, the Velibey formation of Aptian consists mainly of cross-bedded quartz arenites with conglomerate and bioclastic limestone interbeds deposited in a shallow marine environment.

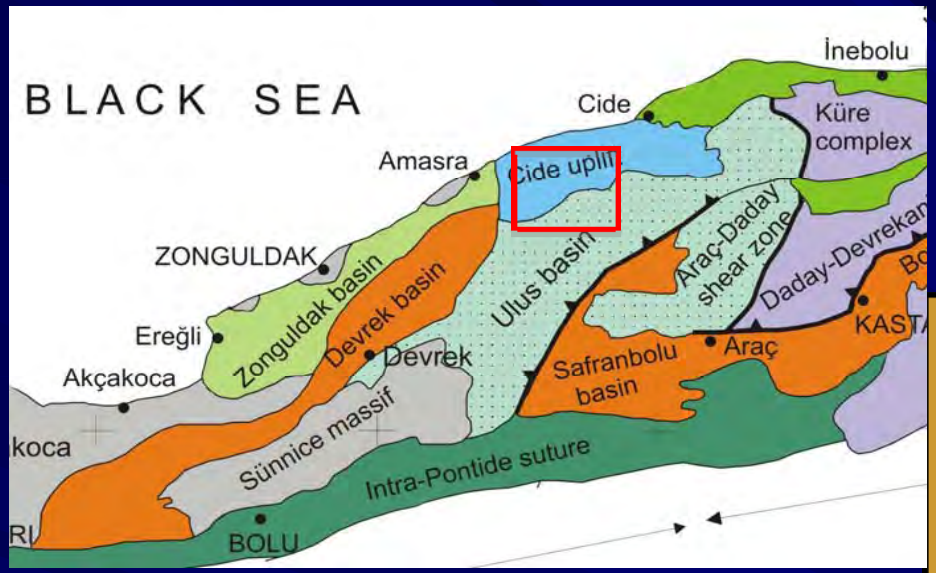
The Sapça formation of Albian age is an alternation of turbiditic sandstones, marls, sandy limestones and shales with abundant glauconite.

The Tasmaca formation of Cenomanian age comprises of organic-rich shales and clayey limestones deposited in a deep marine environment. There are also some exotic blocks in the upper part of the formation as boulder beds, channel fills or individual blocks.

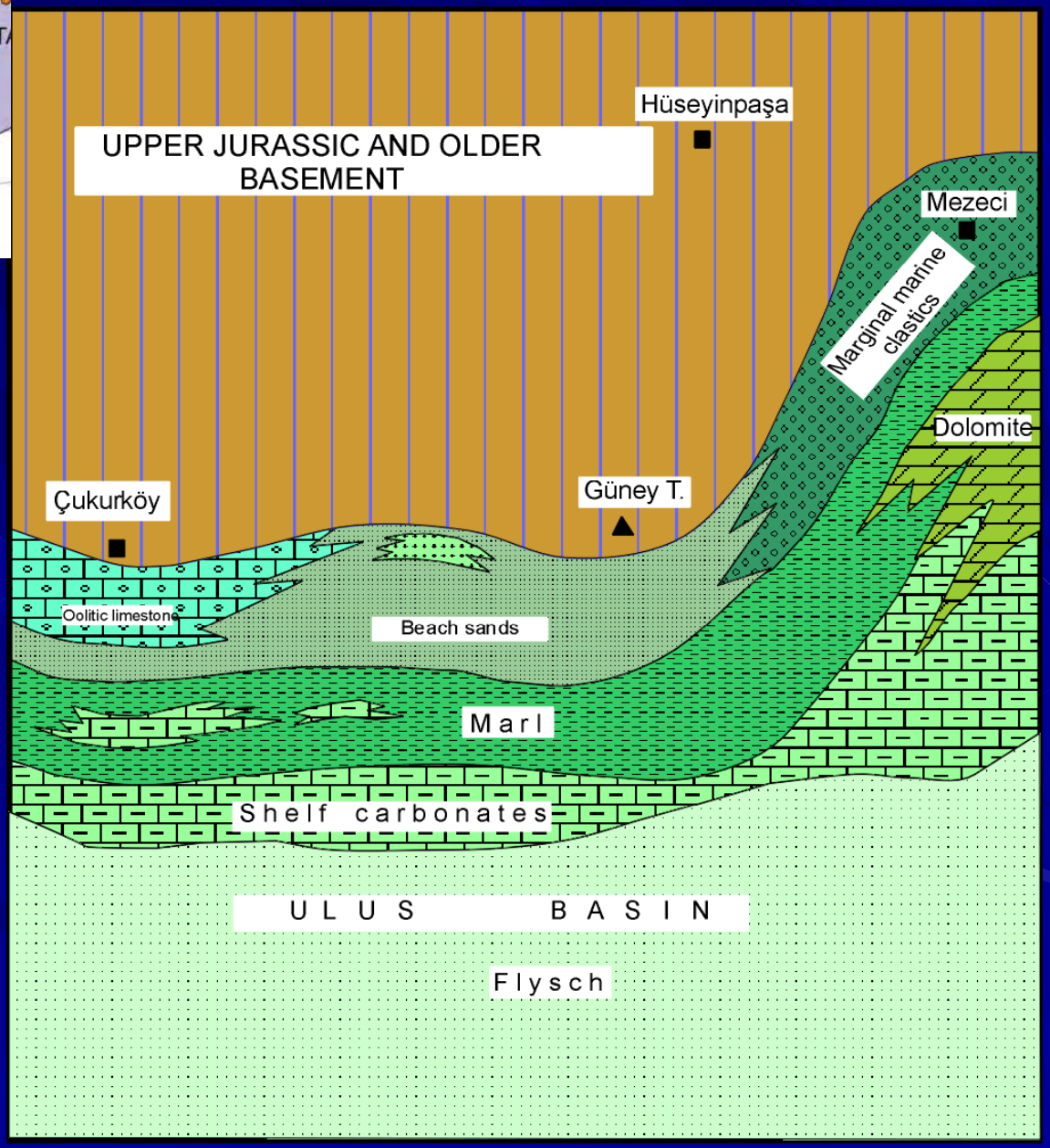
The Türbeyanı Marls are the equivalent of Sapça and Tasmaca formations. All these formations imply the deepening of the basin between Albian to Cenomanian.



