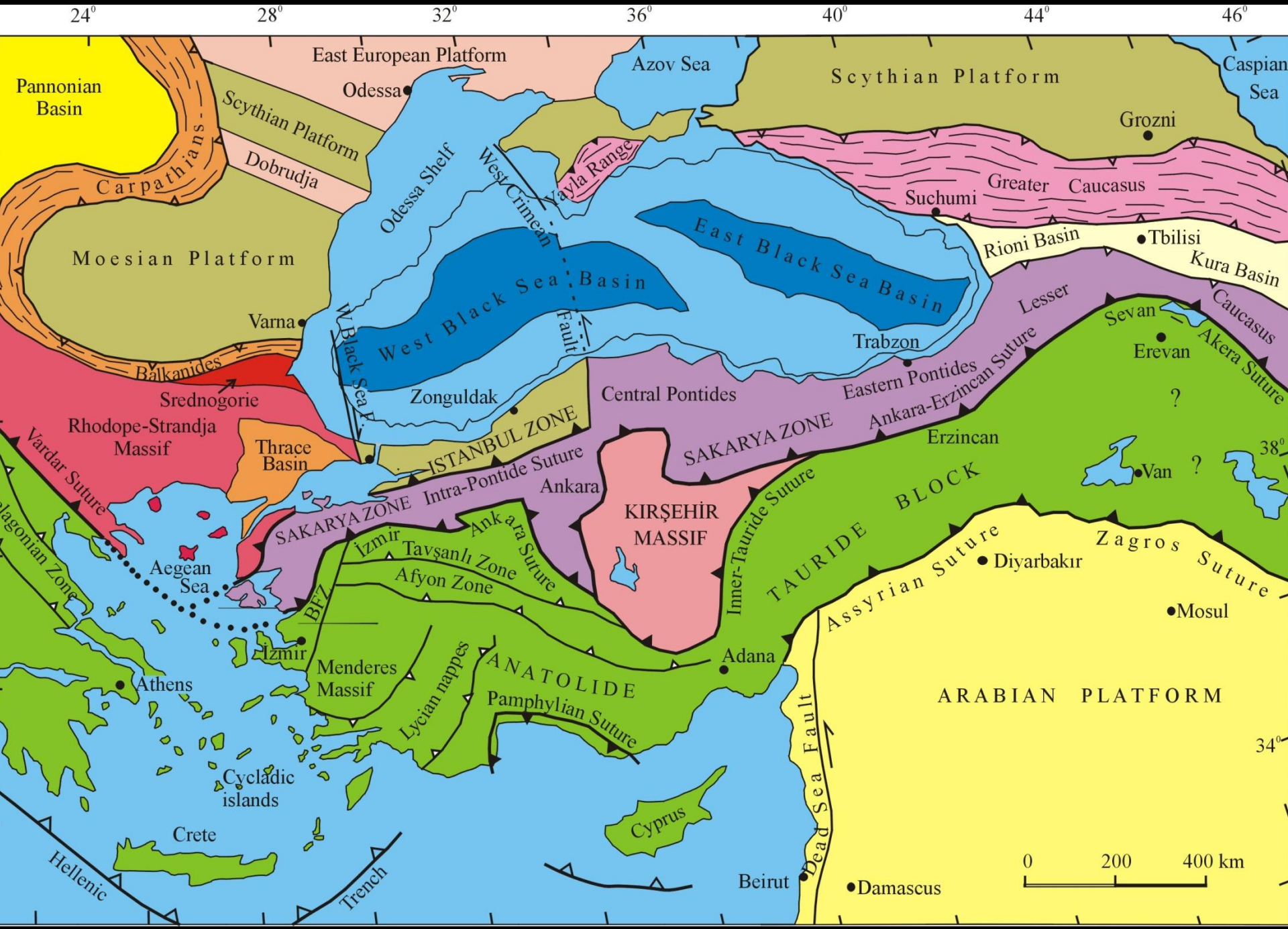
Anatolid-Torid Bloku

Aral I. Okay

İstanbul Teknik Üniversitesi


24°
28°
32°
36°
40°
44°
46°
38°
34°
East European Platform
Azov Sea
Scythian Platform
Caspian Sea
Pannonian Basin
Odessa
Scythian Platform
Dobrudja
Carpathians
Odessa Shelf
West Crimean
Yayla Range
Grozni
Greater Caucasus
Suchumi
Moesian Platform
East Black Sea Basin
Rioni Basin
Tbilisi
Kura Basin
West Black Sea Basin
Varna
W Black Sea F.
Fault
Lesser Caucasus
Sevan
Akera Suture
Erevan
Trabzon
Balkanides
Zonguldak
Central Pontides
Eastern Pontides
Ankara-Erzincan Suture
Srednogorie
Rhodope-Strandja Massif
Thrace Basin
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SAKARYA ZONE
Erzincan
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Ankara
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Inner-Tauride Suture
TAURIDE BLOCK
Van
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Zagros Suture
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Pamphylian Suture
Adana
Athens
ARABIAN PLATFORM
Cycladic islands
Crete
Cyprus
Dead Sea Fault
Hellenic Trench
Beirut
Damascus
0
200
400 km

Anatolid-Torid Bloku platform ve pasif kıta kenarı

Pontidler aktif kıta kenarı

Anatolid-Torid Bloku'nun ayırtman özellikleri

Geç Prekambriyen yaşta kristalen temel

Paleozoyik-Tersiyer sedimenter örtü

- Paleozoyik klastik-karbonat
- Mesozoyik karbonat

Volkanik kayalar çok seyrek

Hersiniyen (Karbonifer) ve Kimmerid (Triyas) orojenezinin etkileri yok.

Alpin sıkışmalı deformasyon ve metamorfizma Geç Kretase'de başlıyor ve Miyosen'e kadar devam ediyor.

Anatolid-Torid Bloku deformasyon ve metamorfizma özelliklerine göre zonlara ayrılıyor:

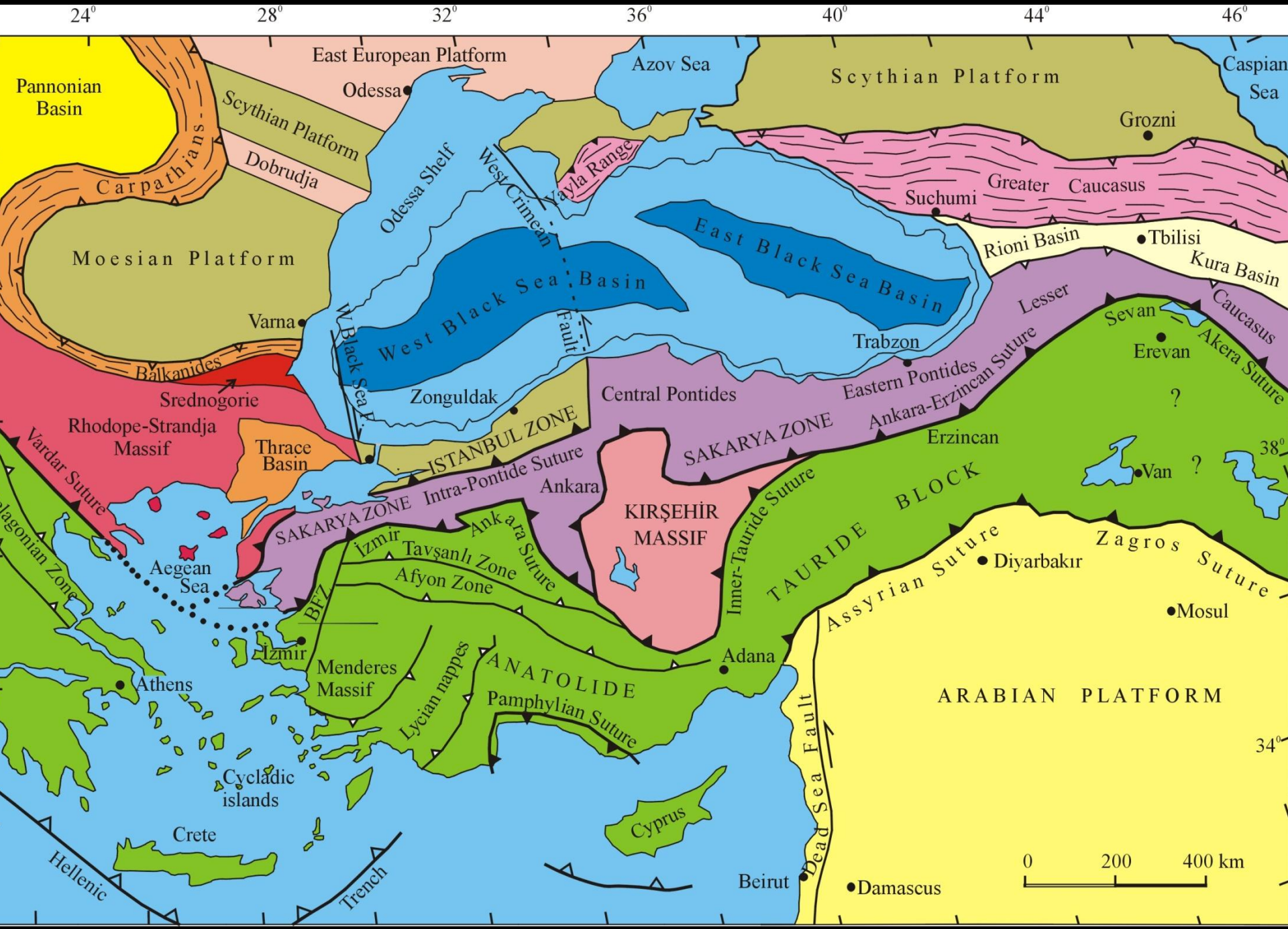
Tavşanlı Zonu: Geç Kretase'de yüksek basınç metamorfizması

Afyon Zonu: Kretase-Tersiyer sınırında yüksek basınç metamorfizması

Menderes Masifi: Eosen'de orta basınç metamorfizması

Bornova Fliş Zonu: Melanj ve olistostrom kuşağı

Toroslar: Kretase-Miyosen aralığında deforme olmuş Paleozoyik-Tersiyer yaşta sedimenter istifler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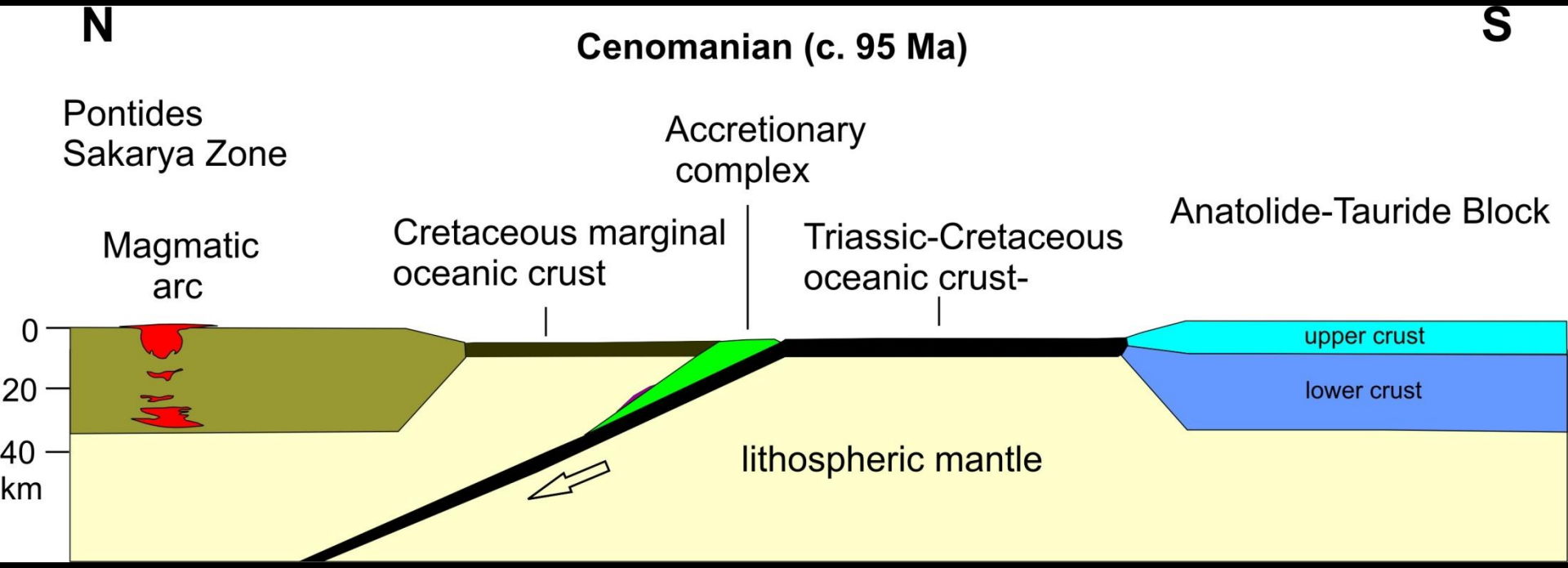
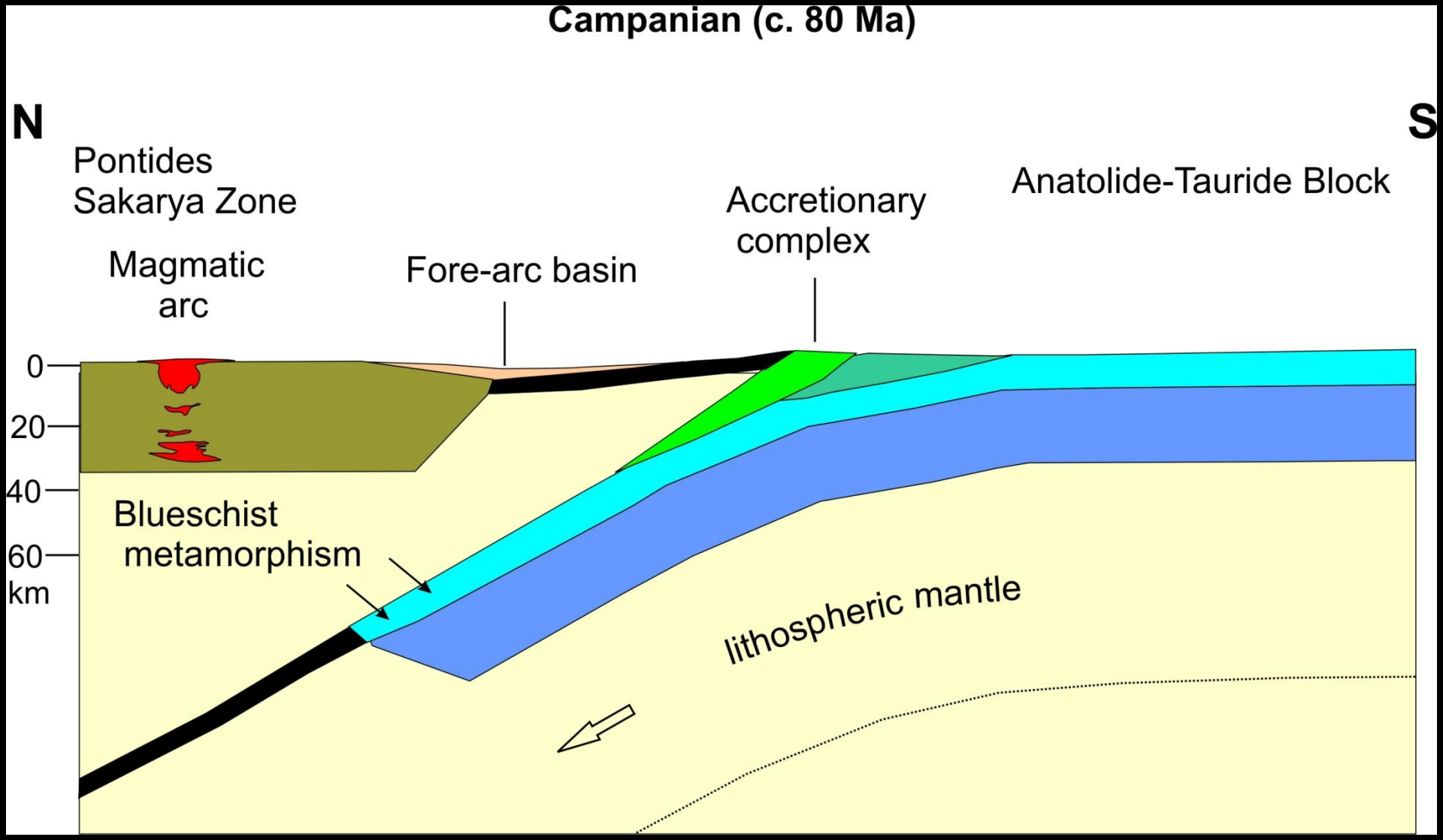
Pamphylian Suture
Adana
Athens
ARABIAN PLATFORM
Cycladic islands
Crete
Cyprus
Dead Sea Fault
Hellenic Trench
Beirut
Damascus
0
200
400 km