Cide Uplift

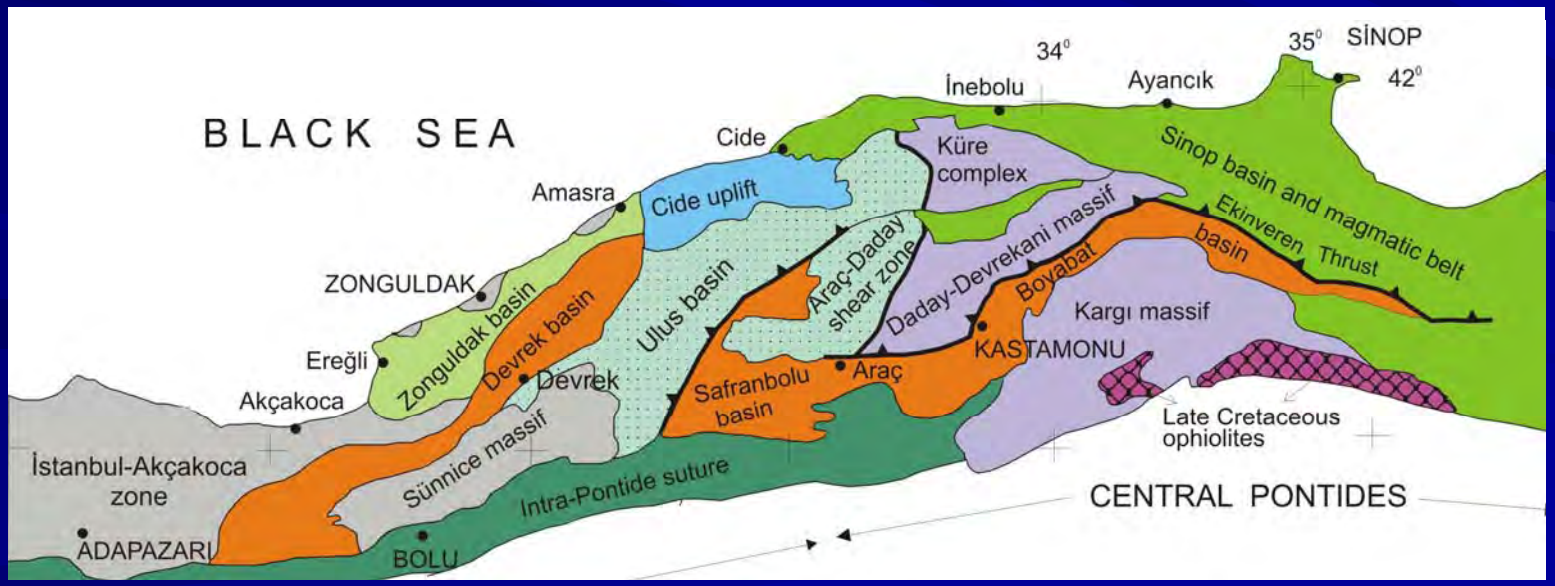


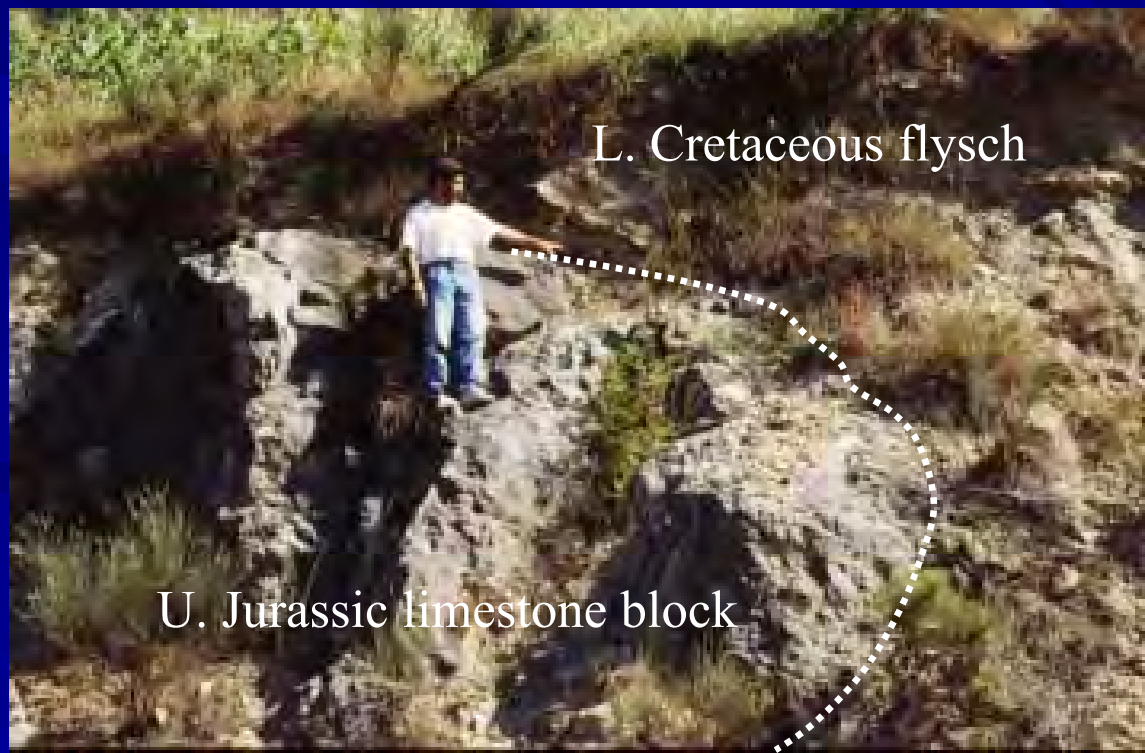
- The Cide uplift represents the easternmost part of the Zonguldak Basin and the northern margin of the Ulus Basin
- Late Barremian-Aptian sediments in the Cide Uplift are represented by coastal clastics resting unconformably on the Jurassic limestones
- These coastal clastics grades southward into turbiditic clastics filling the Ulus Basin in the south



THE ULUS BASIN

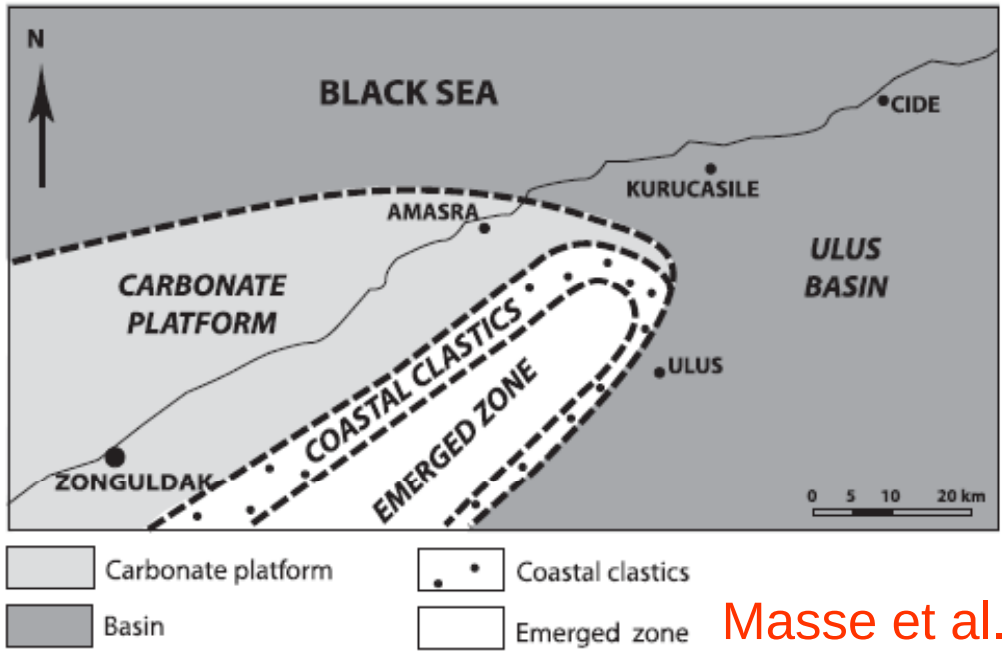
- The Ulus Basin can be separated into two parts.
  - Western part is filled by siliciclastic turbidites resting unconformably on the Jurassic and older rocks
  - It starts with coastal clastics grading upward into southward deepening homogenous turbidite sequence with some hemipelagic mudstones and abundant debris-flows and olistholits
  - Age of the Ulus basin fill is probably Late Barremian to Coniacian
- Eastern part of the Ulus Basin represents the Araç-Daday Shear Zone