Tavşanlı Zonu
Anatolid-Torid Blokunun derine dalmış
en kuzey ucu


N
S
Cenomanian (c. 95 Ma)
Pontides
Sakarya Zone
Accretionary
complex
Anatolide-Tauride Block
Magmatic
arc
Cretaceous marginal
oceanic crust
Triassic-Cretaceous
oceanic crust-
0
20
40
km
upper crust
lower crust
lithospheric mantle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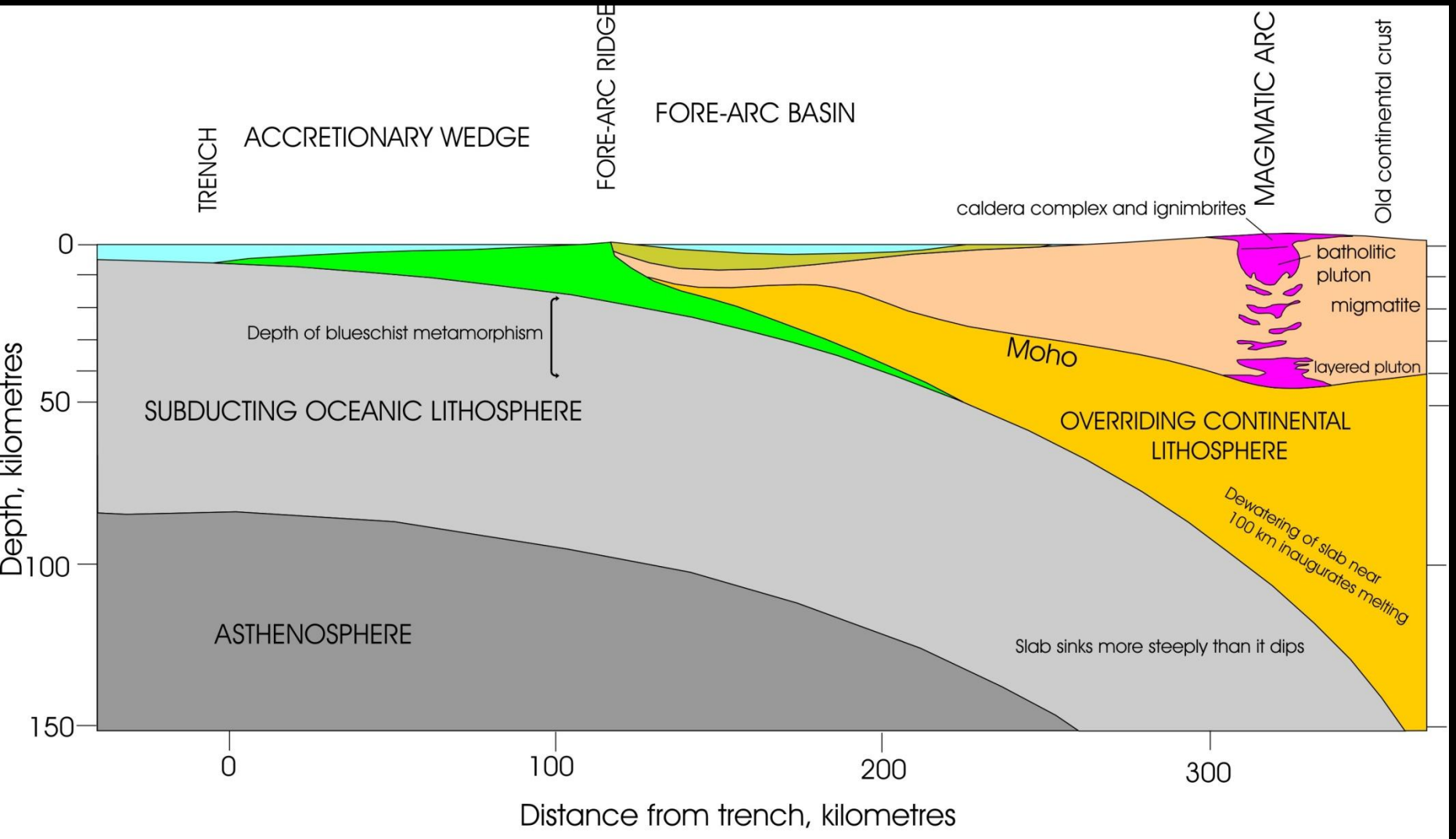
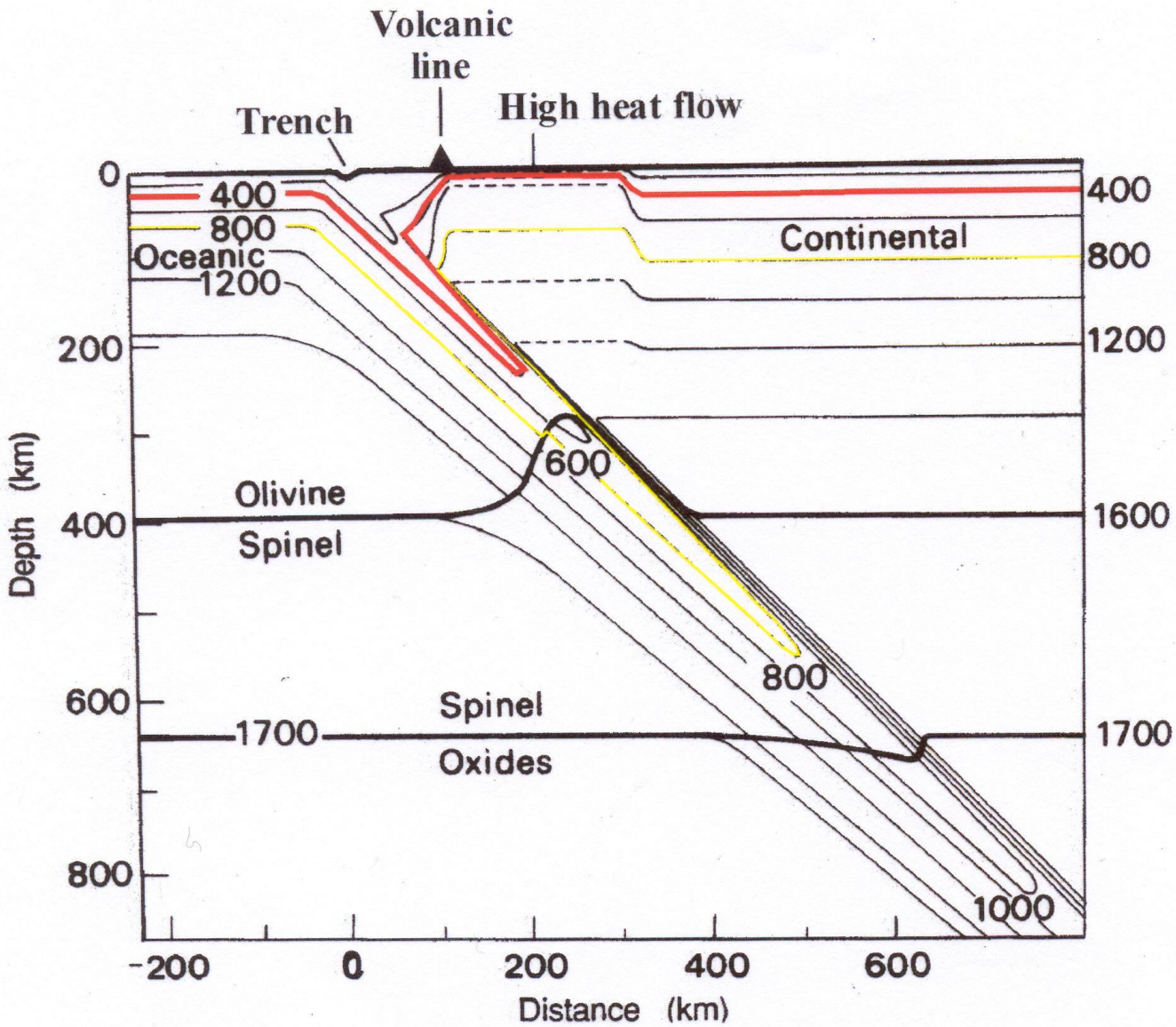
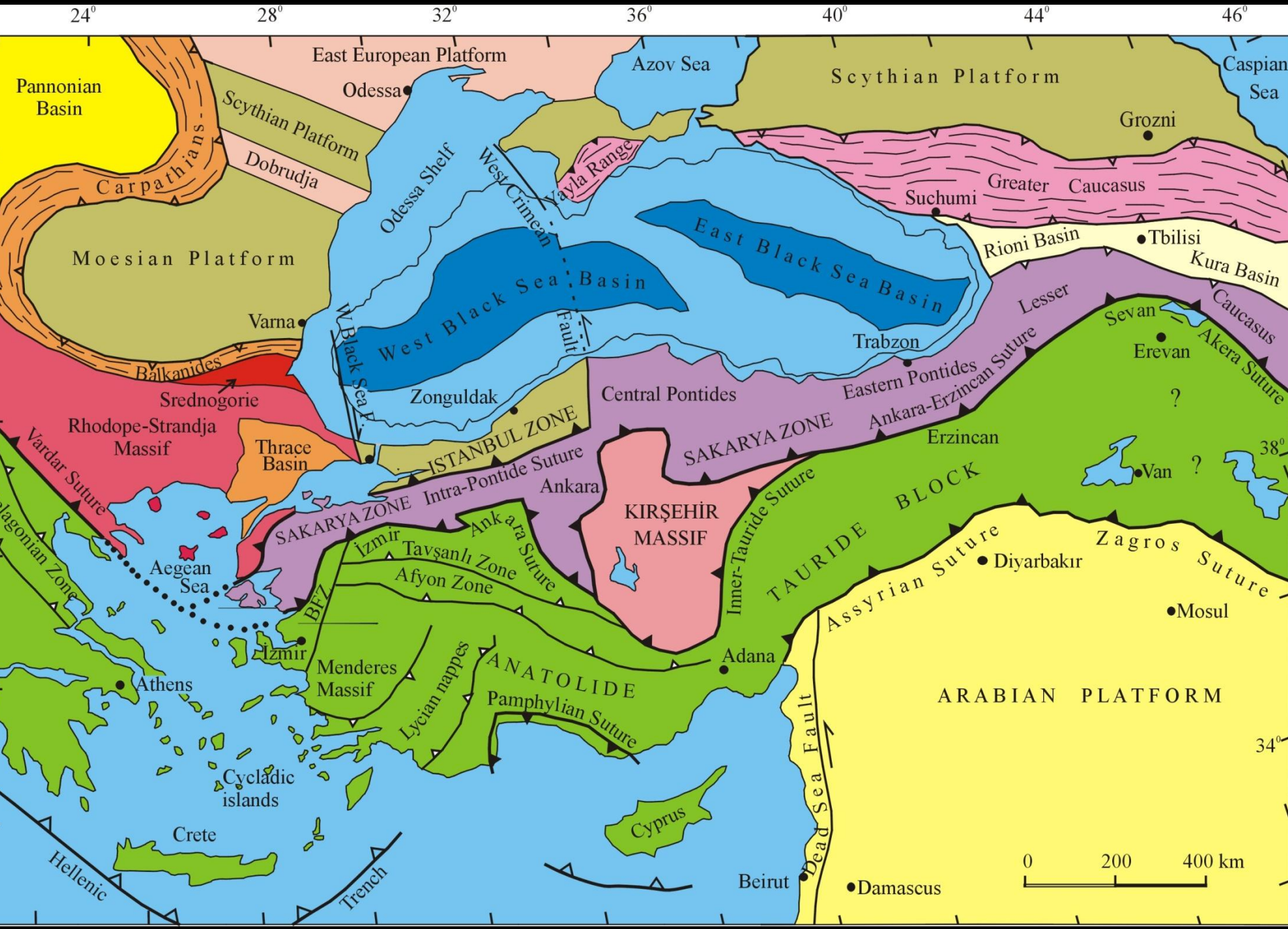
Accretionary
complex
Magmatic
arc
Fore-arc basin
0
20
40
60
km
Blueschist
metamorphism
lithospheric mantle



Section across a continental-margin subduction zone (Hamilton, 1988)



Thermal structure of a subducting oceanic lithosphere (Schubert et al., 1975). Calculations include the effects of frictional heating (to a max. value of 100 MPa)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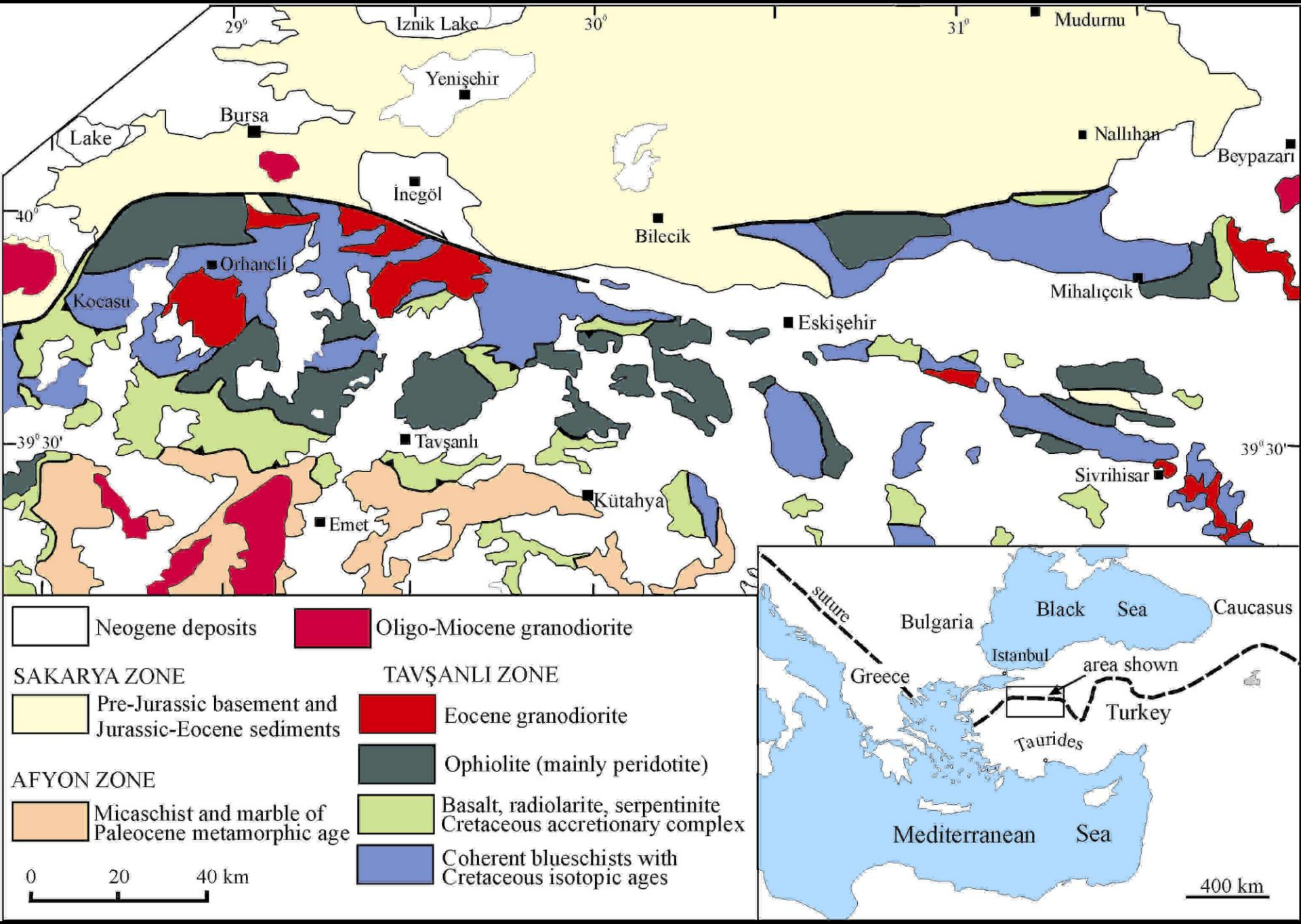
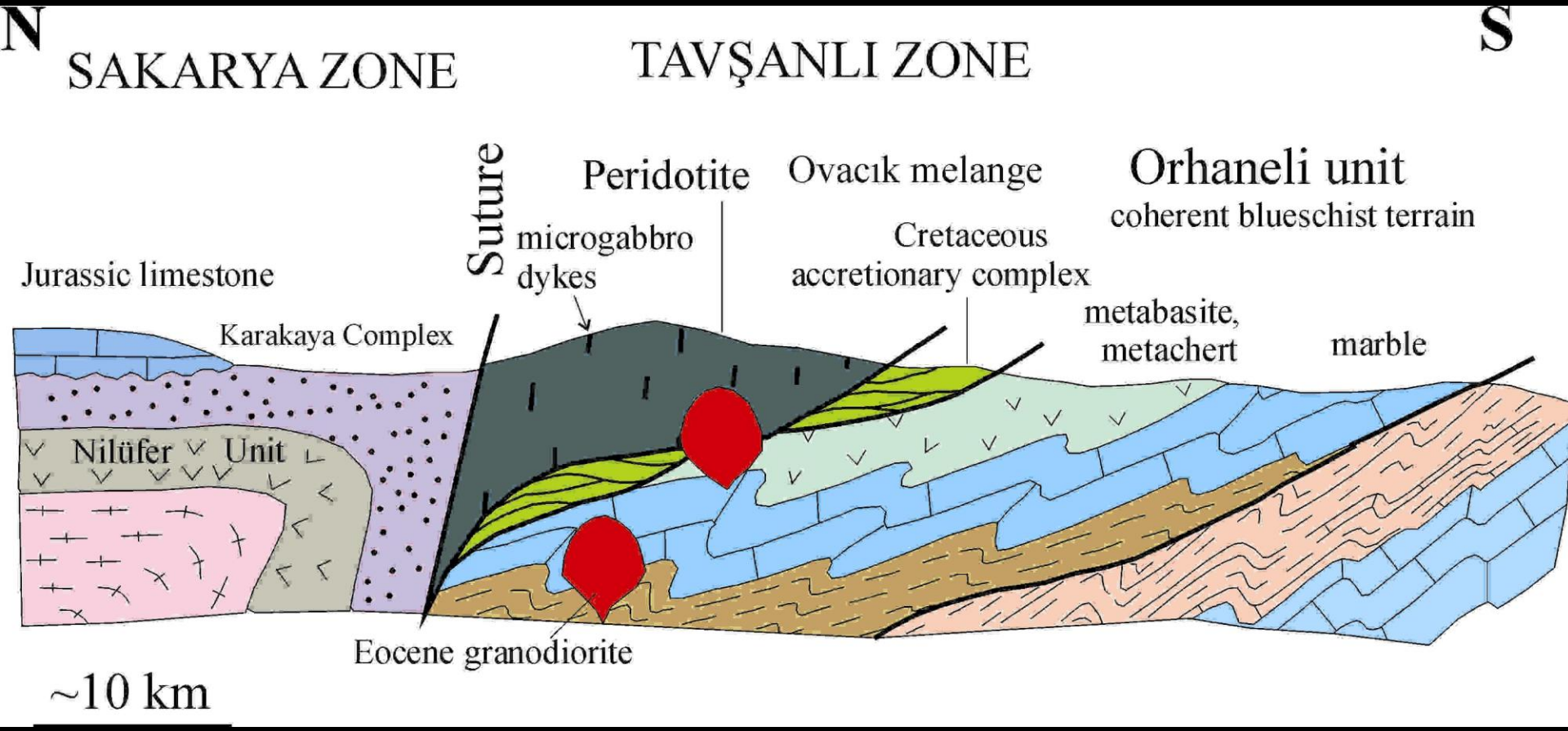
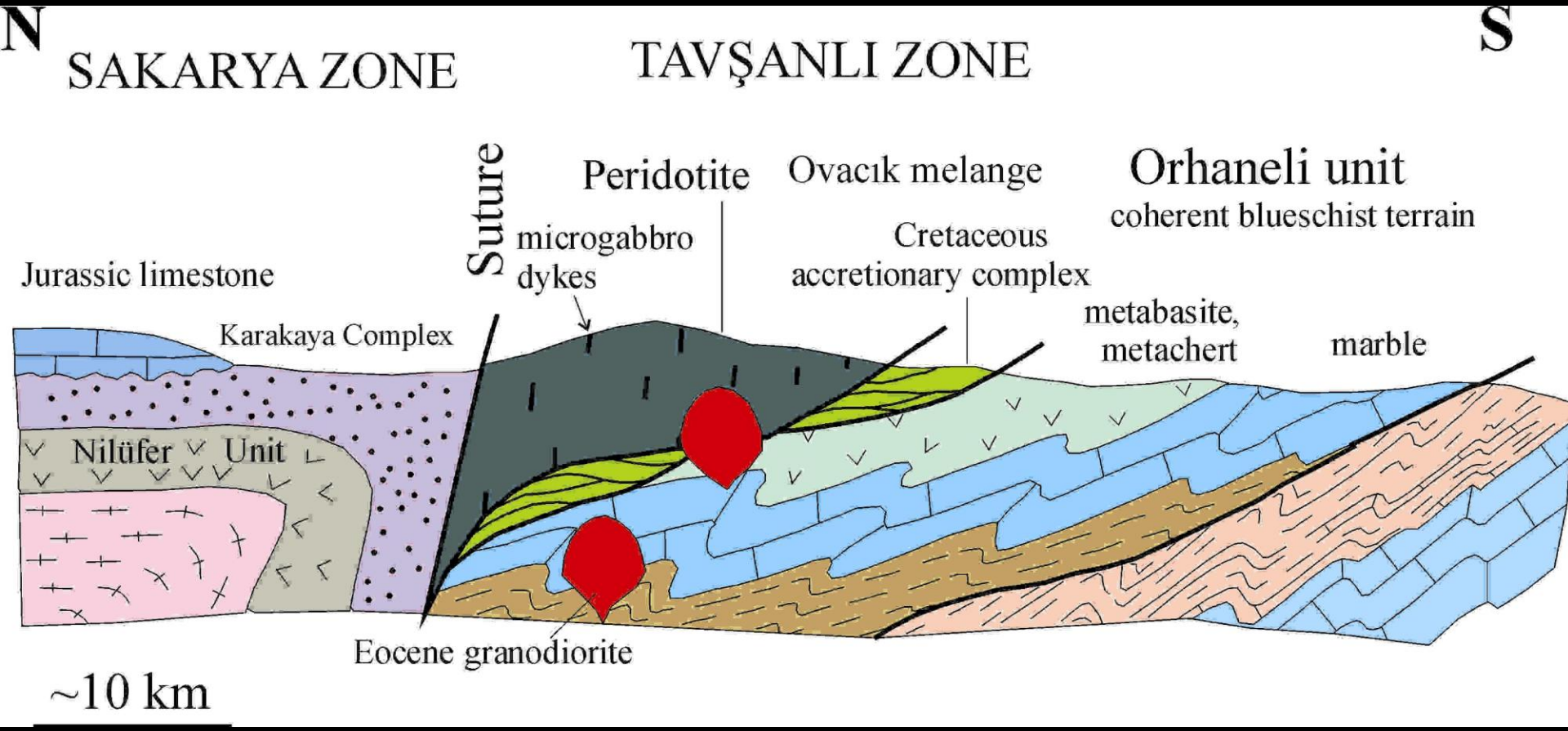
400 km