L. Cretaceous flysch
U. Jurassic limestone block

PALAEOGEOGRAPHIC INTERPRETATION

- During the Late Barremian-Albian, a NE-trending archipelago delimited by extensional faults developed on the Istanbul Zone
- A short-lived carbonate platform developed on this archipelago during the Late Barremian-Aptian
- This archipelago downwarped during the Aptian-Cenomanian time and covered by deep marine basinal sediments such dark shales, marls and turbidites.
- I interpret the Late Barremian-Albian part of the Zonguldak basin as the beginning of the continental rifting in the Western Black Sea Basin.
- No volcanism associating the Late Barremian-Albian deposition have been found on the Istanbul Zone.



Masse et al., 2009

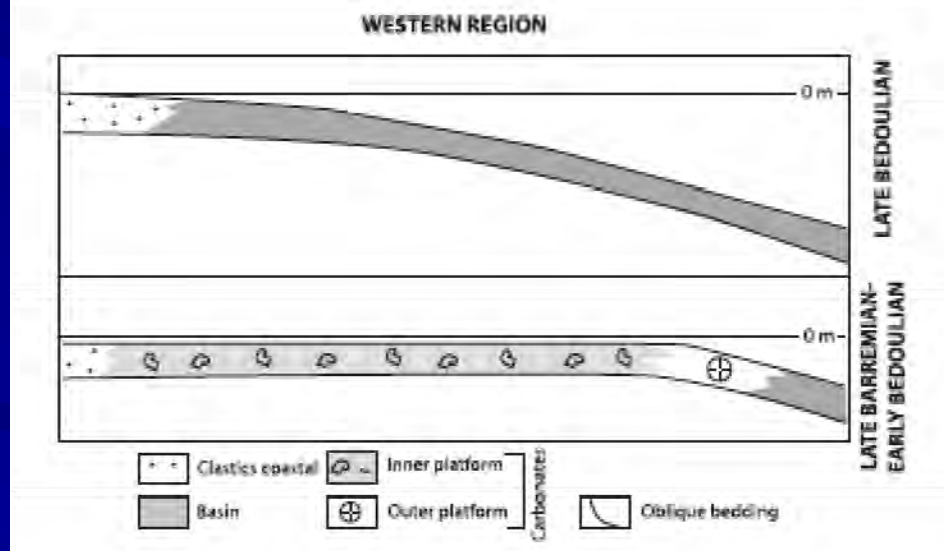
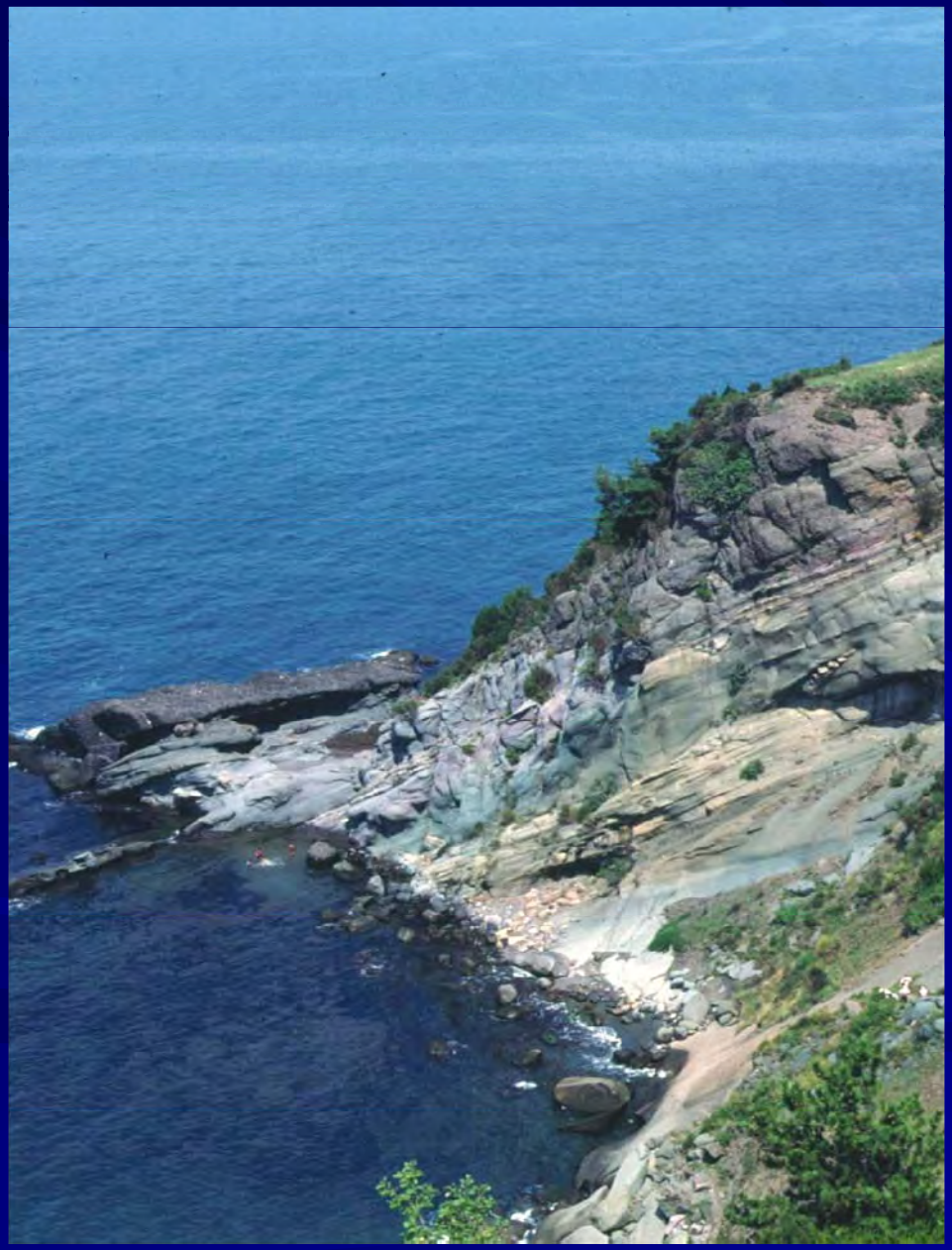


Fig. 11. Cross section of the western region (Zonguldak area) showing the distribution of the main palaeoenvironments and their evolution from a late Barremian-early Bedoulian carbonate platform to a late Bedoulian siliciclastic downwarpped system.