29°
30°
31°
Iznik Lake
Mudurnu
Yenişehir
Bursa
Lake
Nallıhan
Beypazarı
İnegöl
40°
Bilecik
Orhaneli
Kocasu
Mihalıççık
Eskişehir
39°30'
Tavşanlı
39°30'
Sivrihisar
Kütahya
Emet
Neogene deposits
Oligo-Miocene granodiorite
SAKARYA ZONE
Pre-Jurassic basement and Jurassic-Eocene sediments
AFYON ZONE
Micaschist and marble of Paleocene metamorphic age
TAVŞANLI ZONE
Eocene granodiorite
Ophiolite (mainly peridotite)
Basalt, radiolarite, serpentinite Cretaceous accretionary complex
Coherent blueschists with Cretaceous isotopic ages
0
20
40 km
suture
Bulgaria
Black Sea
Caucasus
Istanbul
area shown
Greece
Turkey
Taurides
Mediterranean Sea
400 km


N
S
SAKARYA ZONE
TAVŞANLI ZONE
Suture
Peridotite
Ovacık melange
Orhaneli unit
coherent blueschist terrain
microgabbro
dykes
Cretaceous
accretionary complex
Jurassic limestone
Karakaya Complex
metabasite,
metachert
marble
Nilüfer Unit
Eocene granodiorite
~10 km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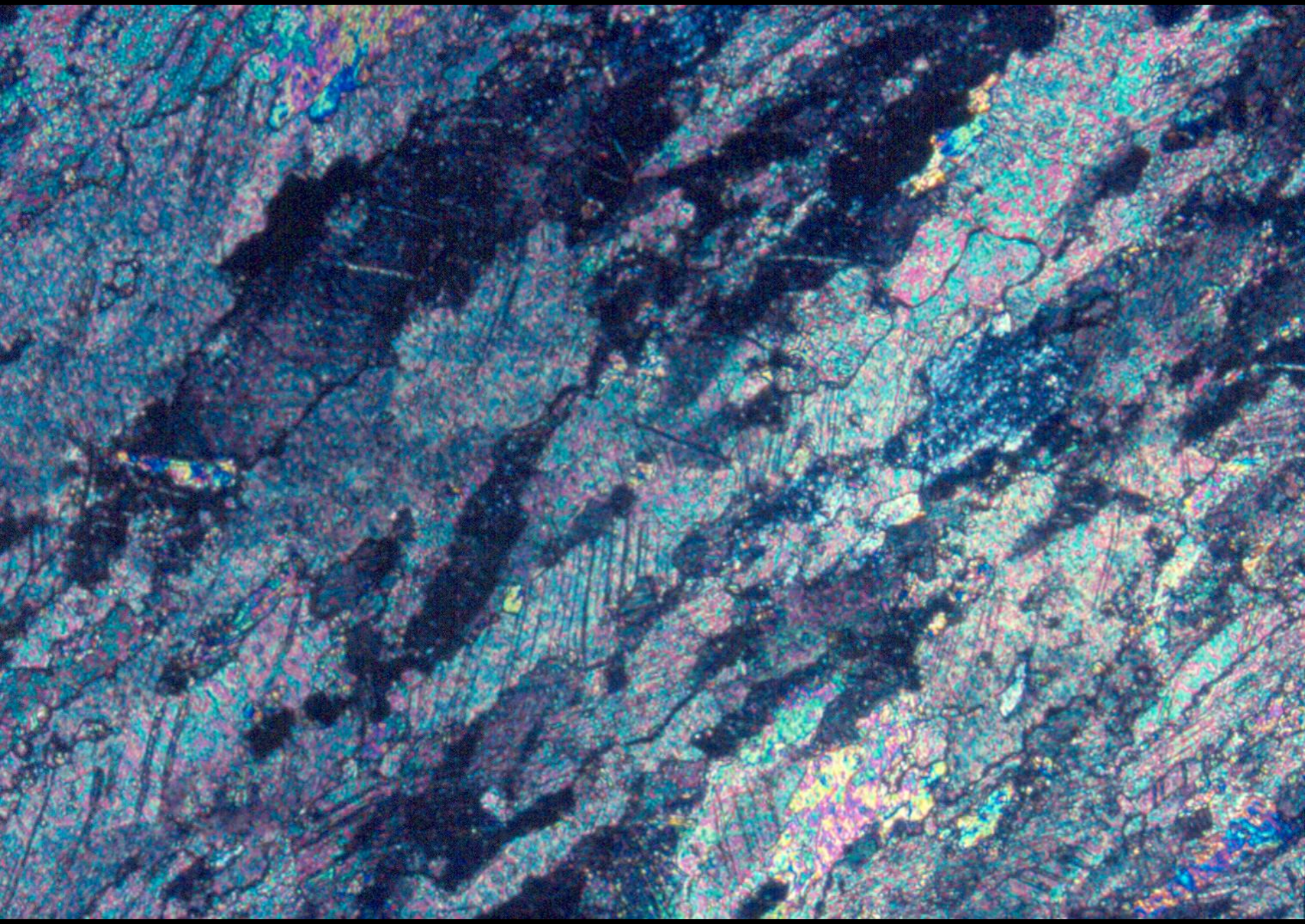

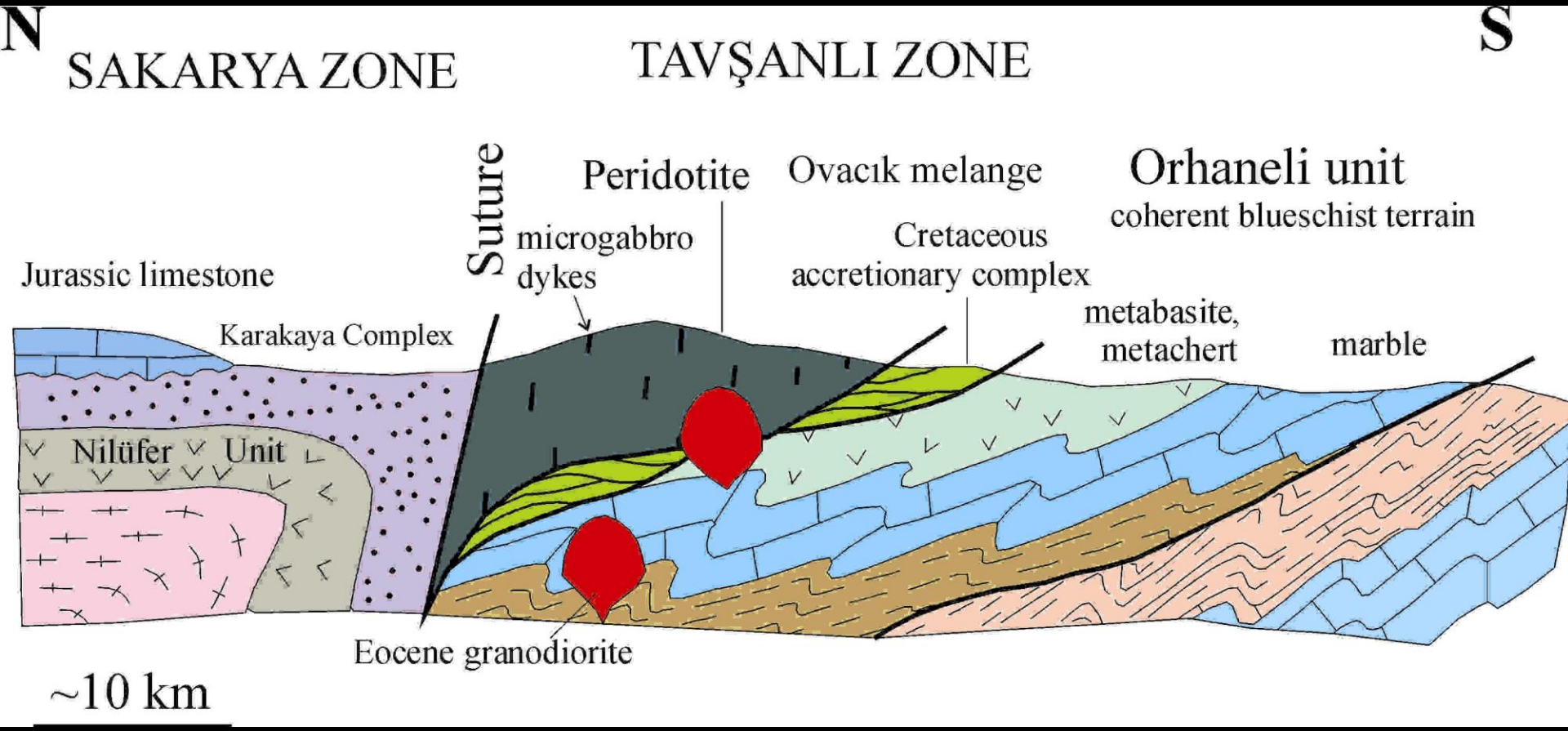
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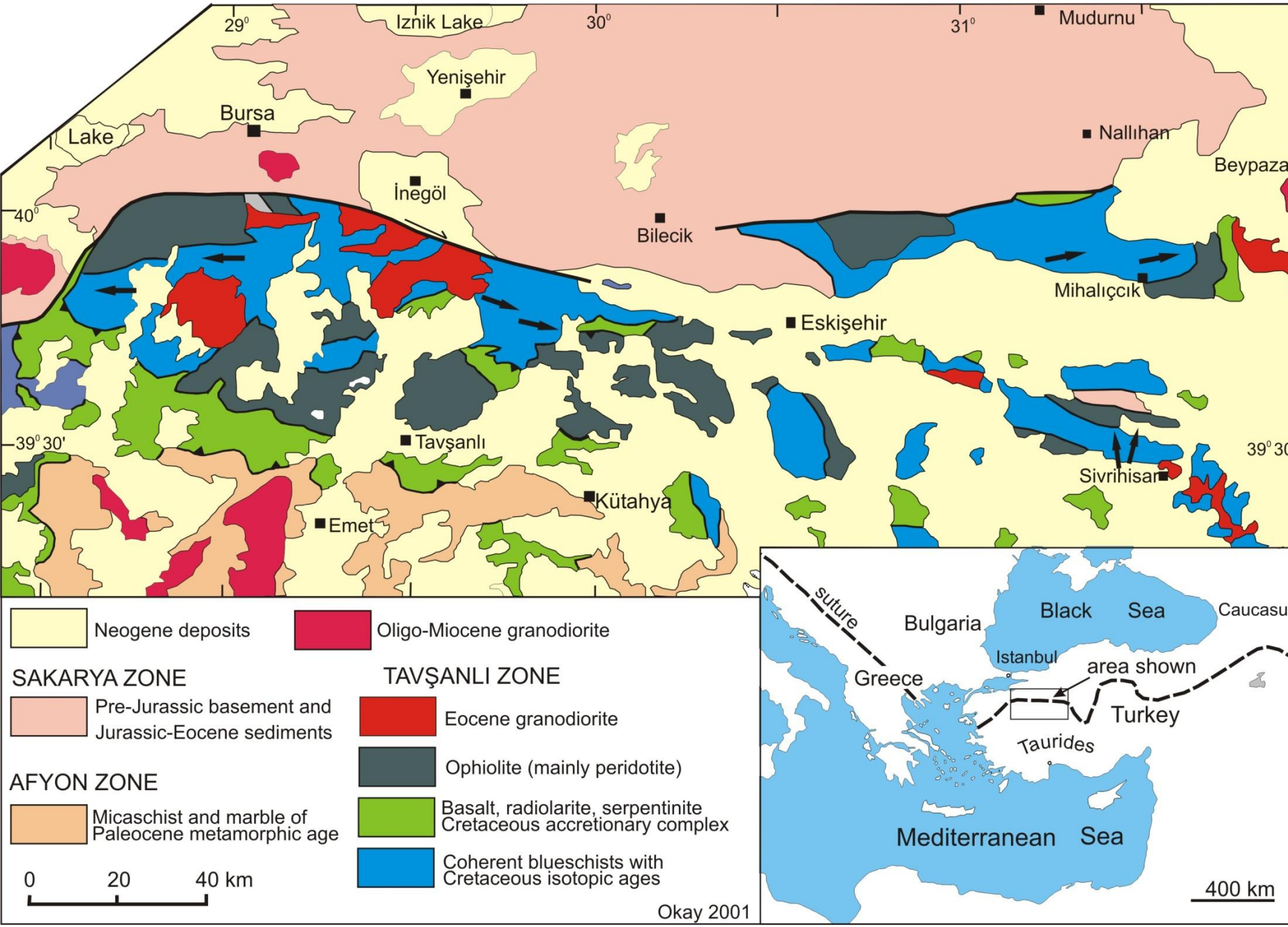
Nilüfer Unit
Eocene granodiorite
~10 km

Düzenli mavişist istifinin yapısal özellikleri


29°
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0 20 40 km
Okay 2001
suture
Bulgaria
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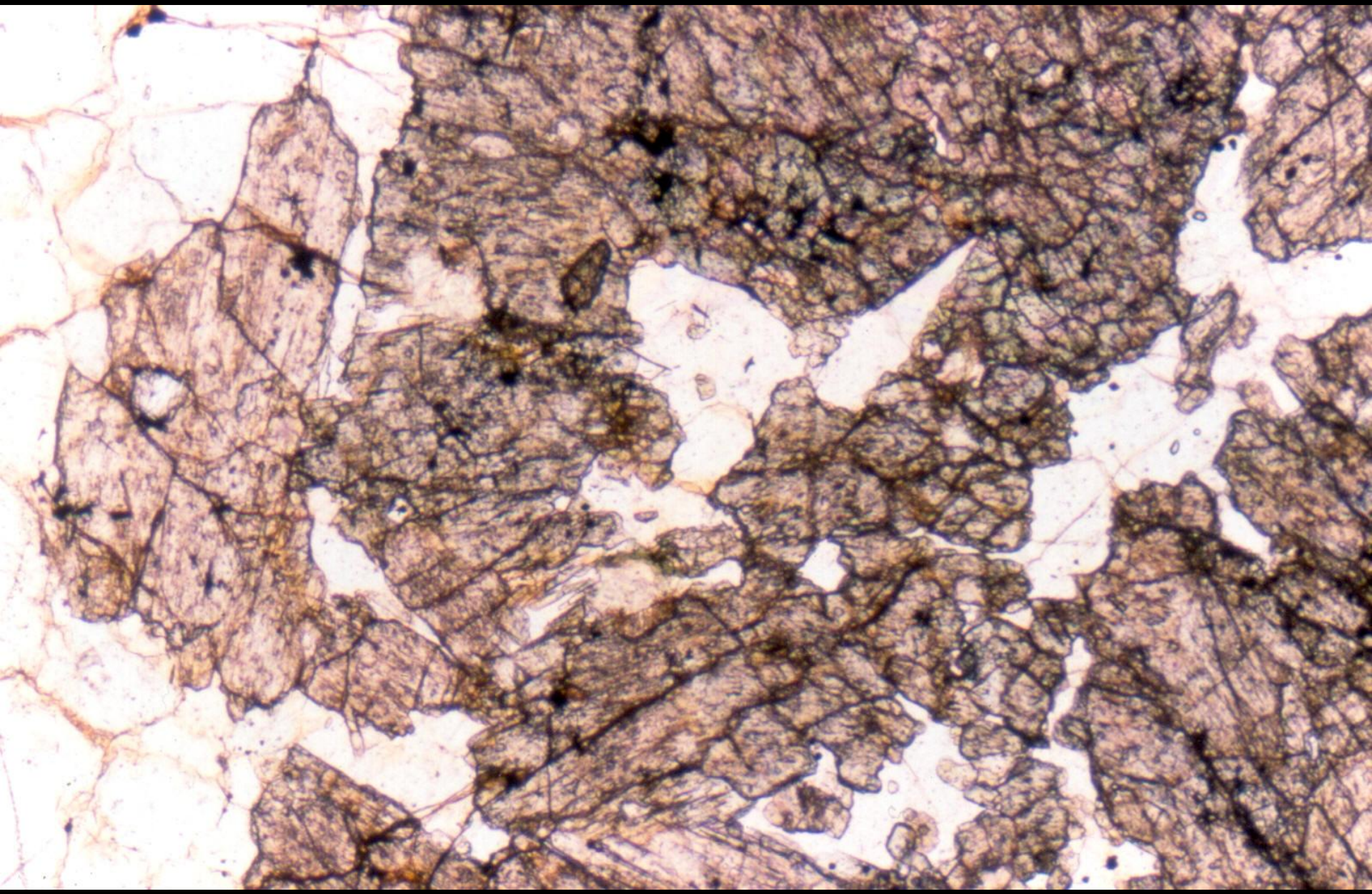
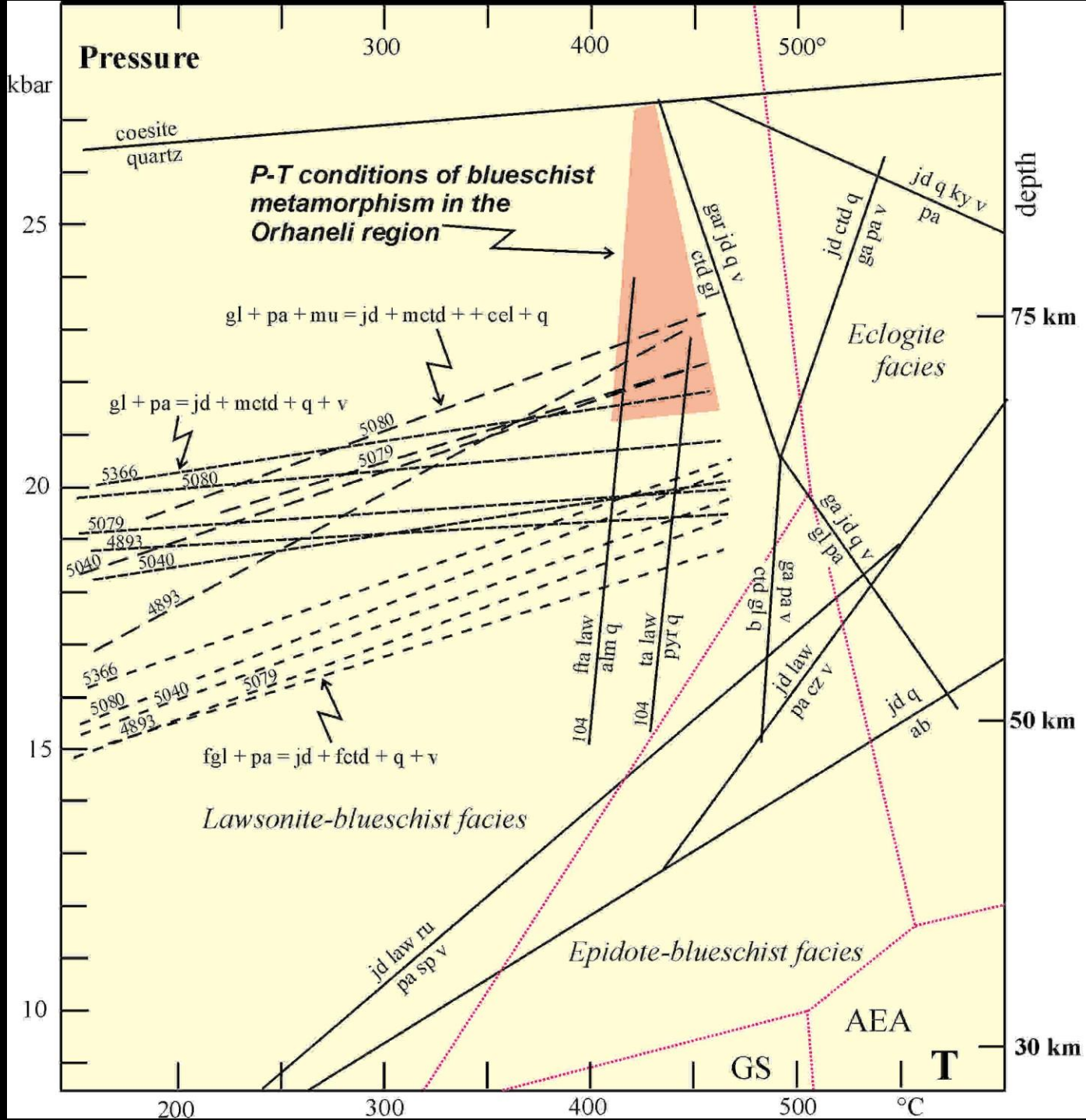
Caucasu
Istanbul
area shown
Greece
Turkey
Taurides
Mediterranean Sea
400 km