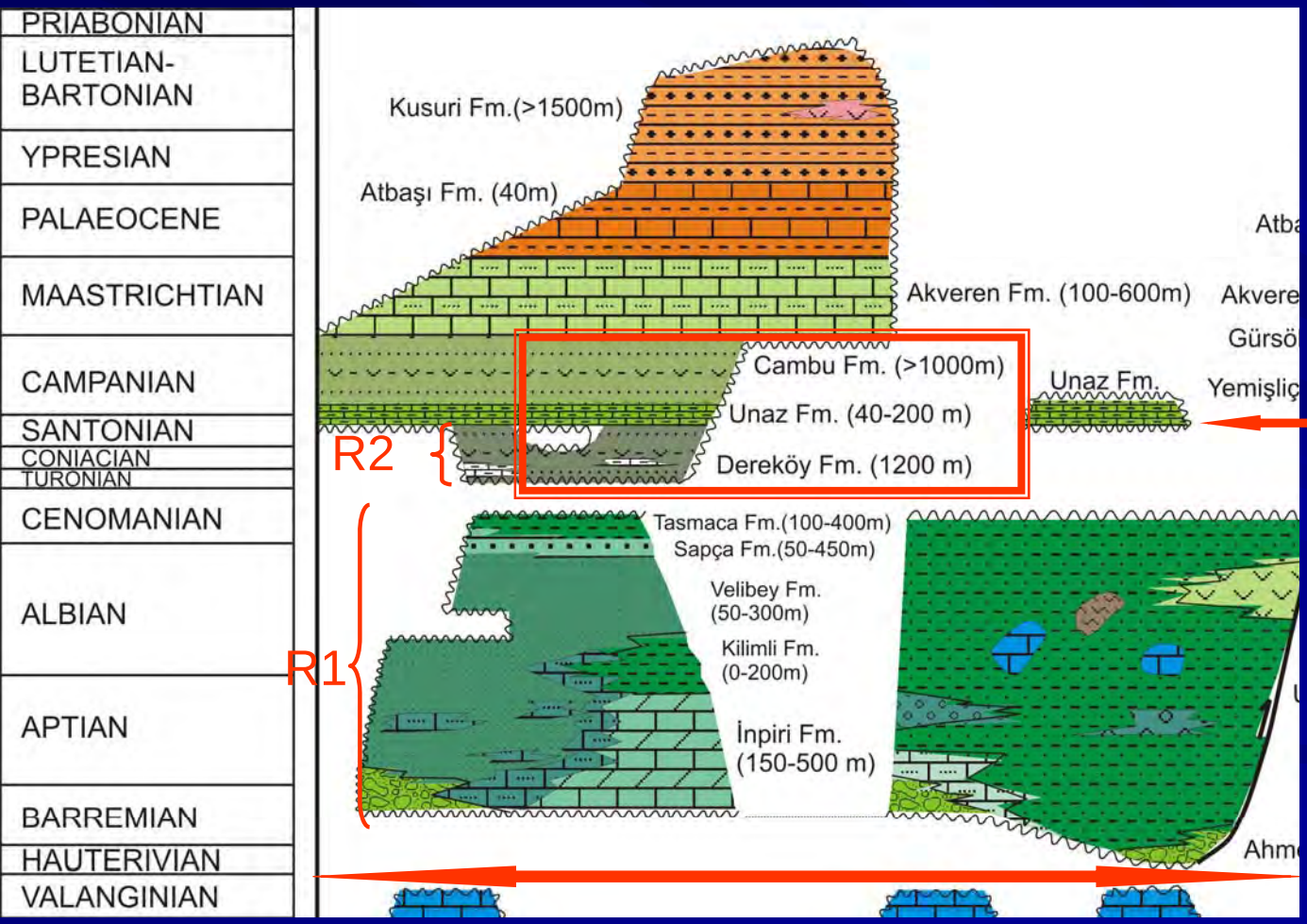
ESTABLISHMENT OF MAGMATIC ARC



- Lower Cretaceous syn-rift deposits of the Istanbul Zone were unconformably covered by an Upper Cretaceous volcanic-volcanoclastic sequence
- With the beginning of volcanism, dark-colored and organic-rich siliciclastic deposition in the Early Cretaceous drastically changed into the accumulation of red pelagic carbonates alternating with dominant volcanoclastics and volcanics
- This drastic change in the sedimentation during the Late Cenomanian-Turonian indicates rapid widening of the Western Black Sea rift to end the anoxia, and the possible effect of the widespread volcanism on the climate

The Upper Cretaceous volcanism is represented by two units separated by a red pelagic limestone

Lower volcanic unit (Dereköy Formation) represents the first stage of Pontide magmatic arc and also consists evidences for the rifting of the Western Black Sea Basin, while upper volcanic unit (Cambu Formation) represents the post-rift deposits.



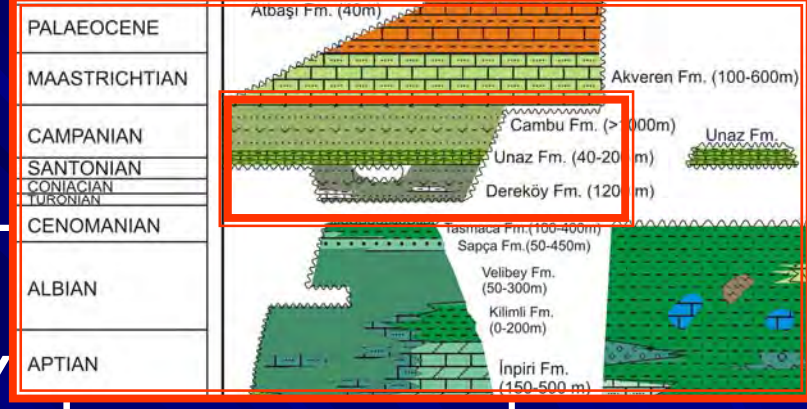
POST-RİFT

Break-up

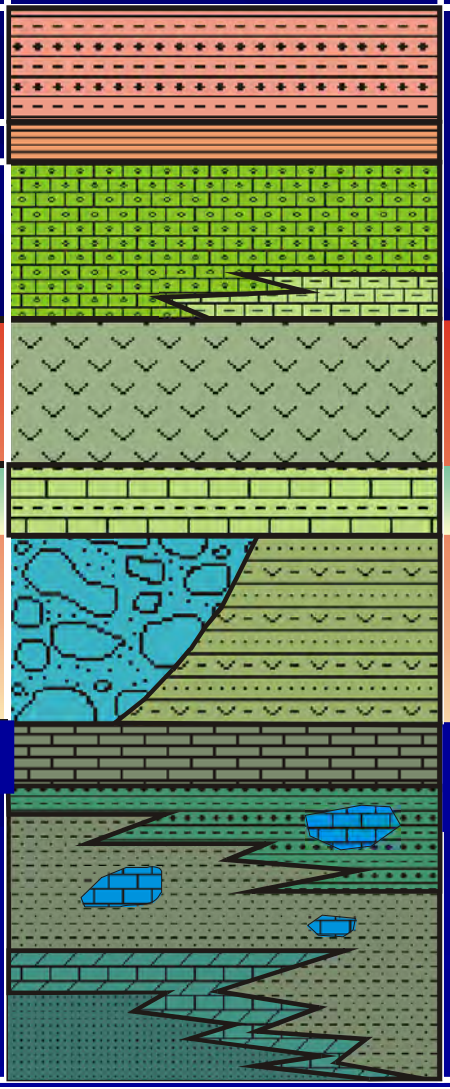
Arc magmatism / BACK-INTRA ARC RIFTING

OPENING OF WESTERN PONTIDE BASINS

ONSET OF SUBDUCTION ?



AGE	Thickness (m)	LITHOLOGY	
EOCENE	> 1000		KUSURİ
PALAEOCENE	50		ATBAŞI
MAASTRICHTIAN	500		AKVEREN
CAMPANIAN	> 1000		CAMBU
U. Santonian Campanian	20-200		UNAZ
TURONIEN CONIACIEN	100-800		DEREKÖY YENİCE
EARLY CRETACEOUS	> 1500 250 200 125		CİDE GROUP



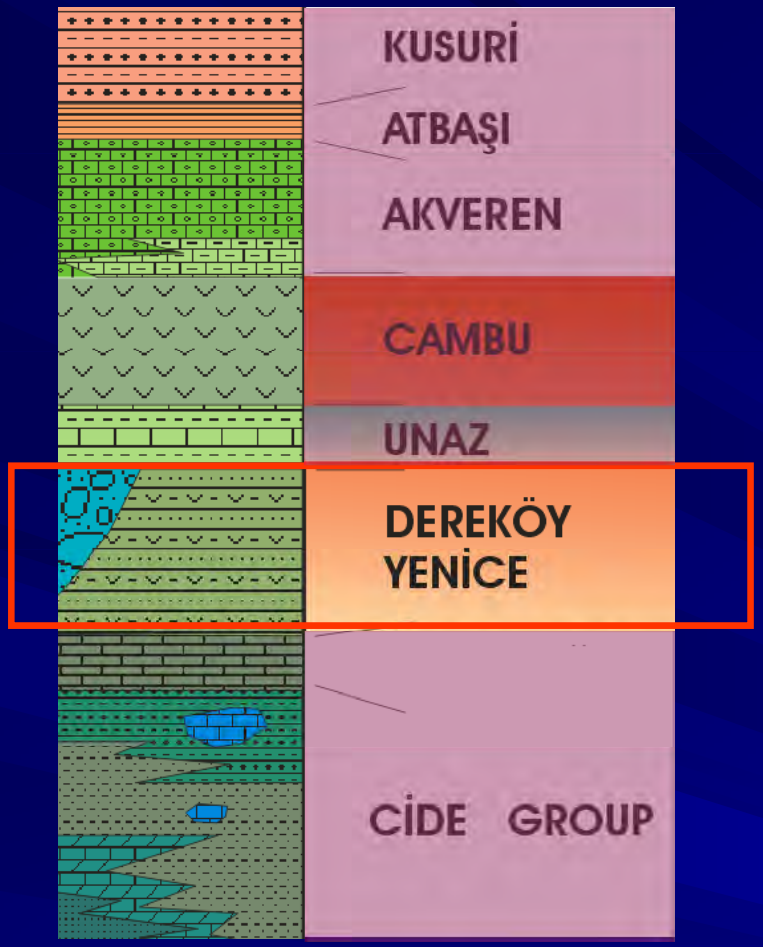
Cessation of the volcanism

volcanism

2

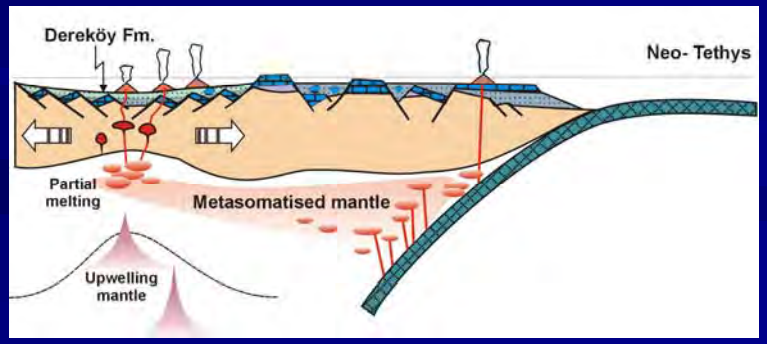
1


Upper volcanic succession
Pelagic limestone
Lower volcanic succession



LOWER VOLCANIC SUCCESSION

- The Lower Volcanic Succession starts in places with a Late Cenomanian shallow marine clastic unit resting unconformably on the Cenomanian and older units.
- Up the section are clastics and pelagic limestones with abundant volcanic material including pyroclastics and andesitic-basaltic lavas.
- Lower volcanic succession, which is Late Cenomanian (?)-Turonian-Santonian in age, represents the first products of Pontide magmatic arc developed as a result of northward subduction of the northern Neo-Tethys