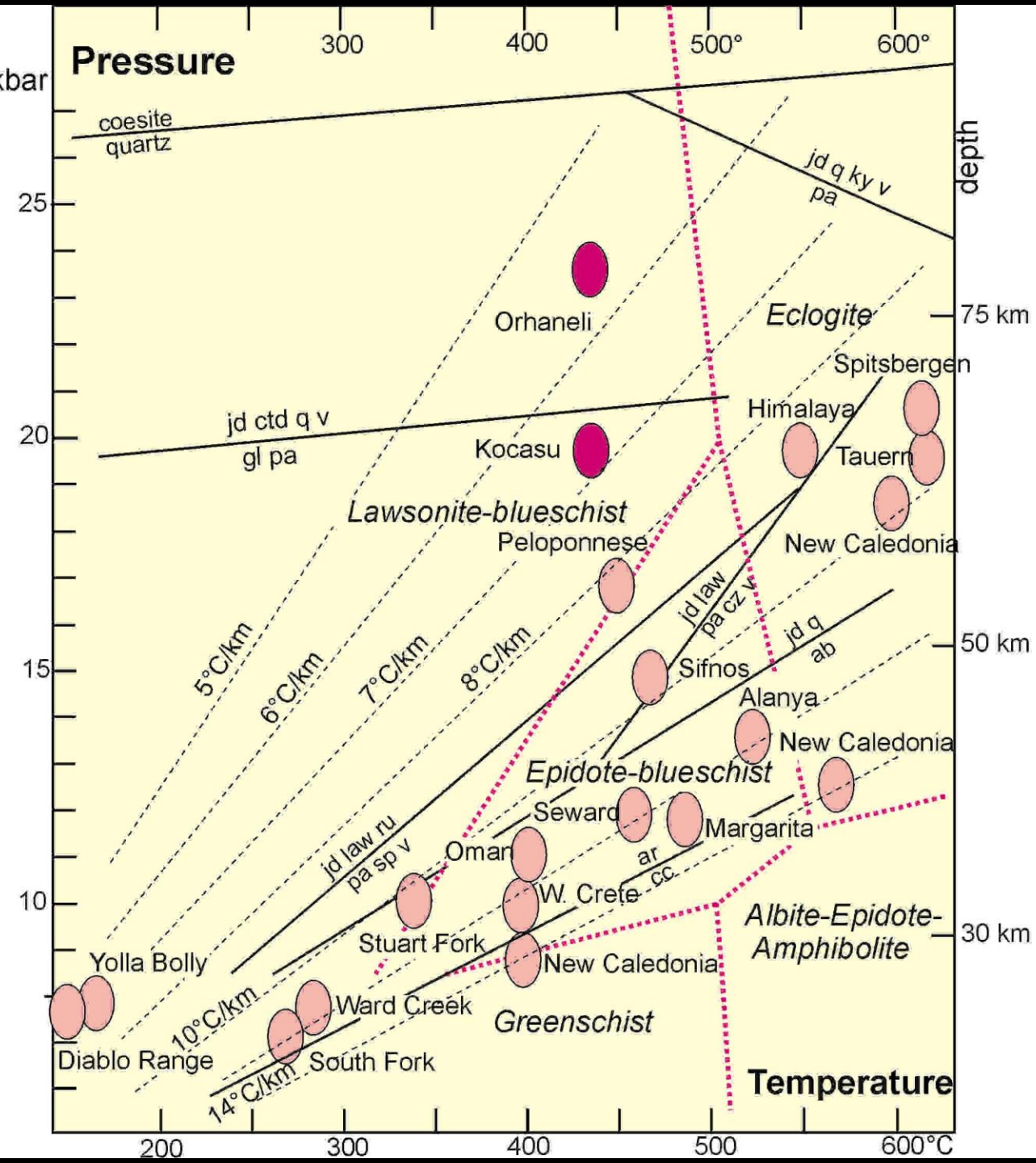

0.7mm

Mavişist metamorfizmasının basınç-sıcaklık koşulları

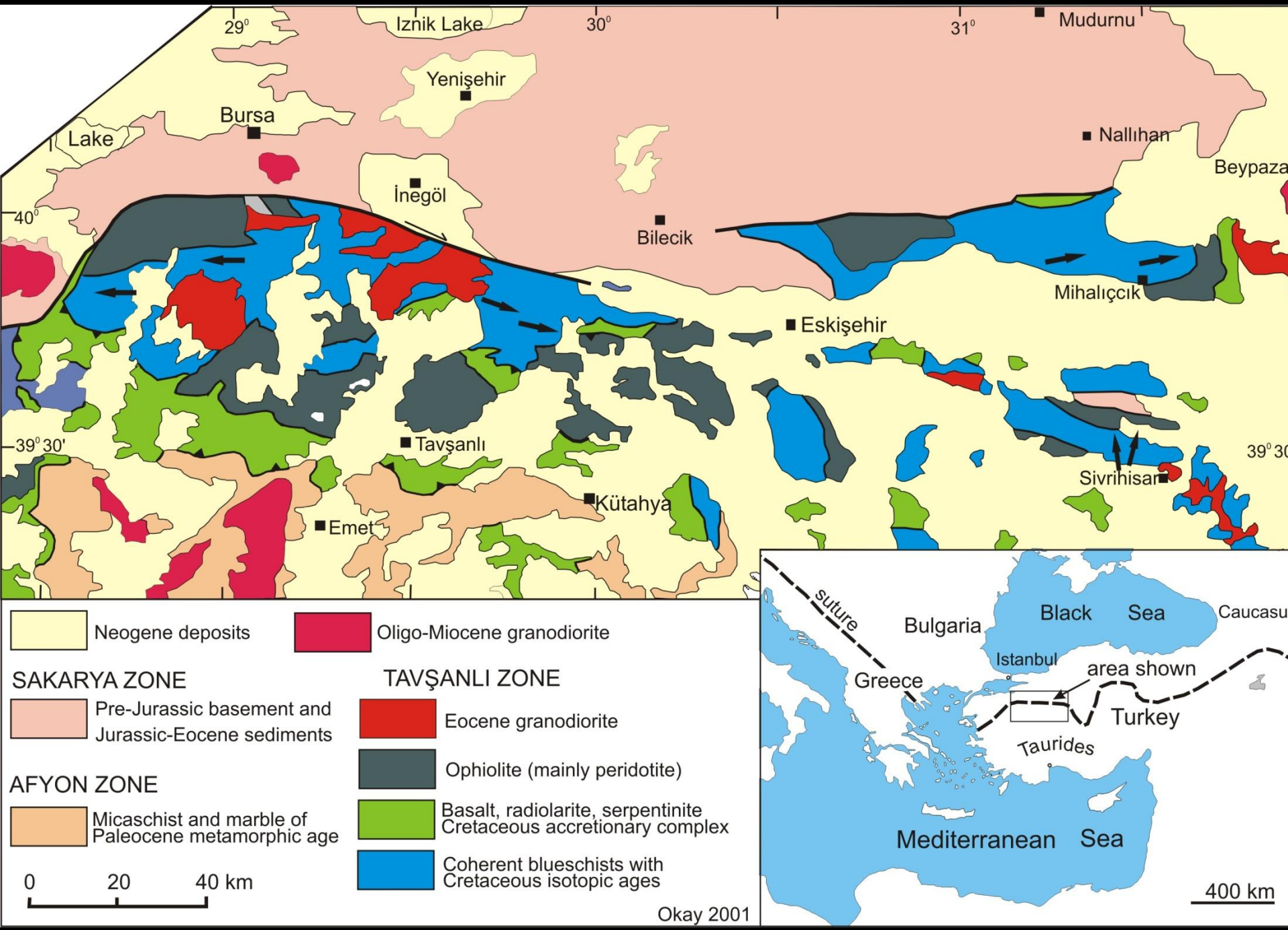




Pressure and temperature stimates of the blueschist facies conditions in the Orhaneli area, northwest Turkey (Okay, 2002)



Estimates of peak P-T conditions of various blueschist and eclogite terrains in the world with the respective geothermal gradients (Okay, 2002).


29°
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area shown
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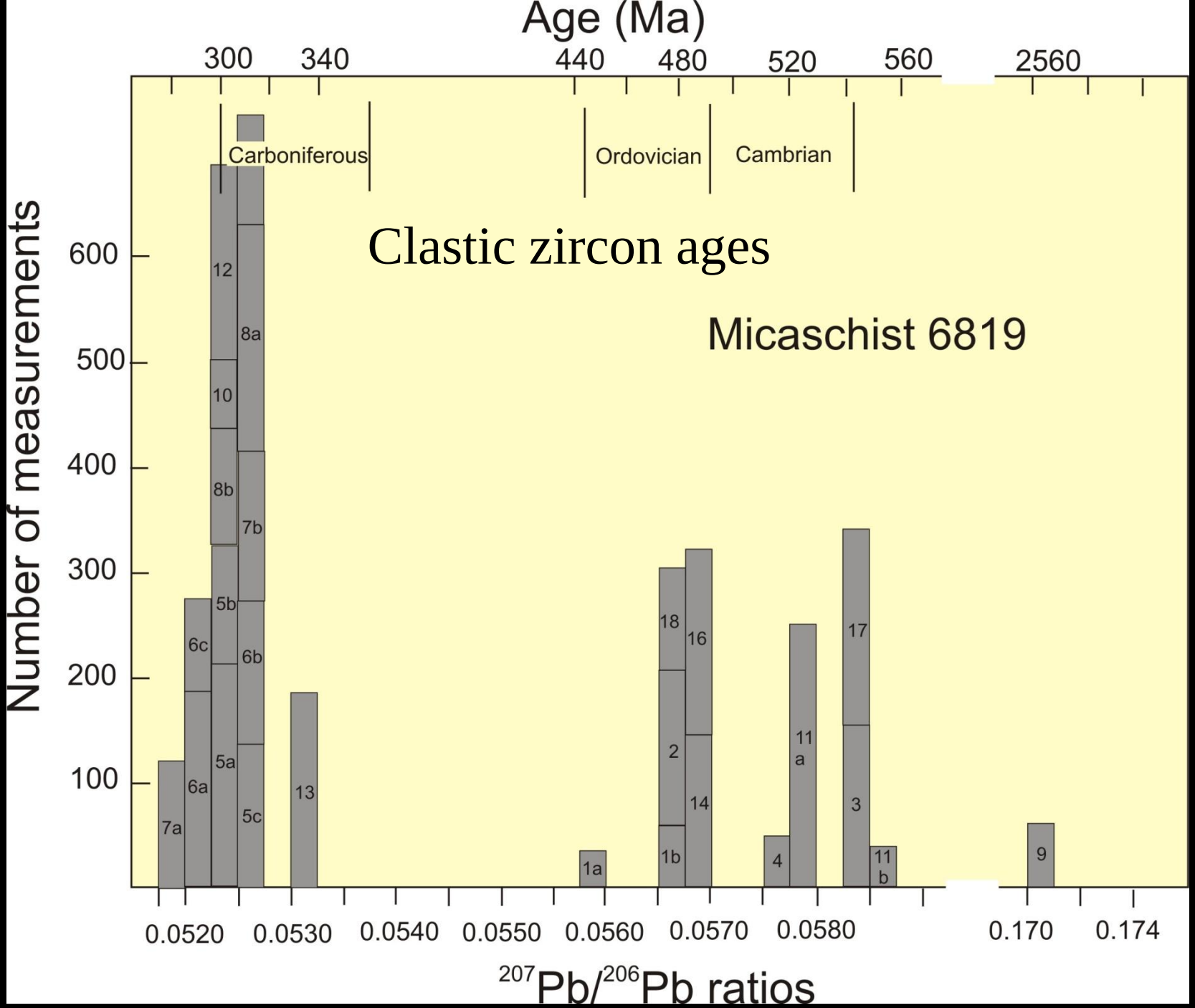
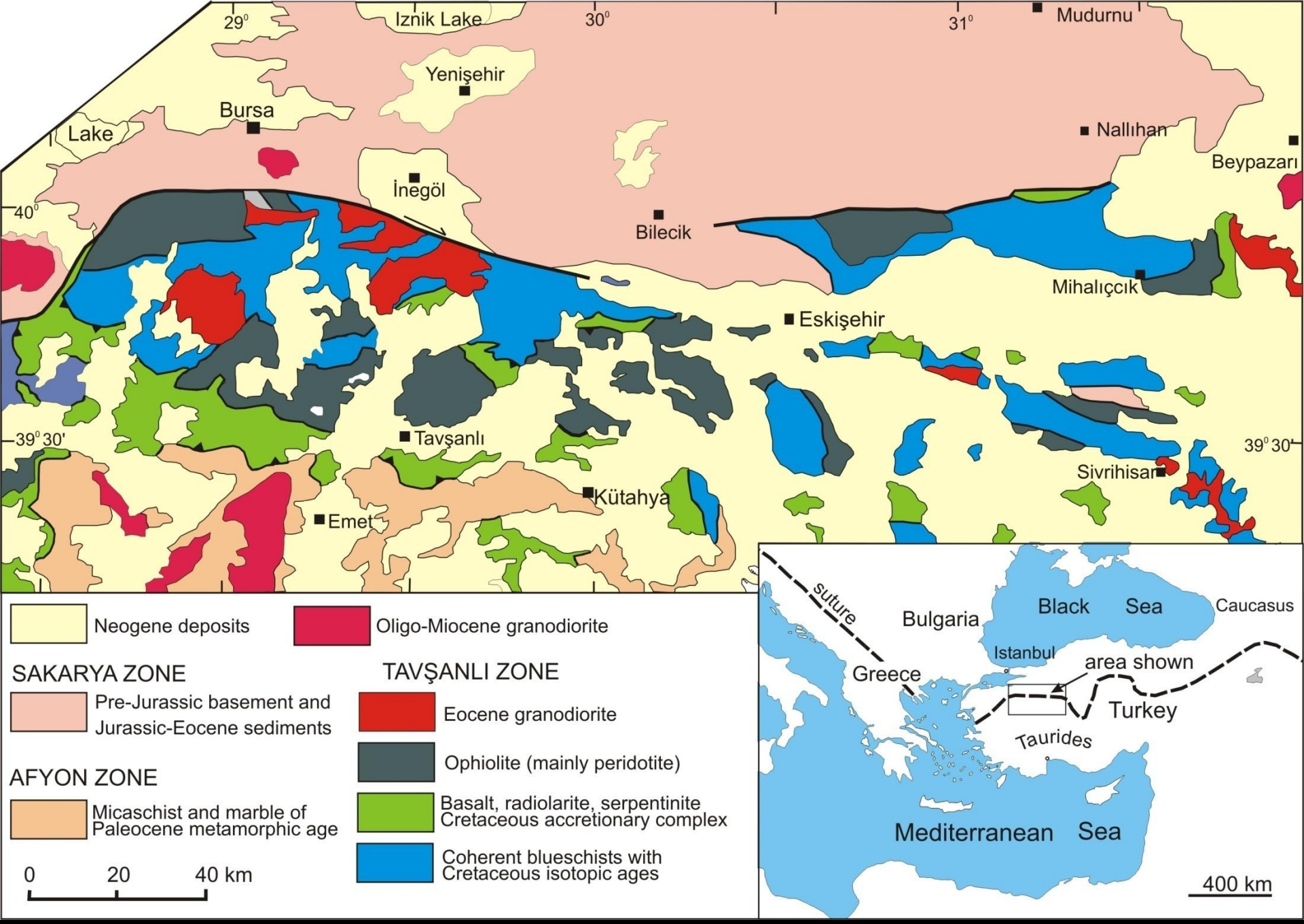
Turkey
Taurides
Mediterranean Sea
400 km

Düzenli mavişist istifinin (Orhaneli Grubu) yaşı

İlksel çökelme yaşı


Age (Ma)
300
340
440
480
520
560
2560
Carboniferous
Ordovician
Cambrian
Clastic zircon ages
Micaschist 6819
Number of measurements
600
500
400
300
200
100
12
8a
10
8b
7b
5b
6c
6b
5a
6a
7a
5c
13
1a
18
16
2
14
1b
4
11
a
17
3
11
b
9
0.0520
0.0530
0.0540
0.0550
0.0560
0.0570
0.0580
0.170
0.174
207Pb/206Pb ratios