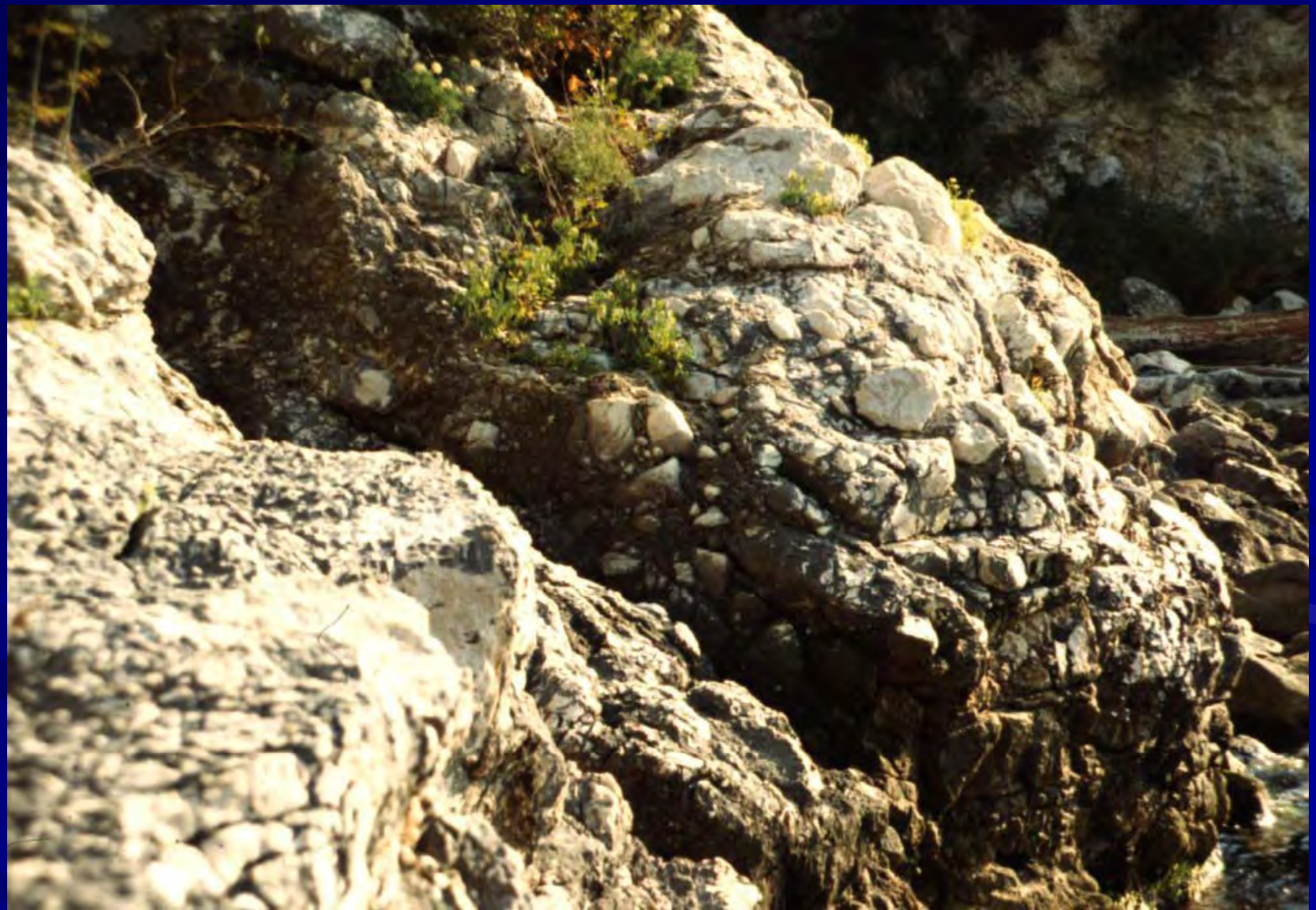


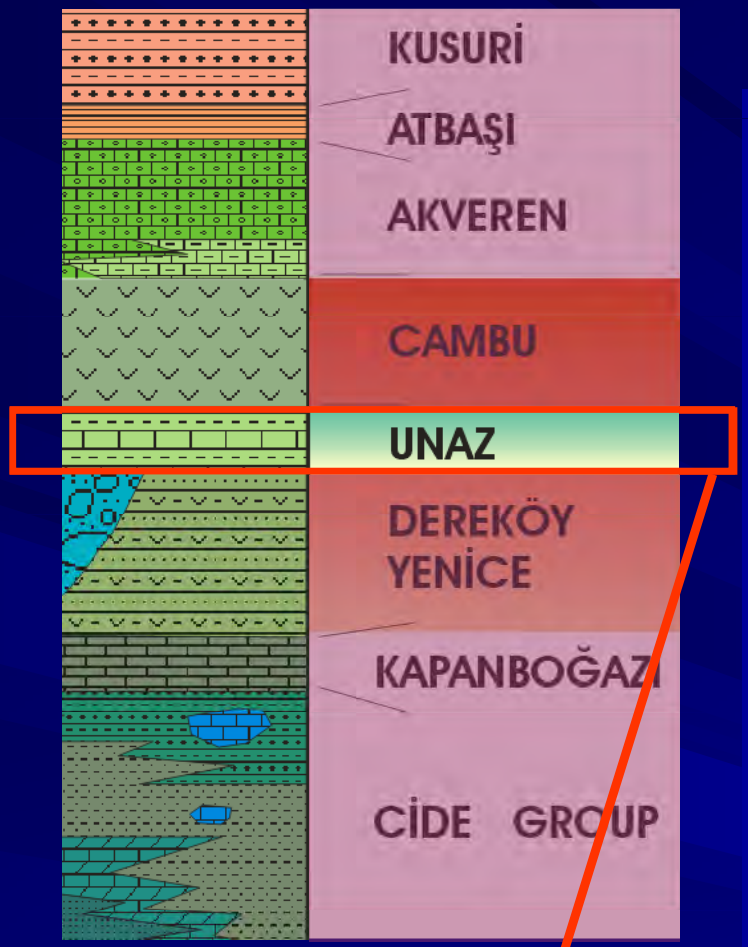
•Thickness and stratigraphy of the lower volcanic unit varies rapidly in close areas

•It consists of thick debris flows and olistoliths deposited in a pelagic environment indicating a very fast and sudden deepening, most probably in front of fault scarps.

•These structures were attributed to an extensional deformation with the beginning of intense arc magmatism during the Late Cenomanian (?)-Turonian

This faulting period, which can be observed all along the Western Pontides probably represents the second and main stage of the rifting of the Western Black Sea back-arc basin (Development of Oceanic Stage).