Mavişist fasiyesi metamorfizmasının yaşı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Mediterranean Sea
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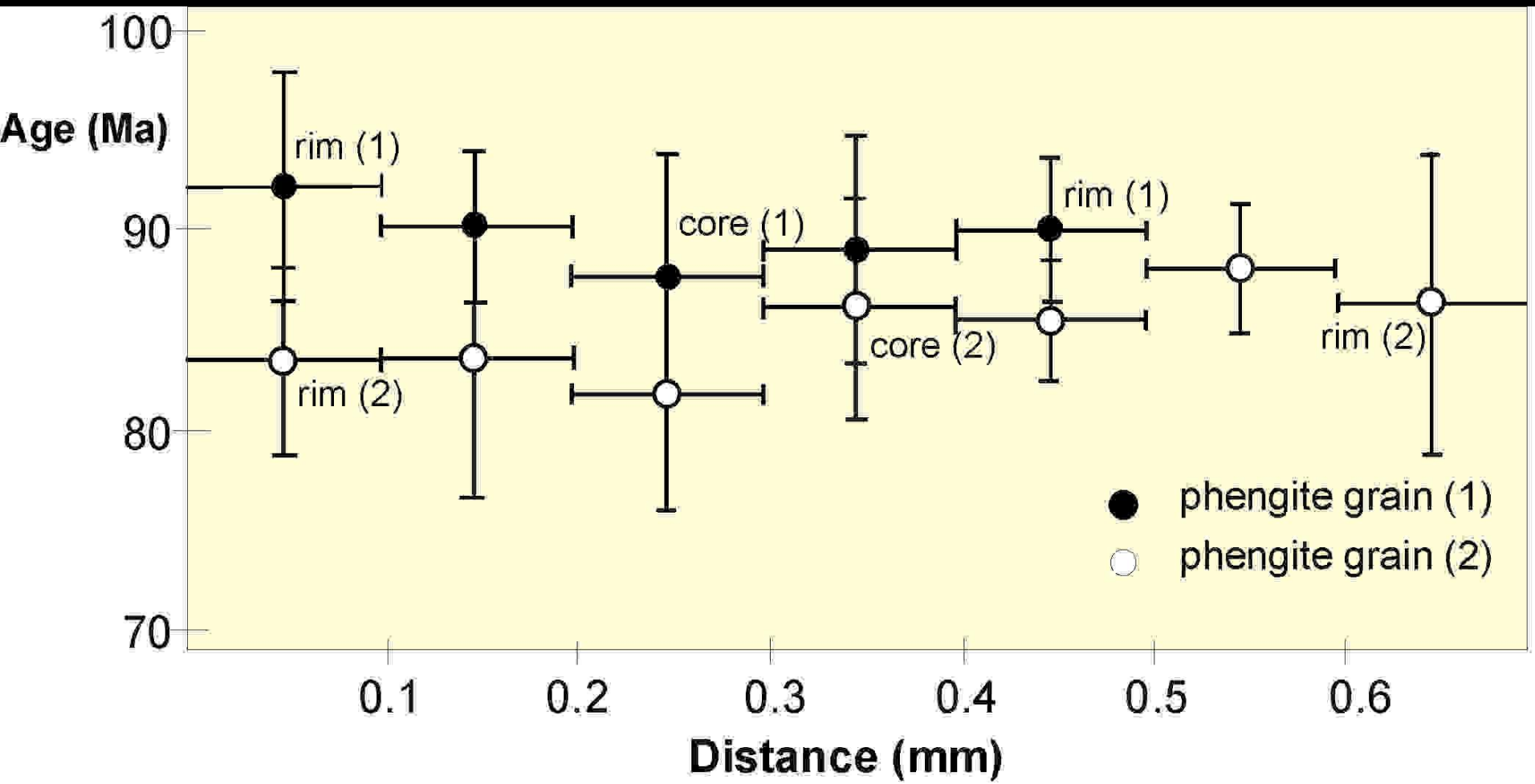
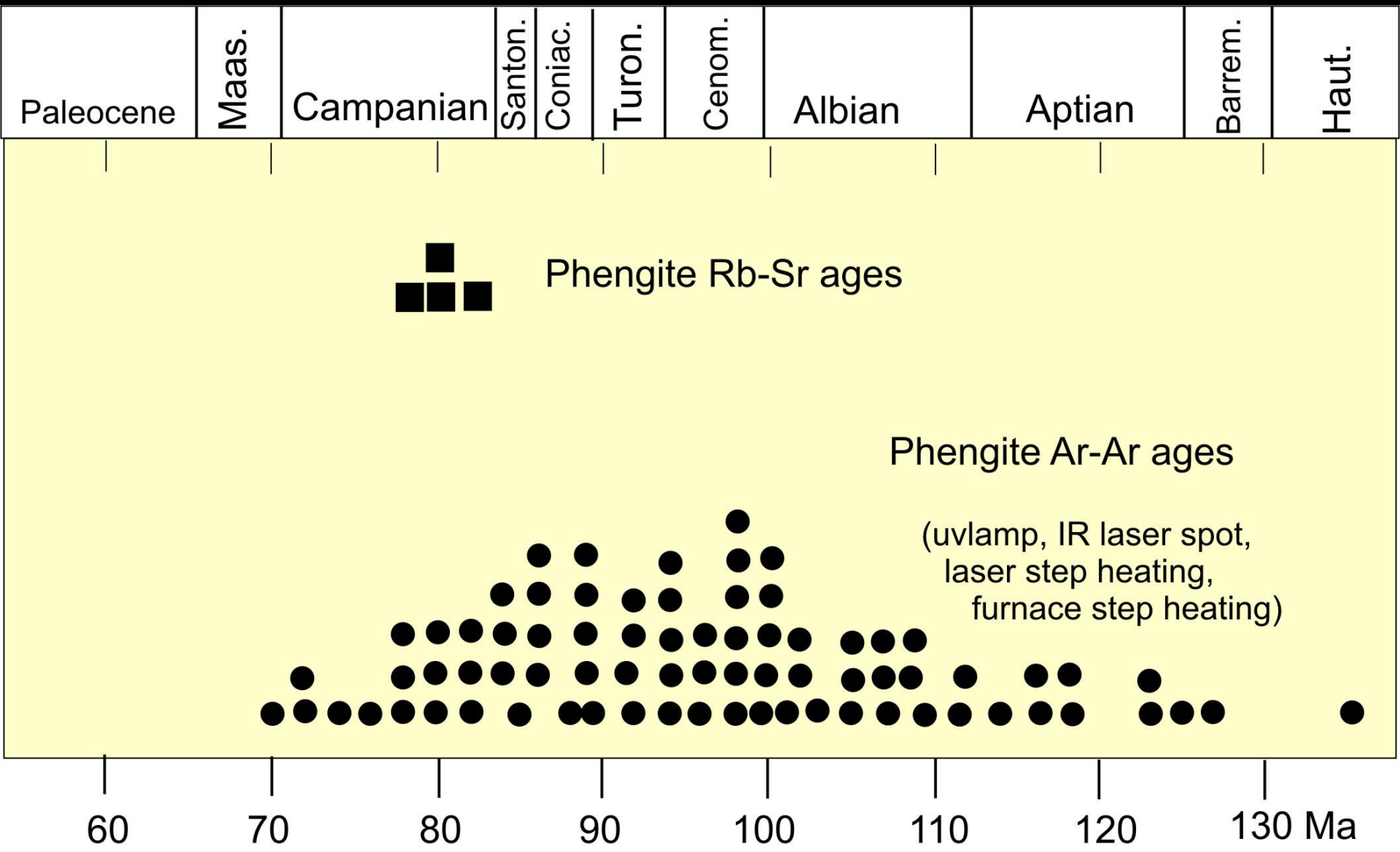
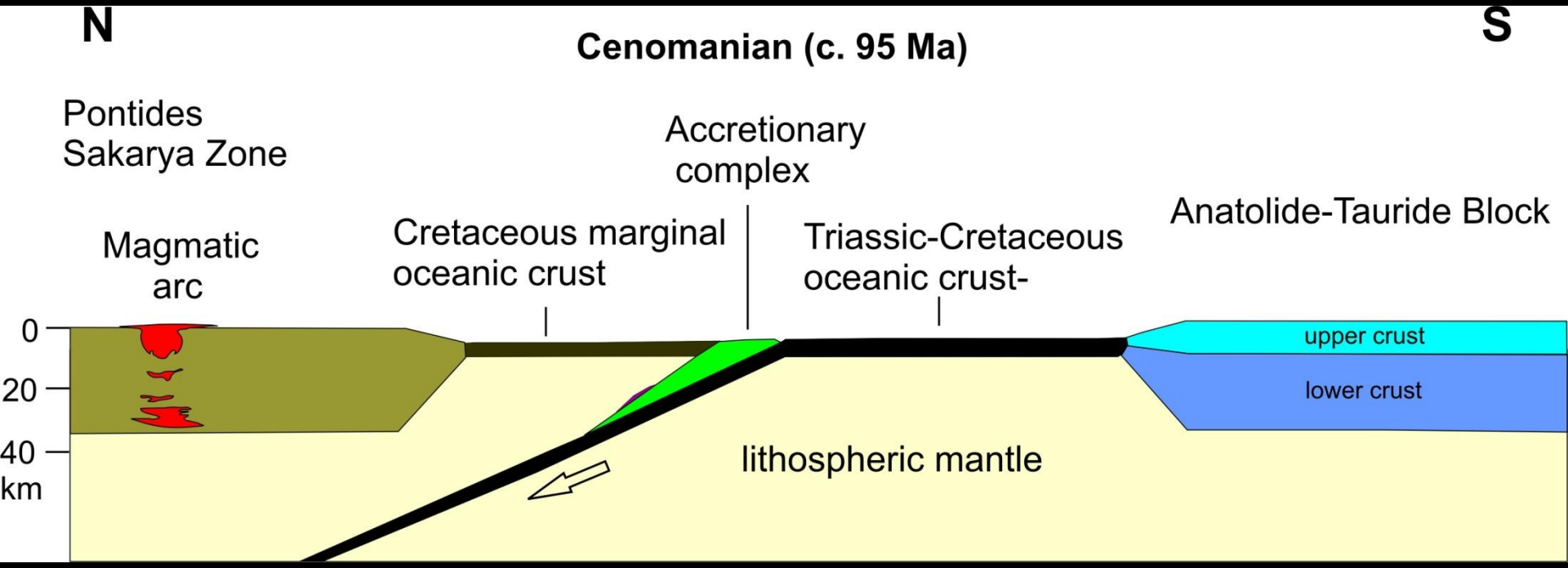


Argon laser ages obtained from two phengite grains from jadeite schist (Okay et al., 1998)



Phengite isotopic ages from the Tavşanlı Zone, Turkey
(Sherlock et al., 1999, Okay and Kelley, 1994)

Tektonik model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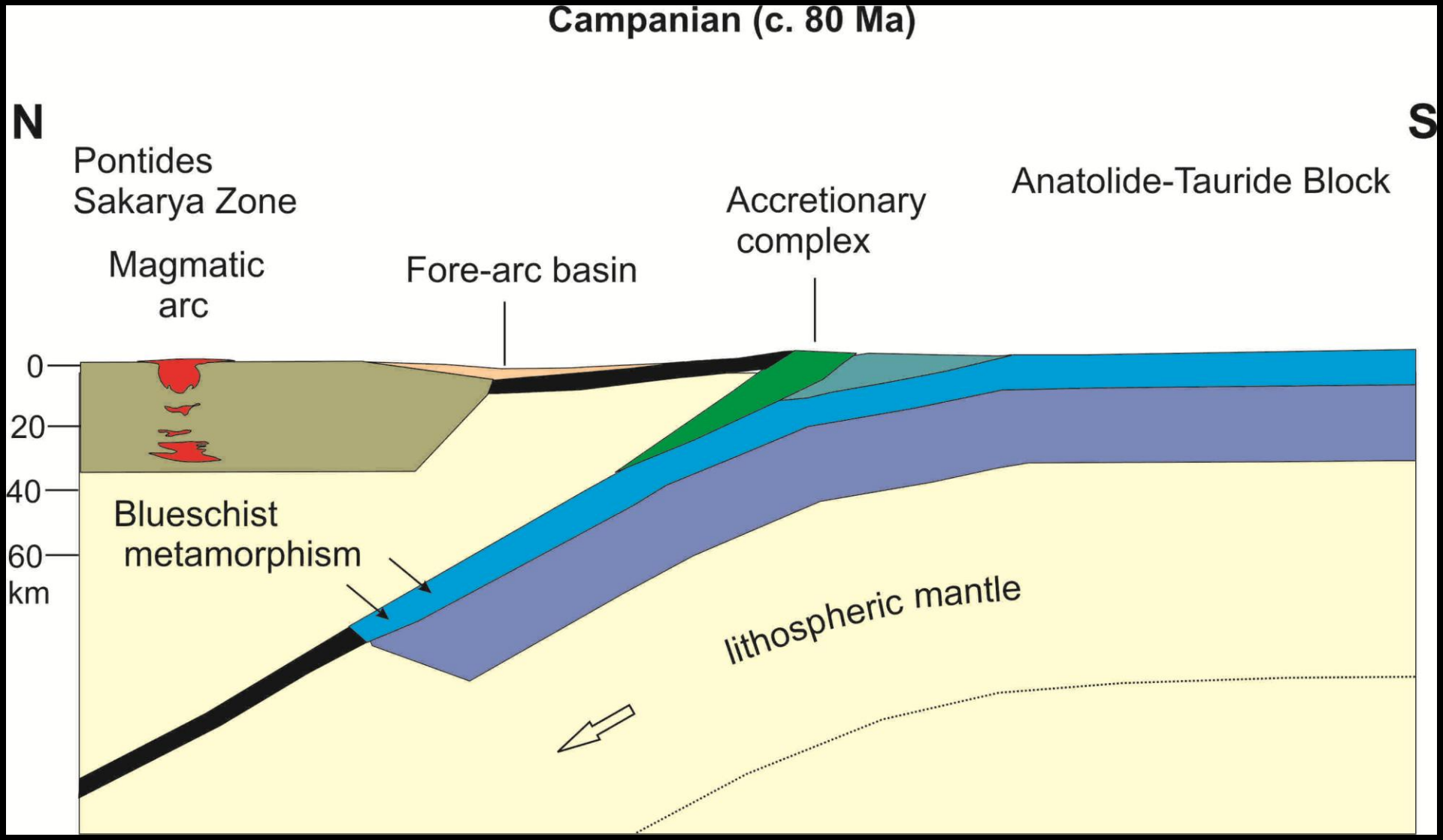
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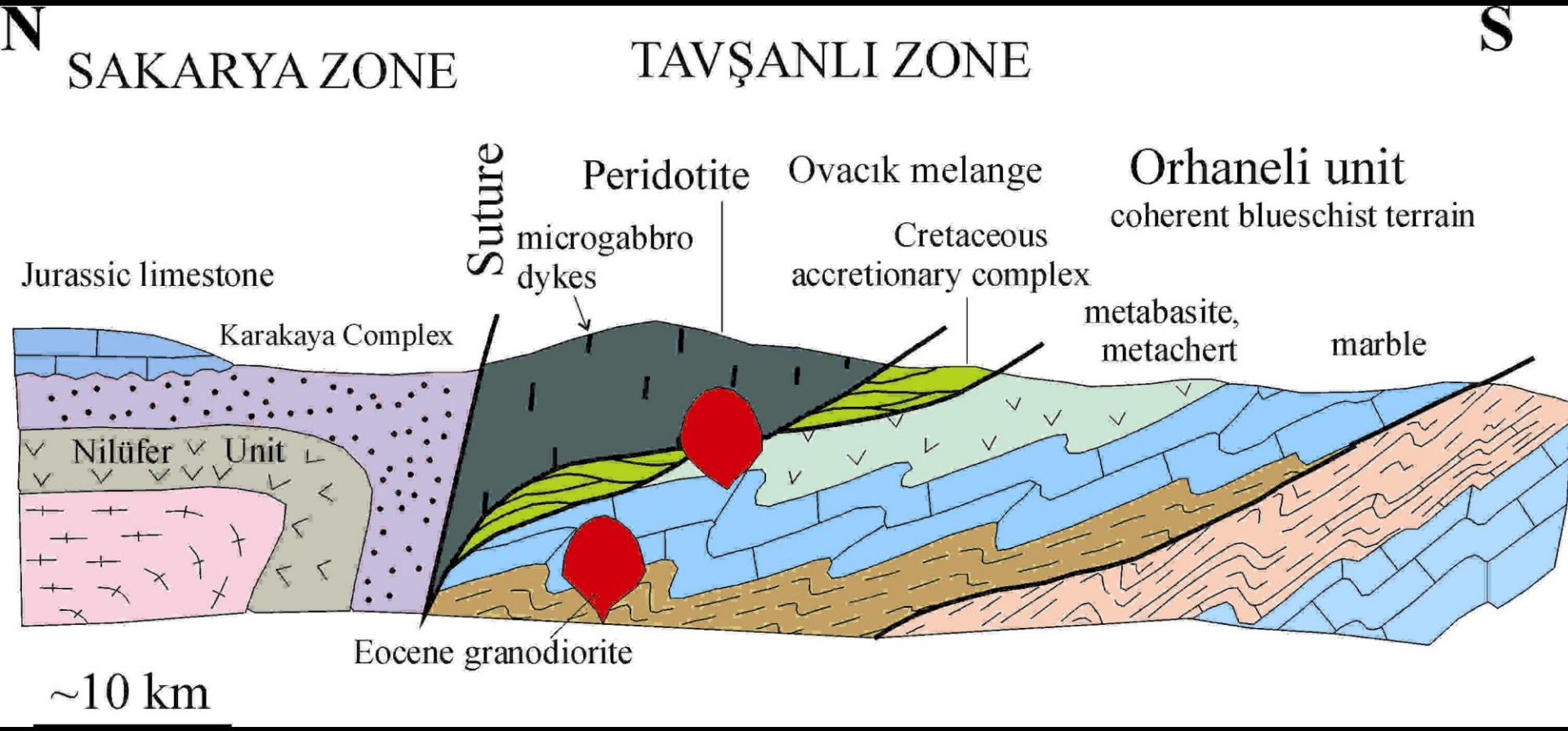
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Ovacık melange
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microgabbro
dykes
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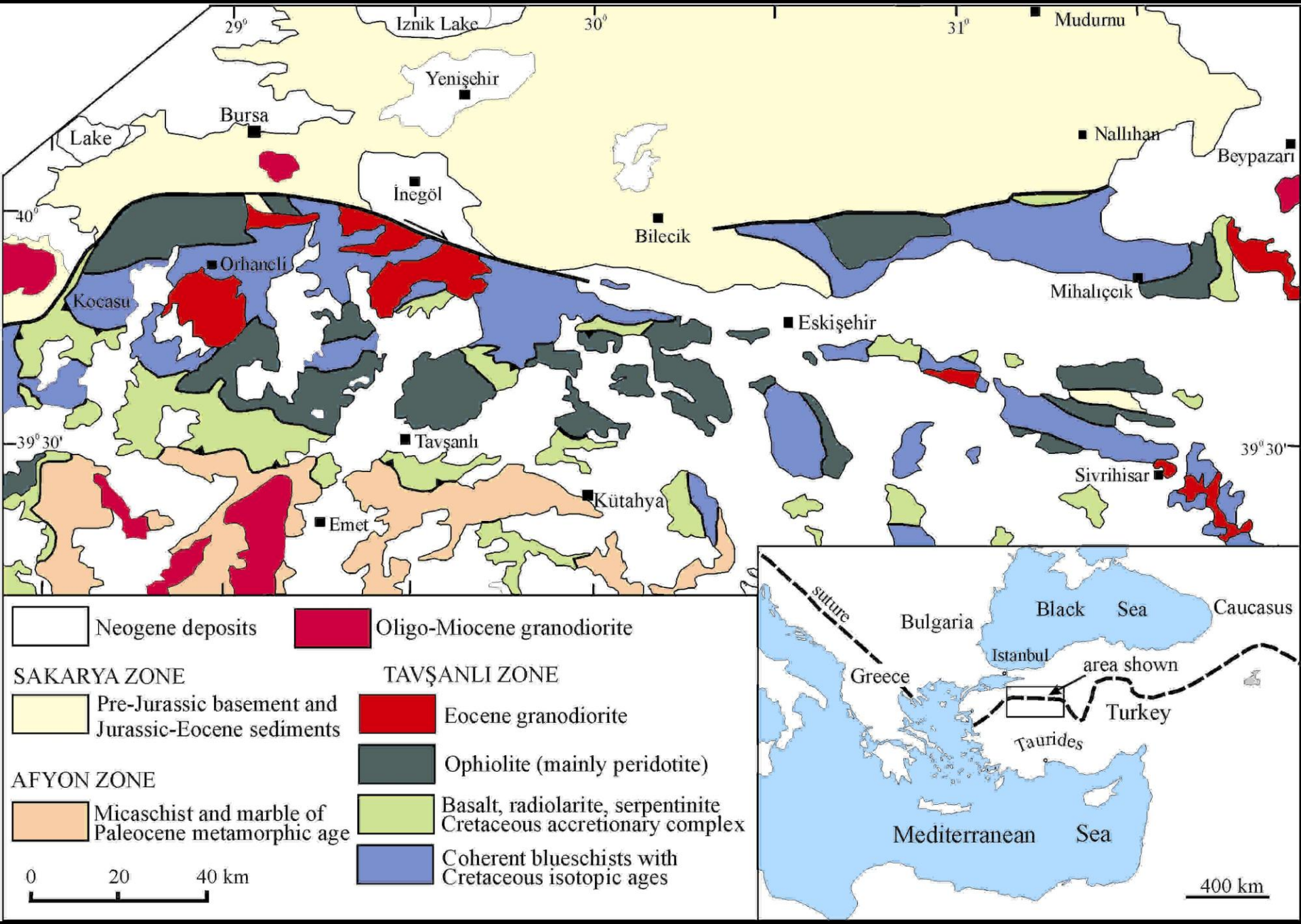
accretionary complex
Jurassic limestone
Karakaya Complex
metabasite,
metachert
marble
Nilüfer Unit
Eocene granodiorite
~10 km

Eklenir prizma
(Ofiyolitli melanj)

Tetis okyanusu üst kabuk kesimlerinden oluşmuş bir dalma-batma kompleksi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Yenişehir
Bursa
Lake
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Beypazarı
İnegöl
40°
Bilecik
Orhaneli
Kocasu
Mihalıççık
Eskişehir
39°30'
Tavşanlı
39°30'
Sivrihisar
Kütahya
Emet
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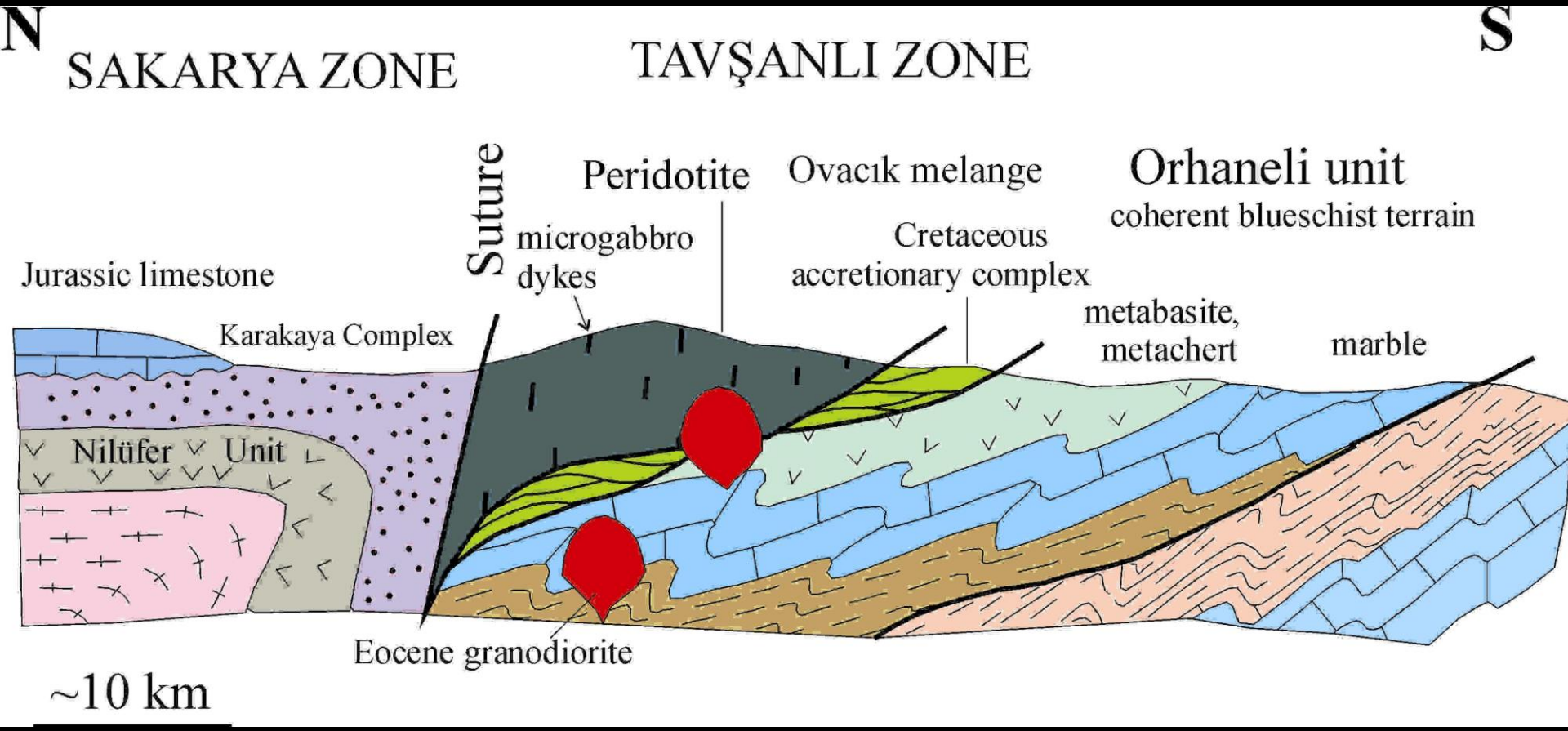
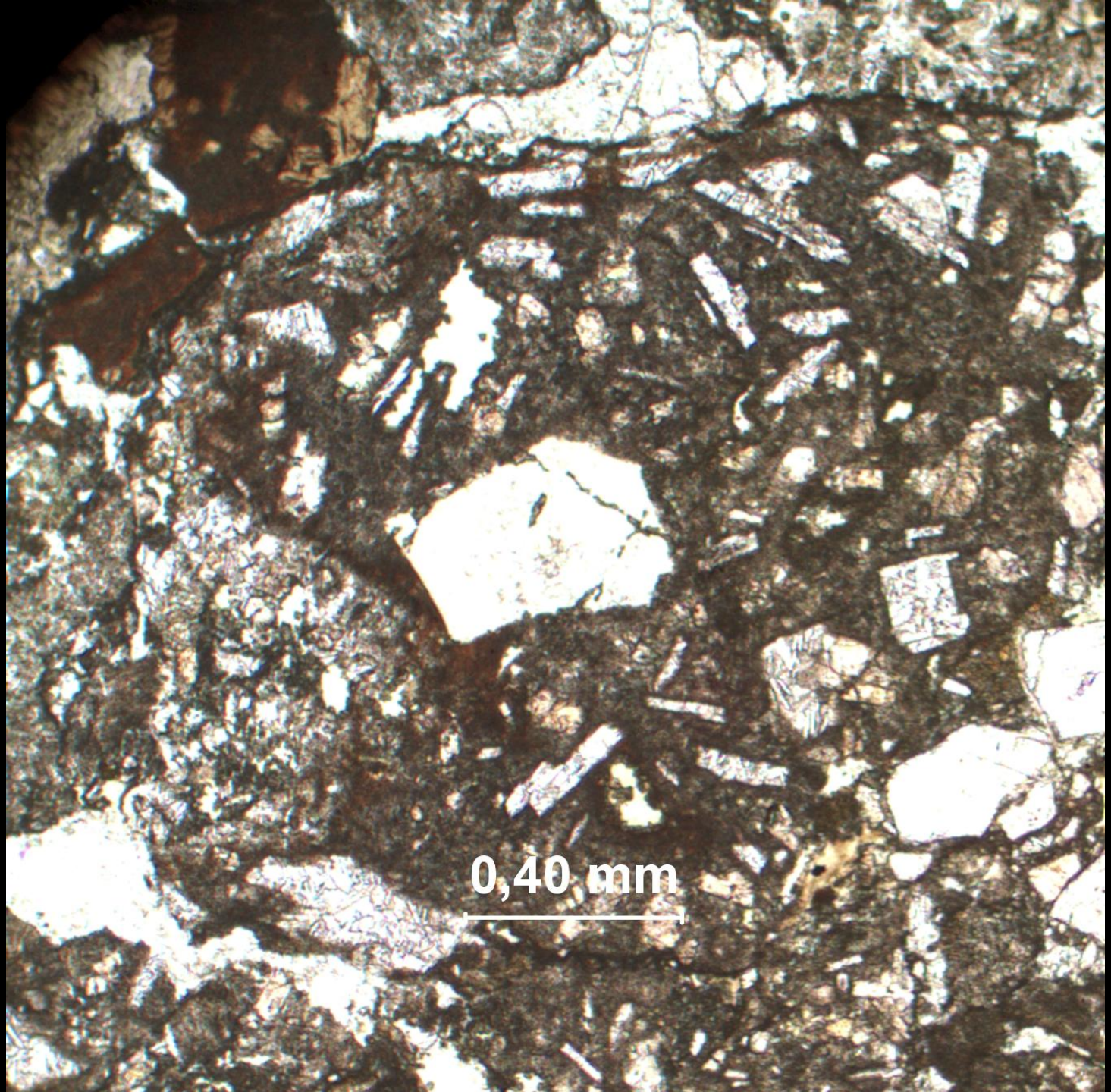
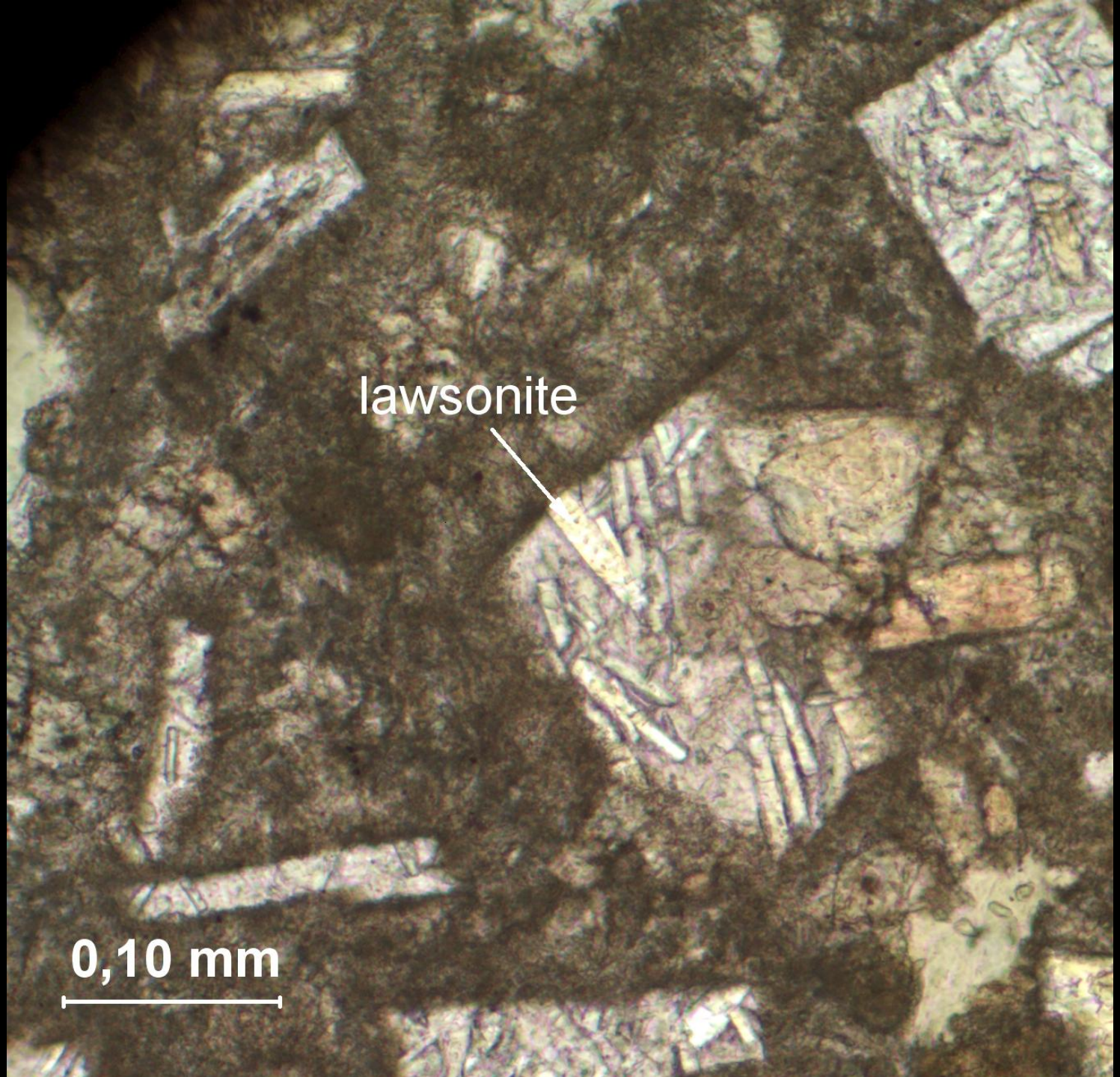
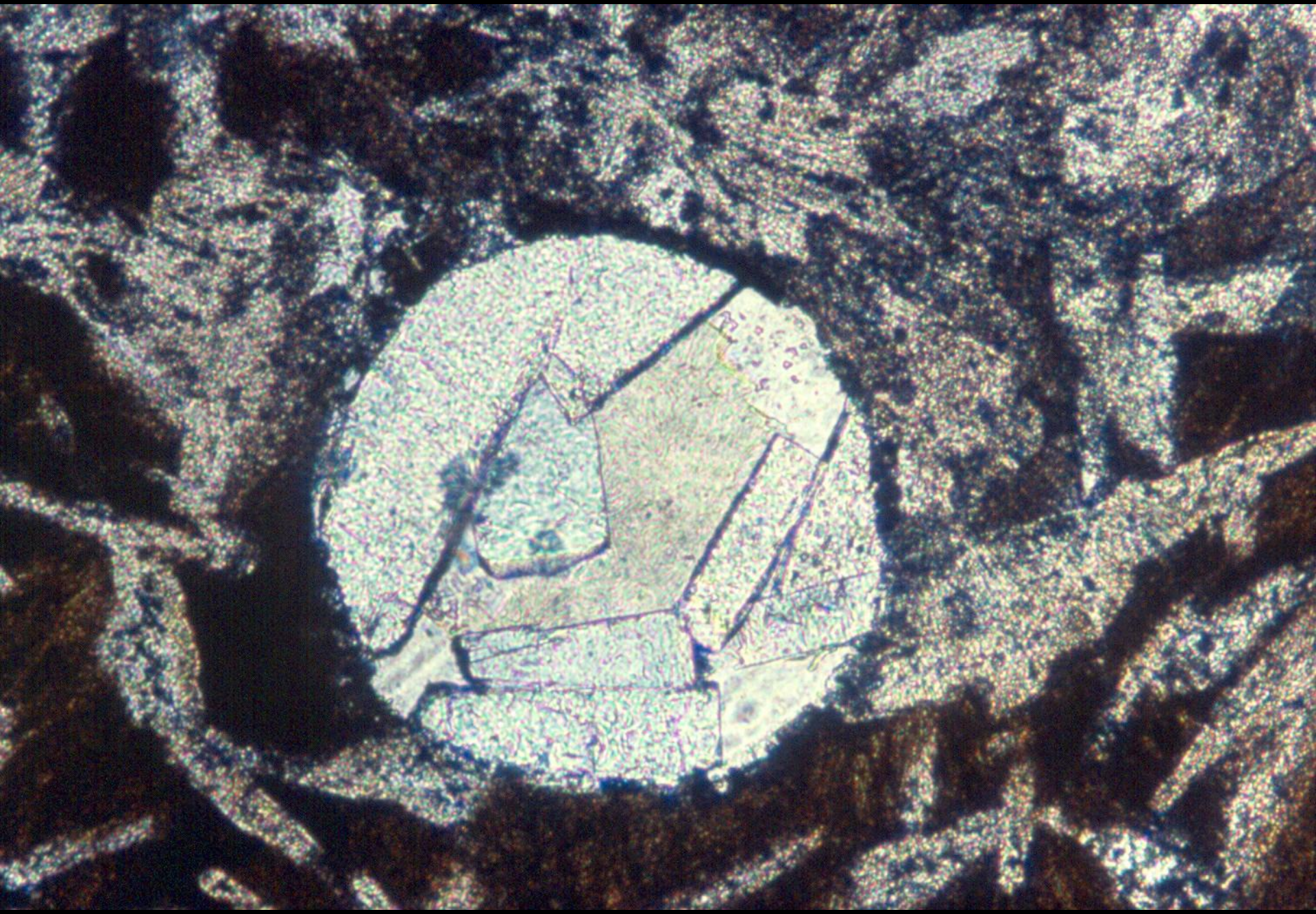
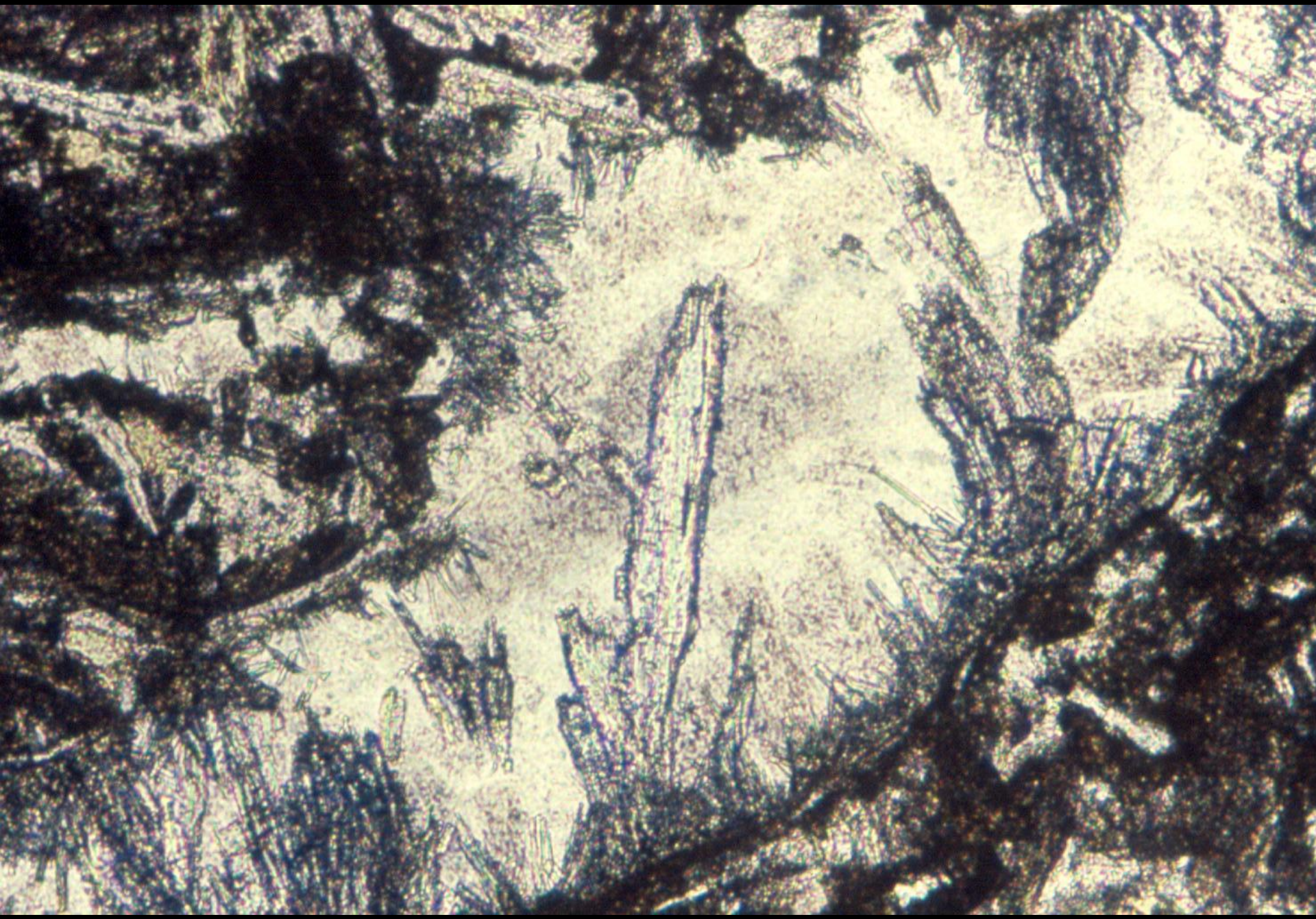
Mediterranean Sea
400 km

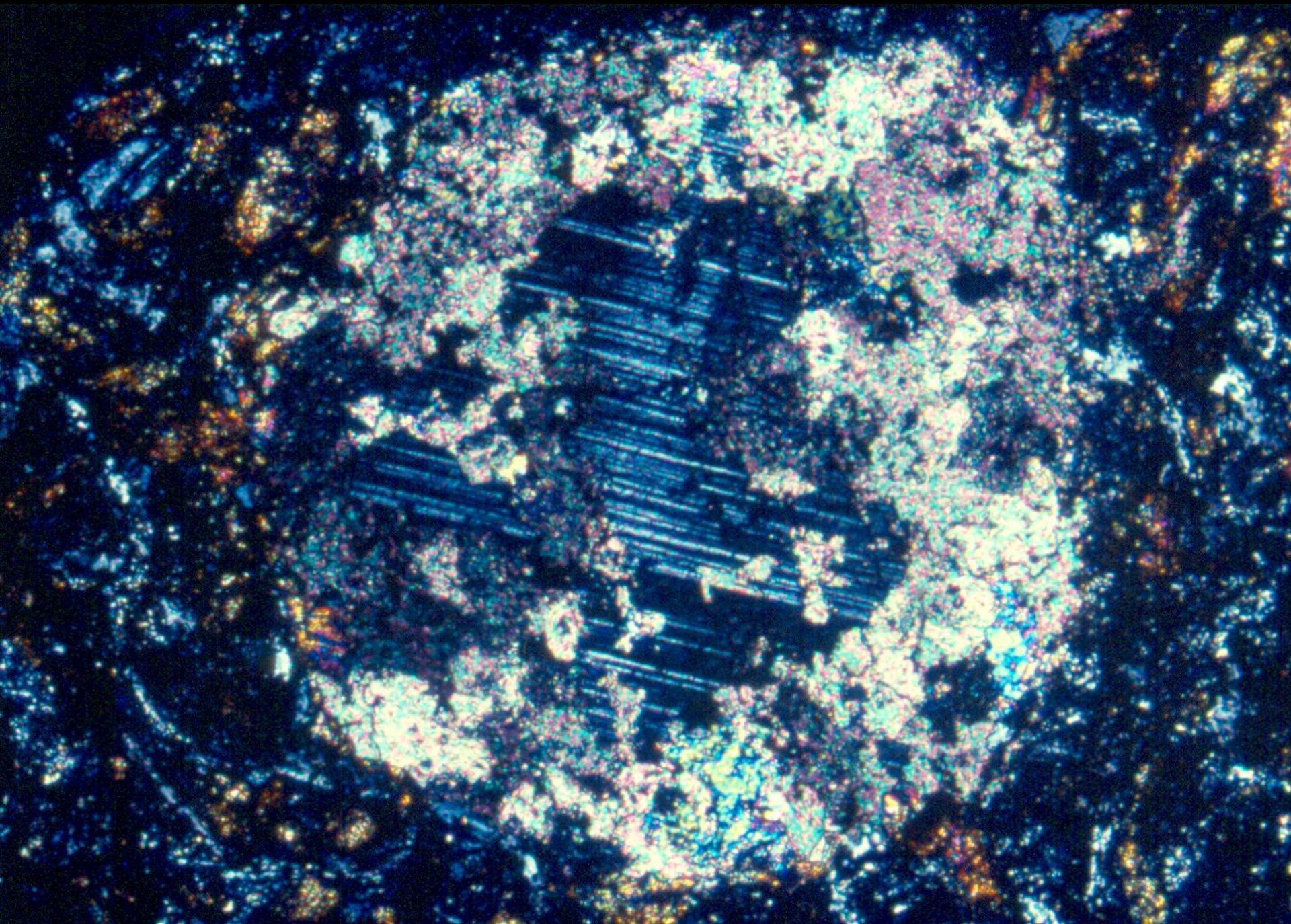

N
S
SAKARYA ZONE
TAVŞANLI ZONE
Suture
Peridotite
Ovacık melange
Orhaneli unit
coherent blueschist terrain
microgabbro
dykes
Cretaceous
accretionary complex
Jurassic limestone
Karakaya Complex
metabasite,
metachert
marble
Nilüfer Unit
Eocene granodiorite
~10 km