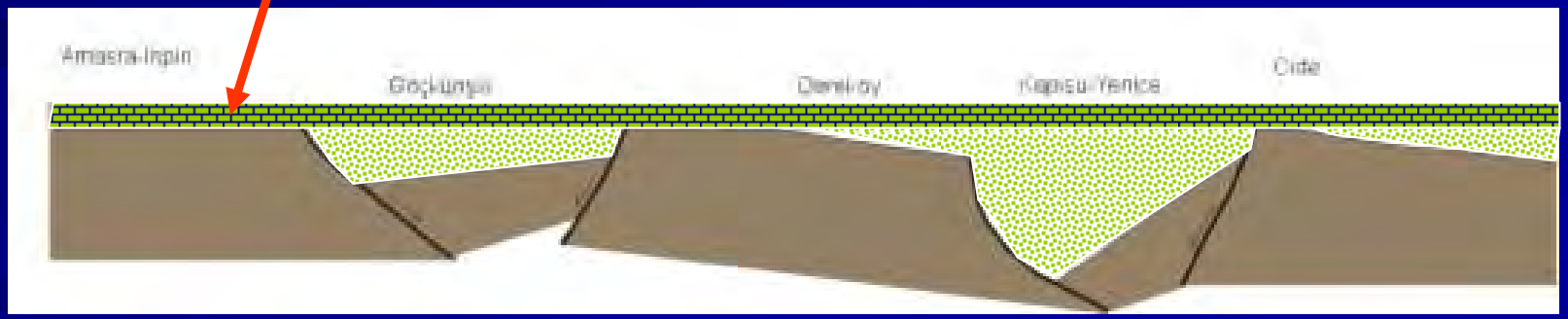


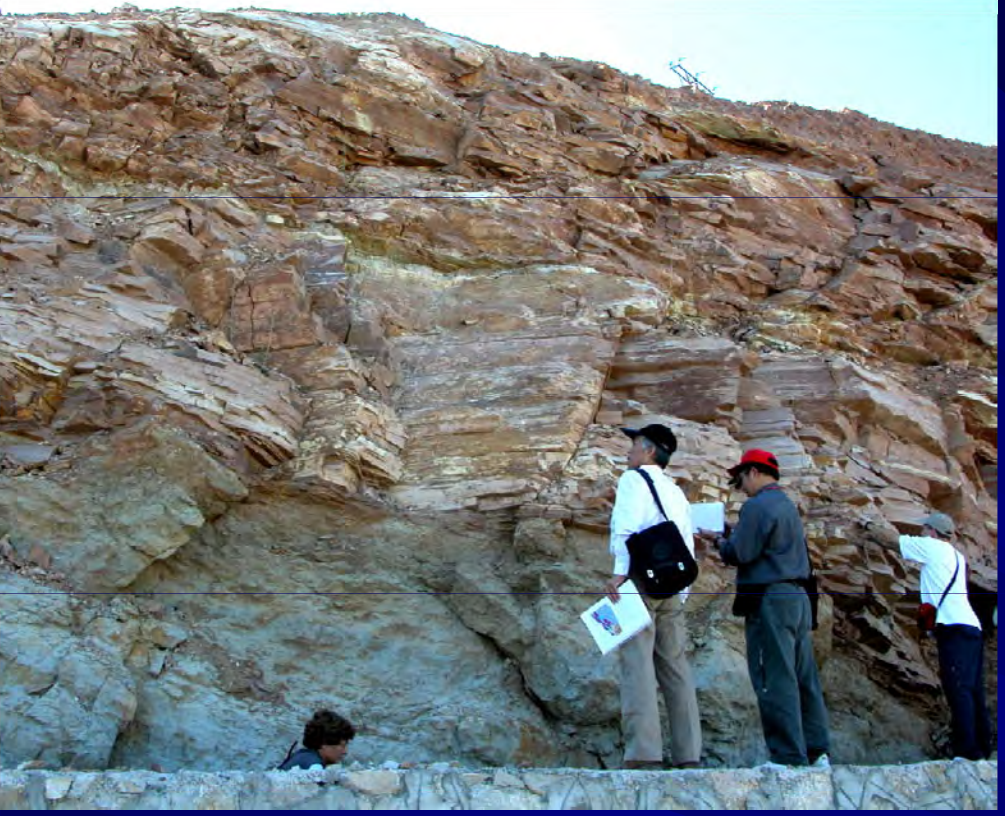
RED PELAGIC LIMESTONE (Unaz formation)

10-30 m-thick pelagic limestone separating the lower and upper volcanic successions can be traced all along the Pontides.

Dissected topography, which developed during the deposition of the lower volcanic succession, was covered by the pelagic carbonates of the Unaz formation. This formation indicates the end of the rifting and also first period of volcanism, and a sudden regional subsidence in the Late Santonian.

This period is intepreted as the time of breaking up of the continental crust and onset of the oceanic spreading in the Western Black Sea Basin during the Late Santonian.





The Unaz formation rests unconformably on the Lower volcanic succession or older units forming the basement or basin fills of the Western Pontides

The Unaz formation implies:

(1) End of normal faulting period

(2) Stopping the first stage of volcanism

(3) Sudden subsidence of the whole region

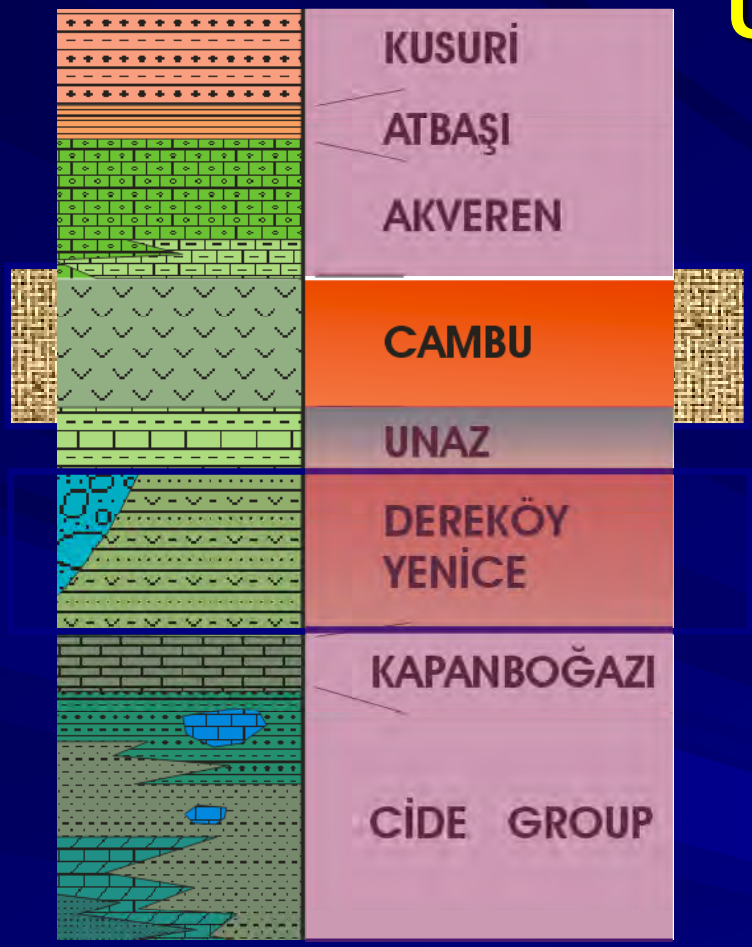
(4) This subsidence on the southern continental margin of the Black Sea allowed a wide transgression, eliminated most of the terrigeneous sediment sources on this margin

- All these events are interpreted to imply that formation of oceanic crust in the axis of the Western Black Sea Basin started during the deposition of these carbonates.

- The Unaz Formation represents the first post-breakup sediments

- Water exchange with the Neo-Tethys Ocean was perhaps also increased during this period and the water column therefore became well stirred and characterized by high fertility, contributing together with the warm climate, to both the blooming of pelagic foraminifera in surface waters and their supply to the sea-floor.

UPPER VOLCANIC SUCCESSION



(Cambu Formation)

(Campanian)

- During the Campanian, clastic sedimentation and volcanic activity restarted producing a thick pile of coarse-grained volcaniclastic beds intercalated with relatively abundant debris flows,lava flows and some pelagic limestones.

- Volcanism became intensified during the deposition the Cambu formation.