0,40 mm

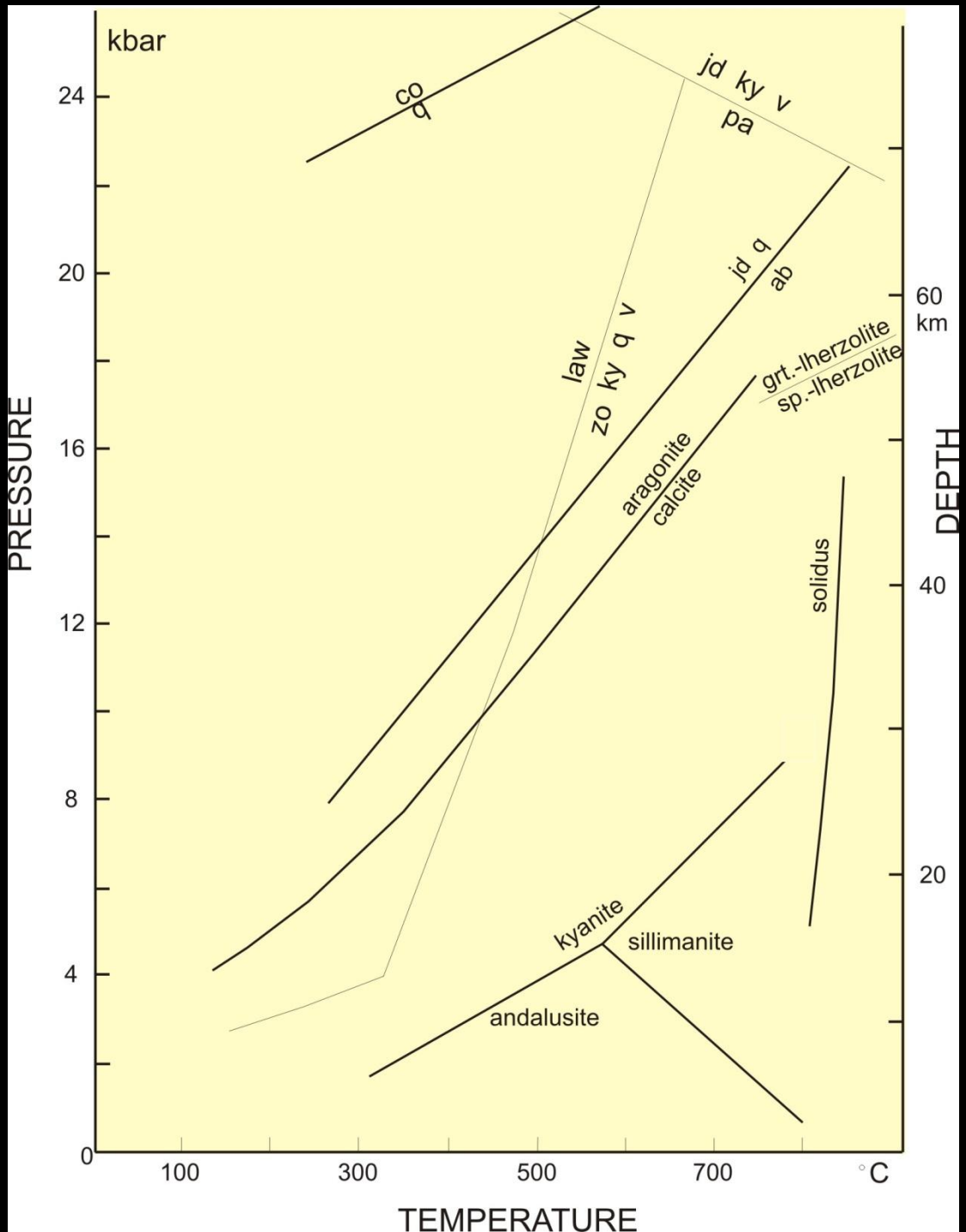

lawsonite
0,10 mm







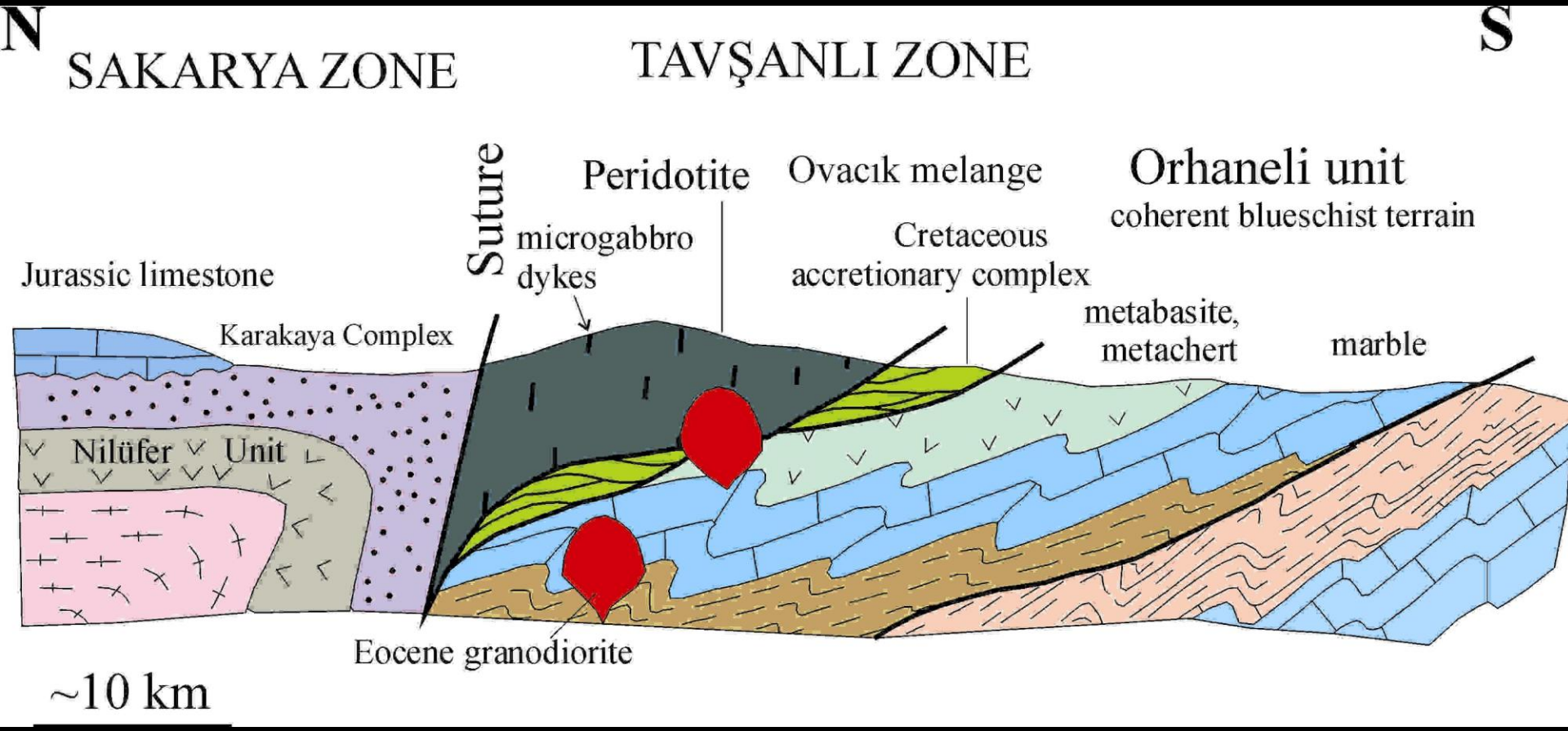
Kısmen aragonitleşmiş mikritik kireçtaşları

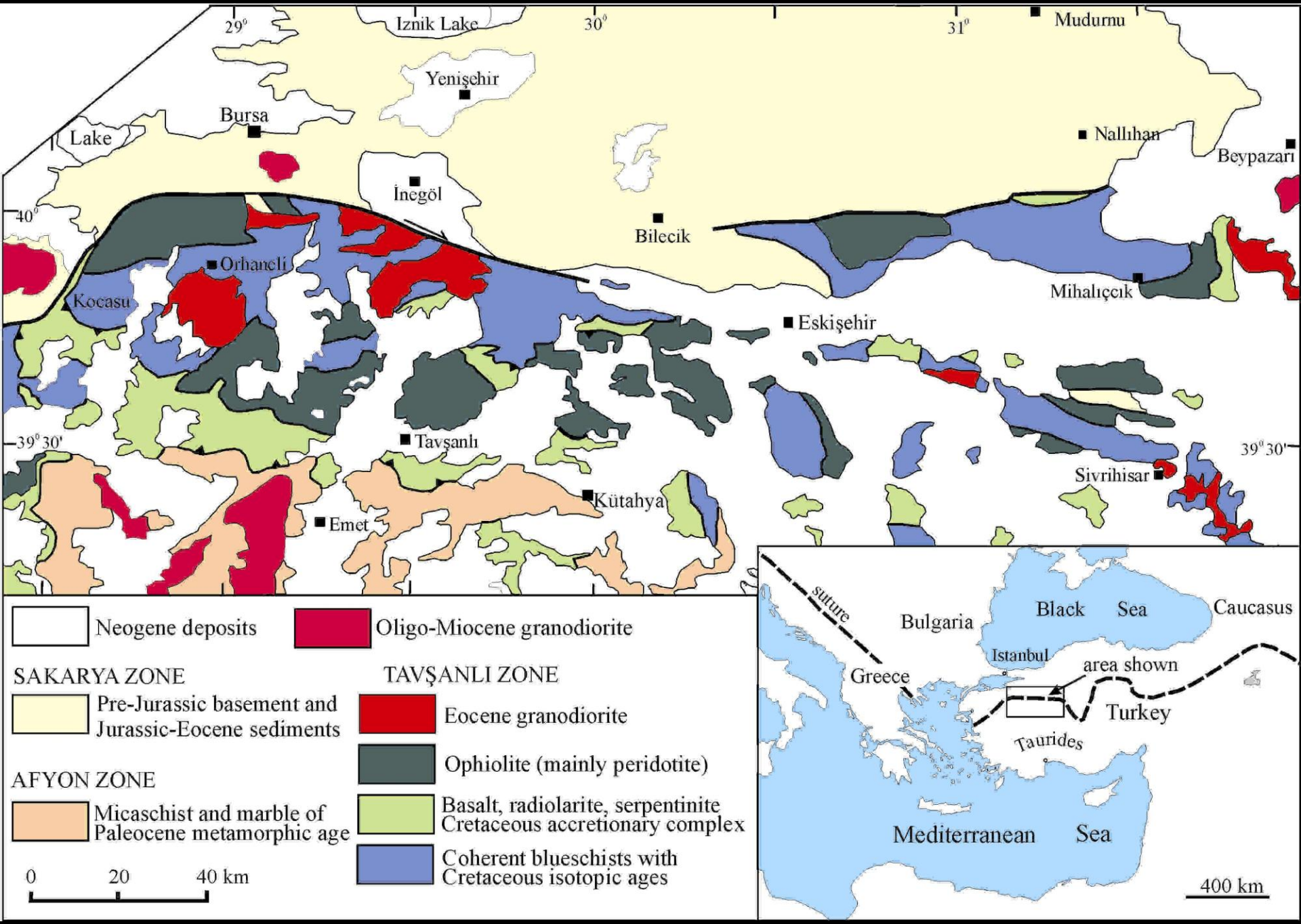

kbar
PRESSURE
24
20
16
12
8
4
0
co
q
jd ky v
pa
jd q
ab
law
zo ky q v
grt.-lherzolite
sp.-lherzolite
aragonite
calcite
solidus
kyanite
sillimanite
andalusite
60
km
40
20
DEPTH
100
300
500
700
°C
TEMPERATURE

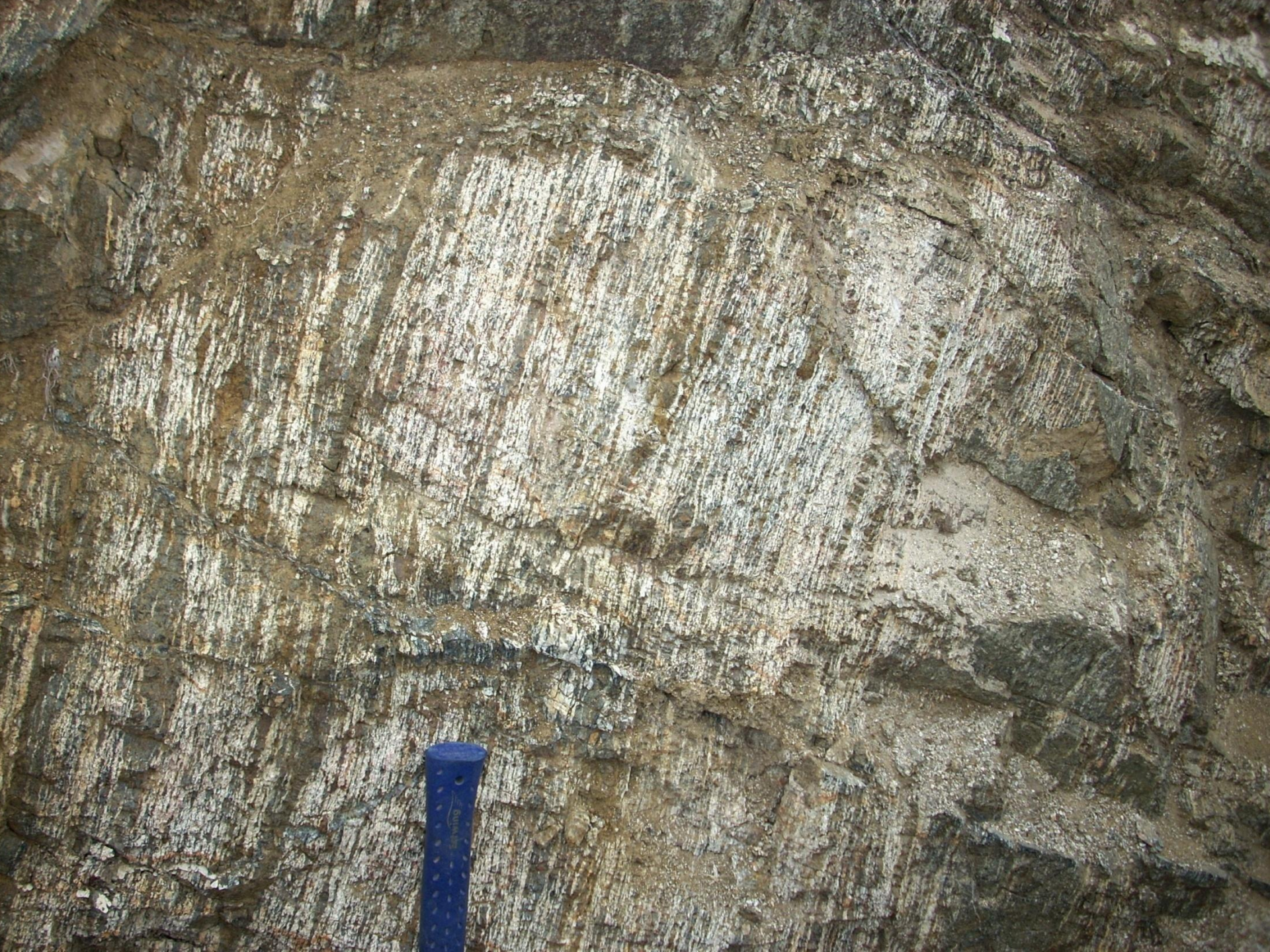

Estwing

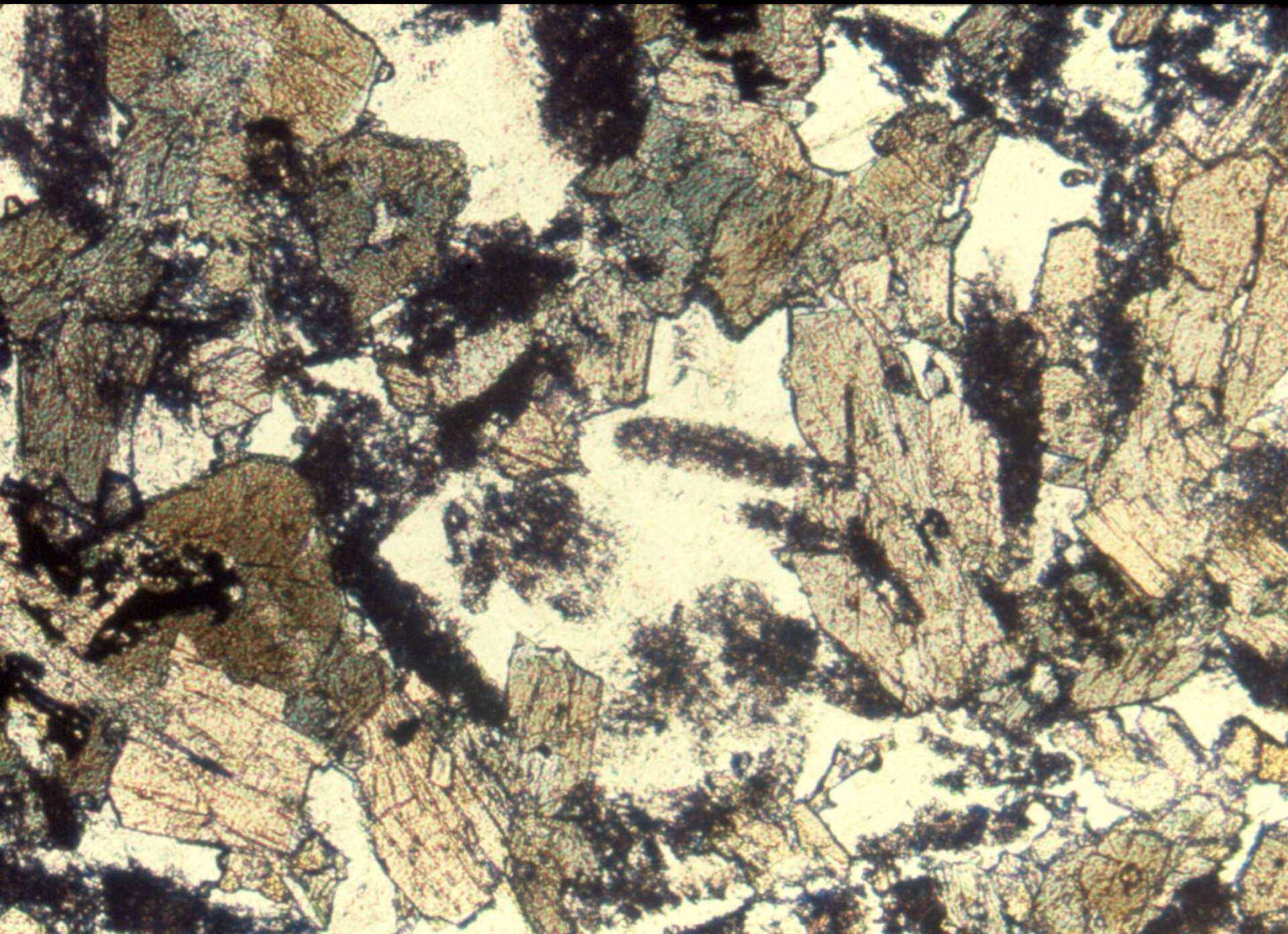
Peridotit
(Ofiyolit)

Tetis okyanusu üst mantosunu temsil eden ultramafik kayalar, az oranda gabro ve diyabaz daykı