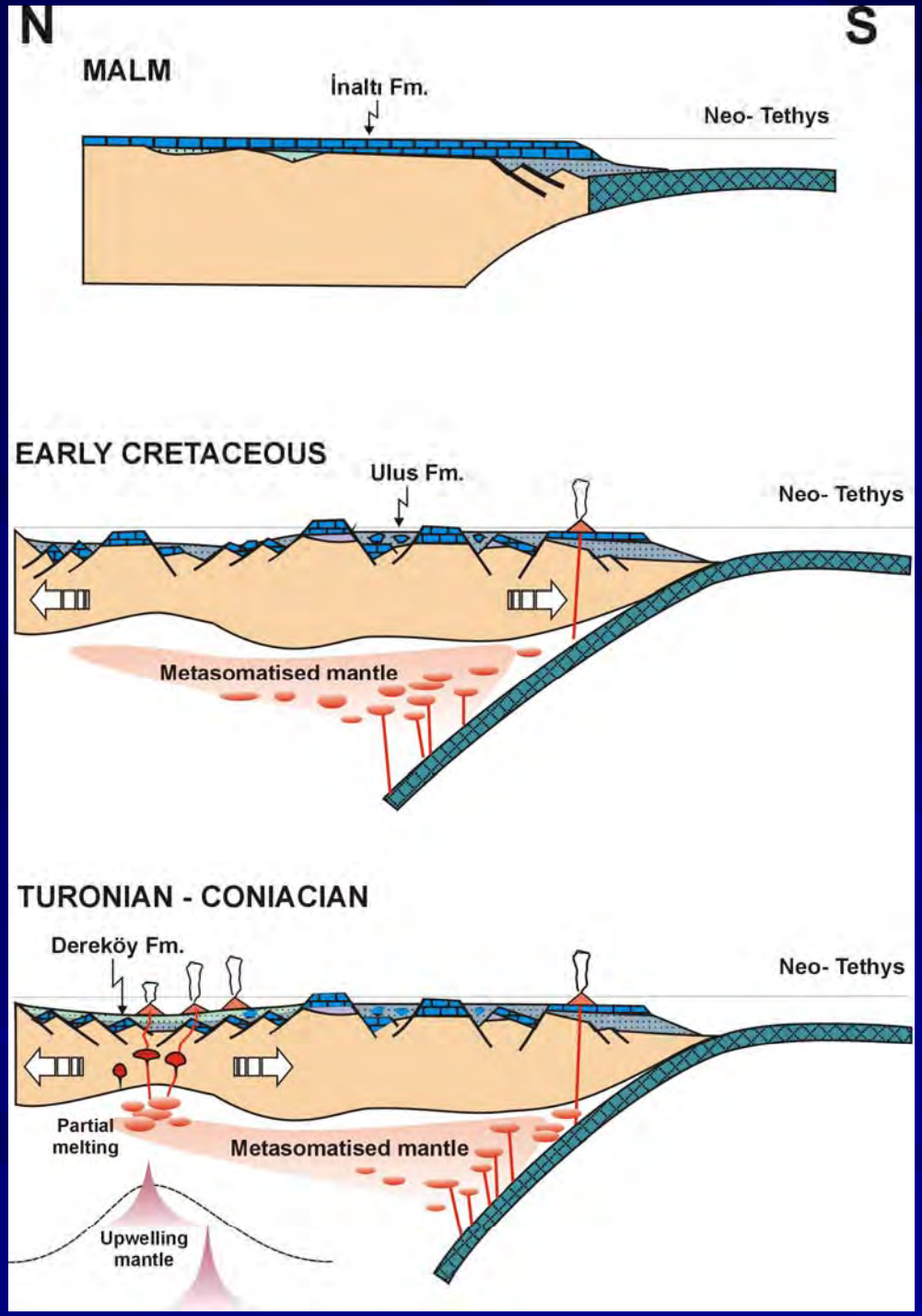
Pillow lava within the upper volcanic succession

Columnar structures and basalt rose within the Upper volcanic succession

The magmatism ceased at the end of the Campanian.

In the southern margin of the Black Sea the sedimentation was continuous during the post-arc period. Pelagic limestones, marls and calciturbidites were deposited from Maastrichtian to Eocene.

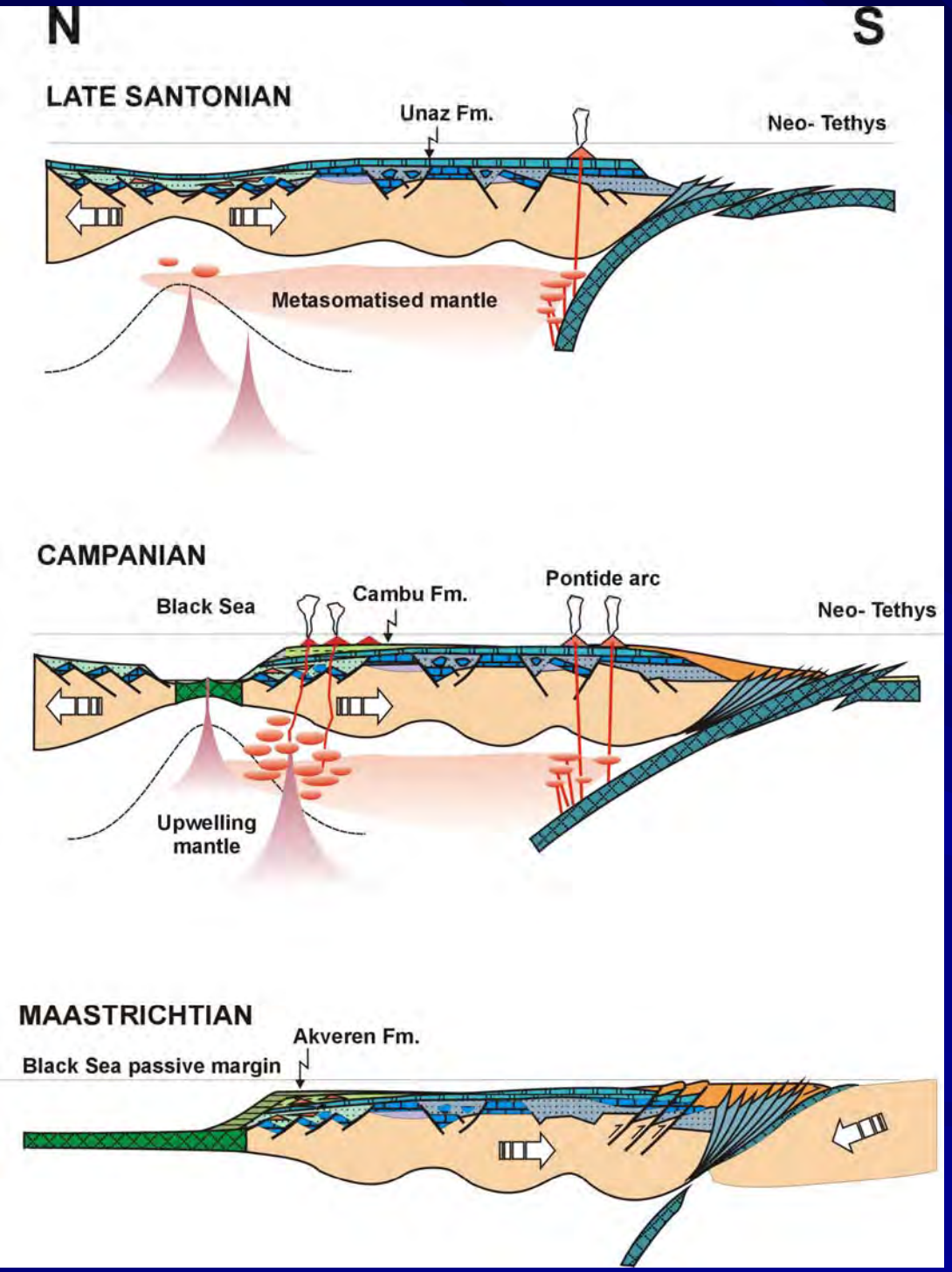
The whole Pontides are affected by a compressional regime since late Maastrichtian and became a fold and thrust belt.



Deposition of platform carbonates on the Pontides

Starting of northward subduction, extensional deformation, first stage of rifting, anoxia

Intensfying of volcanism, end of anoxia, second and main stage of rifting



Onset of oceanic spreading, end of first stage of volcanism, post-break-up subsidence

Second stage of volcanism

End of arc magmatism, continental collision, post-collisional basins, passive continental margin deposition

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Thank You....