N
S
SAKARYA ZONE
TAVŞANLI ZONE
Suture
Peridotite
Ovacık melange
Orhaneli unit
coherent blueschist terrain
microgabbro
dykes
Cretaceous
accretionary complex
Jurassic limestone
Karakaya Complex
metabasite,
metachert
marble
Nilüfer Unit
Eocene granodiorite
~10 km

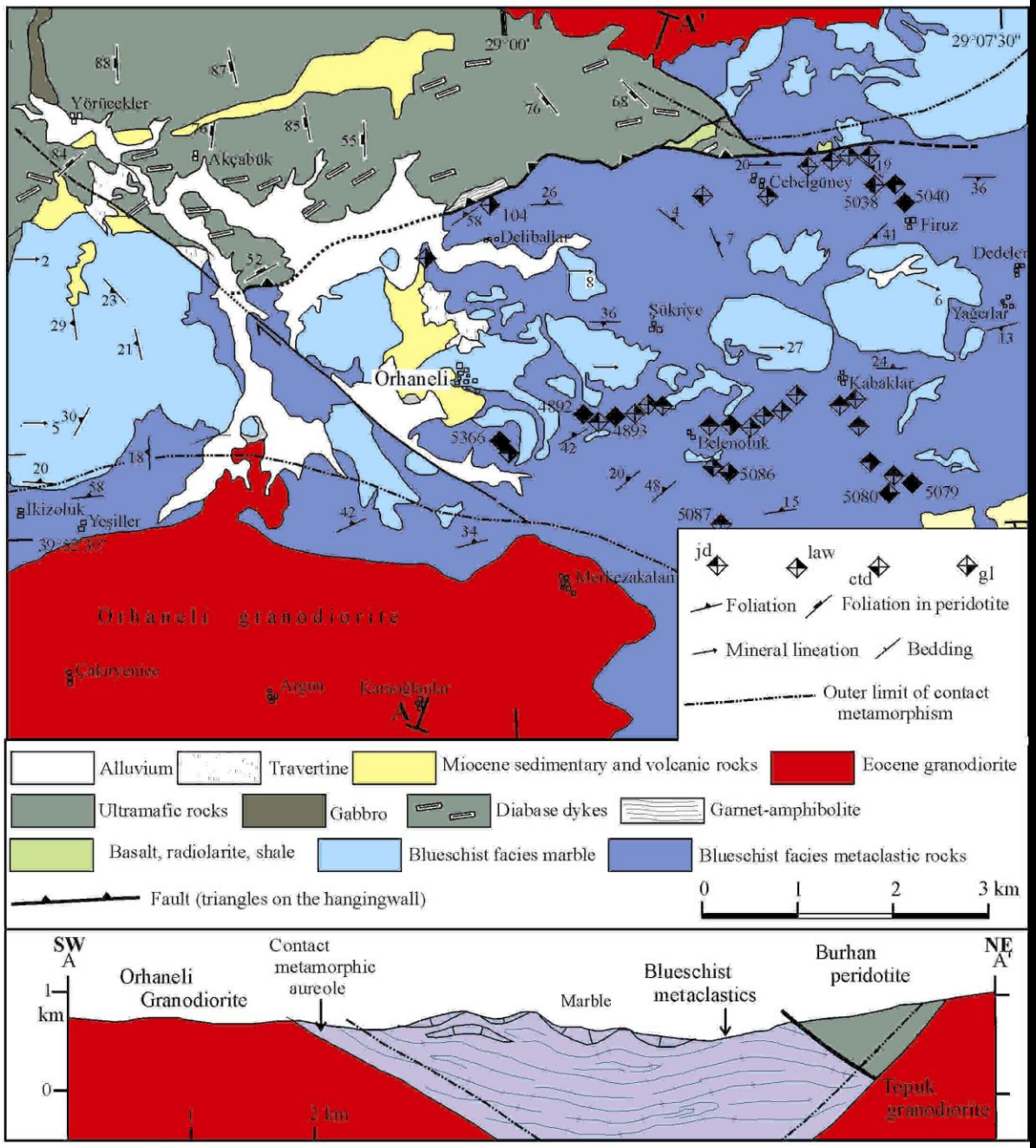

29°
30°
31°
Iznik Lake
Mudurnu
Yenişehir
Bursa
Lake
Nallıhan
Beypazarı
İnegöl
40°
Bilecik
Orhaneli
Kocasu
Mihalıççık
Eskişehir
39°30'
Tavşanlı
39°30'
Sivrihisar
Kütahya
Emet
Neogene deposits
Oligo-Miocene granodiorite
SAKARYA ZONE
Pre-Jurassic basement and Jurassic-Eocene sediments
AFYON ZONE
Micaschist and marble of Paleocene metamorphic age
TAVŞANLI ZONE
Eocene granodiorite
Ophiolite (mainly peridotite)
Basalt, radiolarite, serpentinite Cretaceous accretionary complex
Coherent blueschists with Cretaceous isotopic ages
0
20
40 km
suture
Bulgaria
Black Sea
Caucasus
Istanbul
area shown
Greece
Turkey
Taurides
Mediterranean Sea
400 km



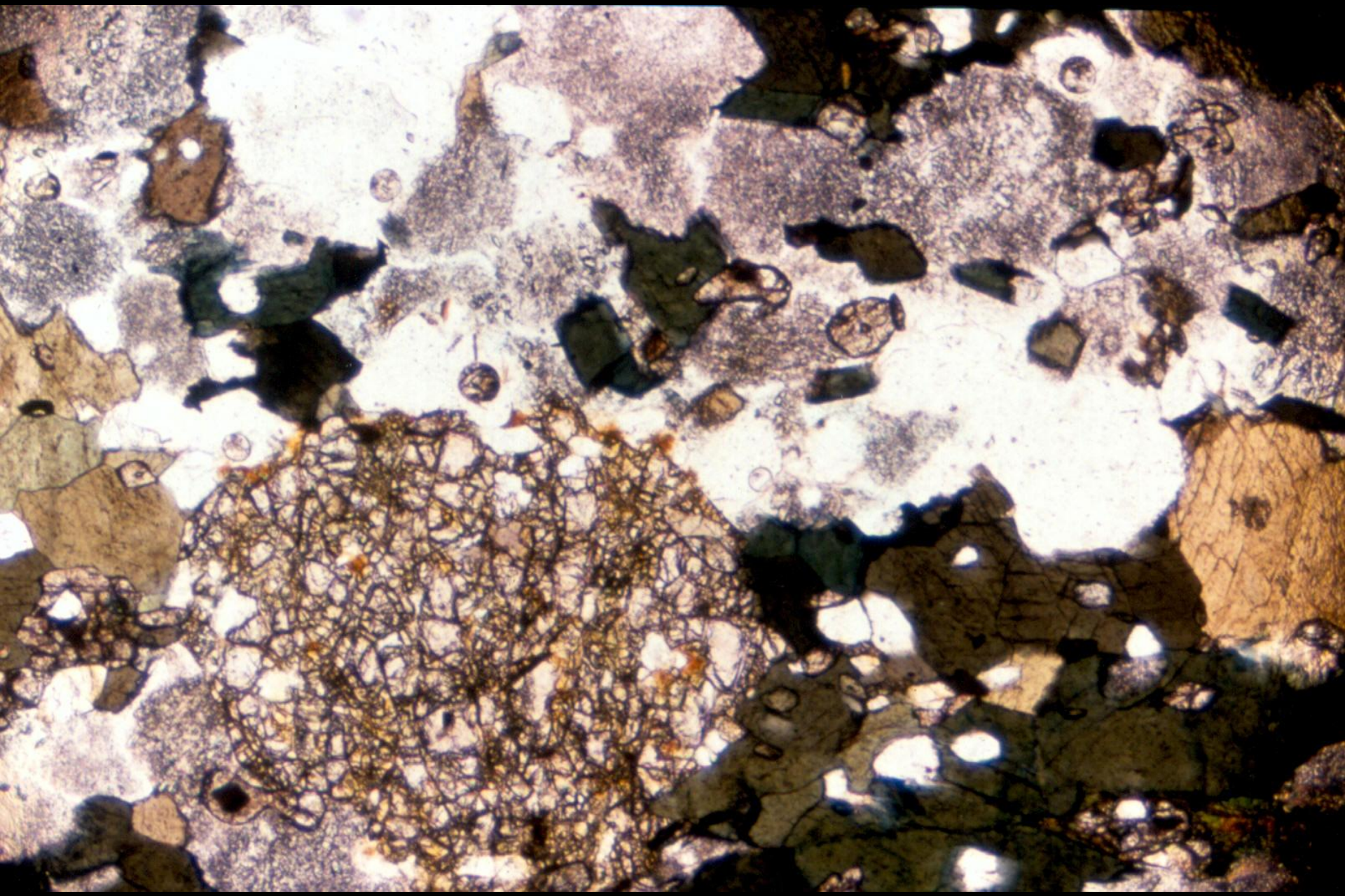


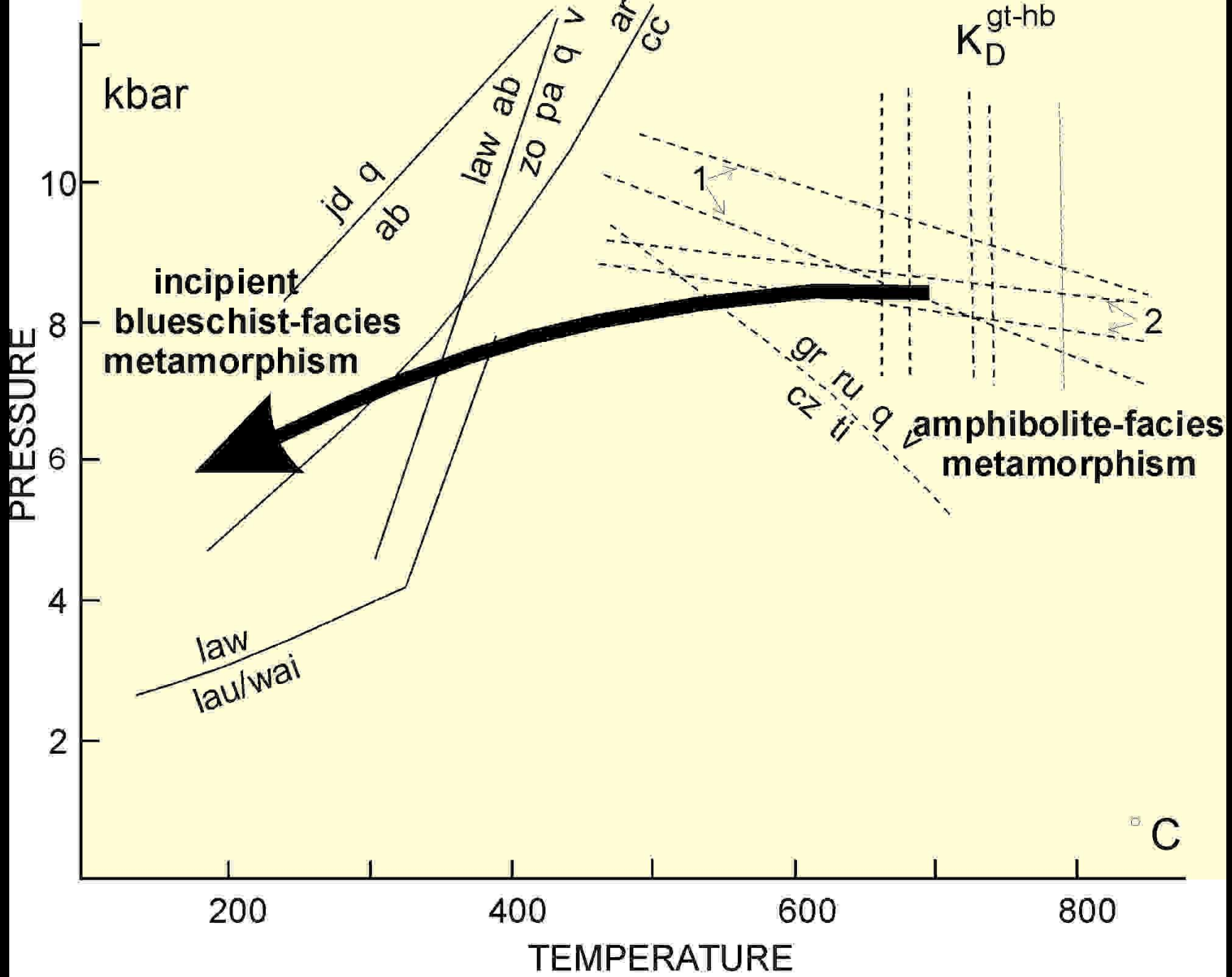
Ofiyolit tabanı metamorfitleri

Ofiyolit üzerlemesinin ilk aşamasında ofiyolitin tabanında gelişen metamorfitler

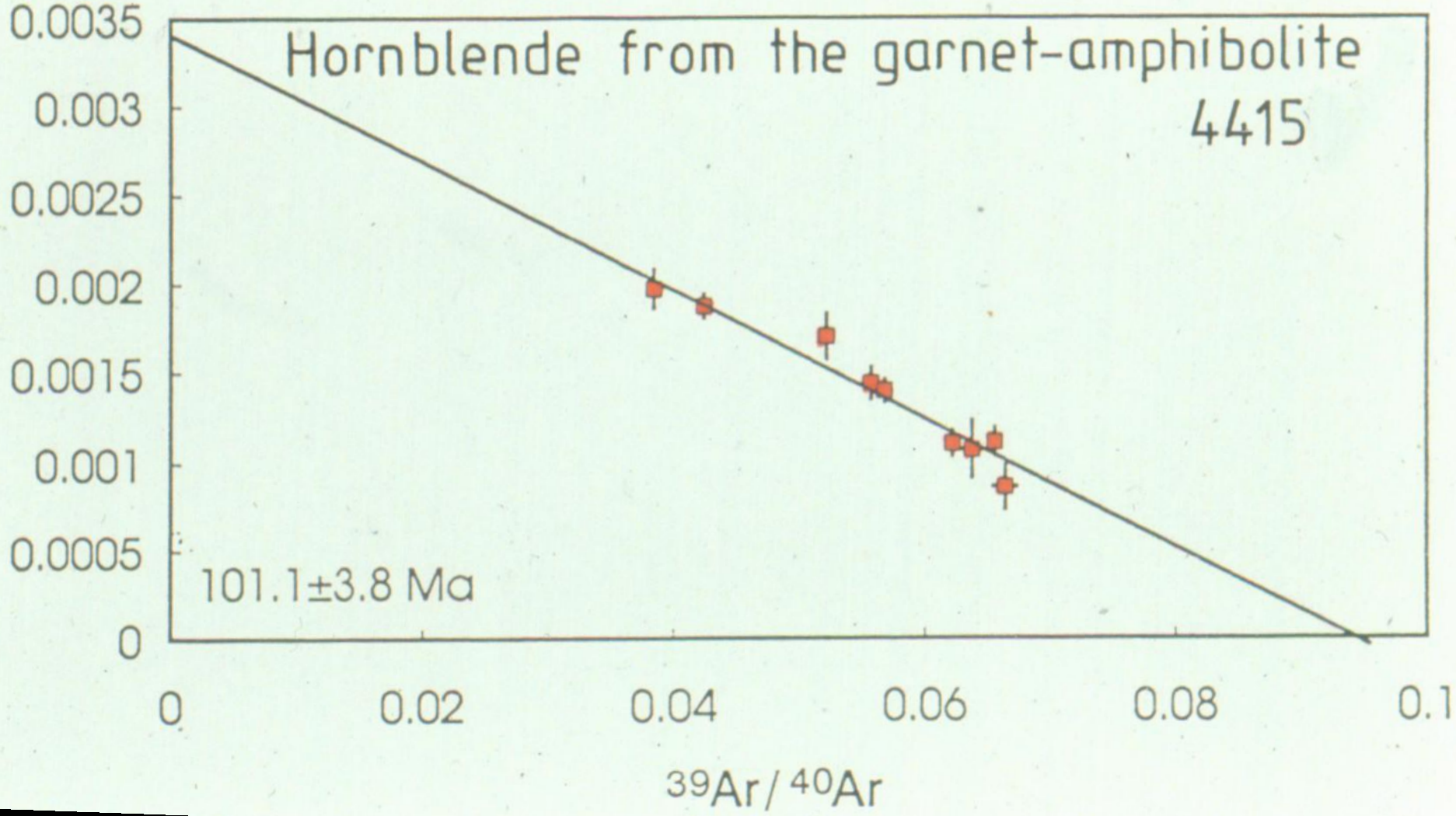


Geological map and cross-section of the Orhaneli region (Okay, 2002)





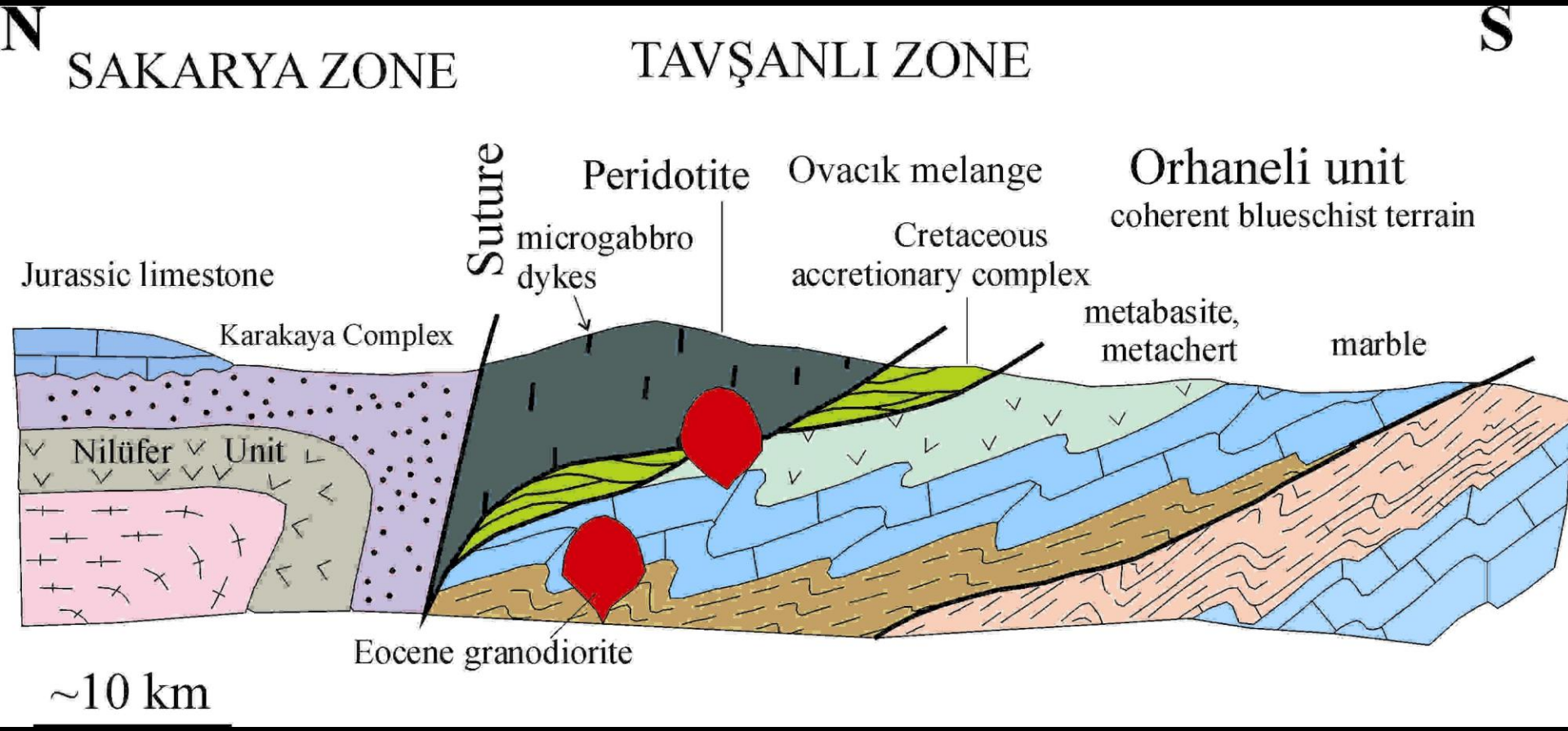
Pressure-temperature path of the garnet-amphibolites from the base of the peridotite in the Tavşanlı Zone (Okay et al., 1998)

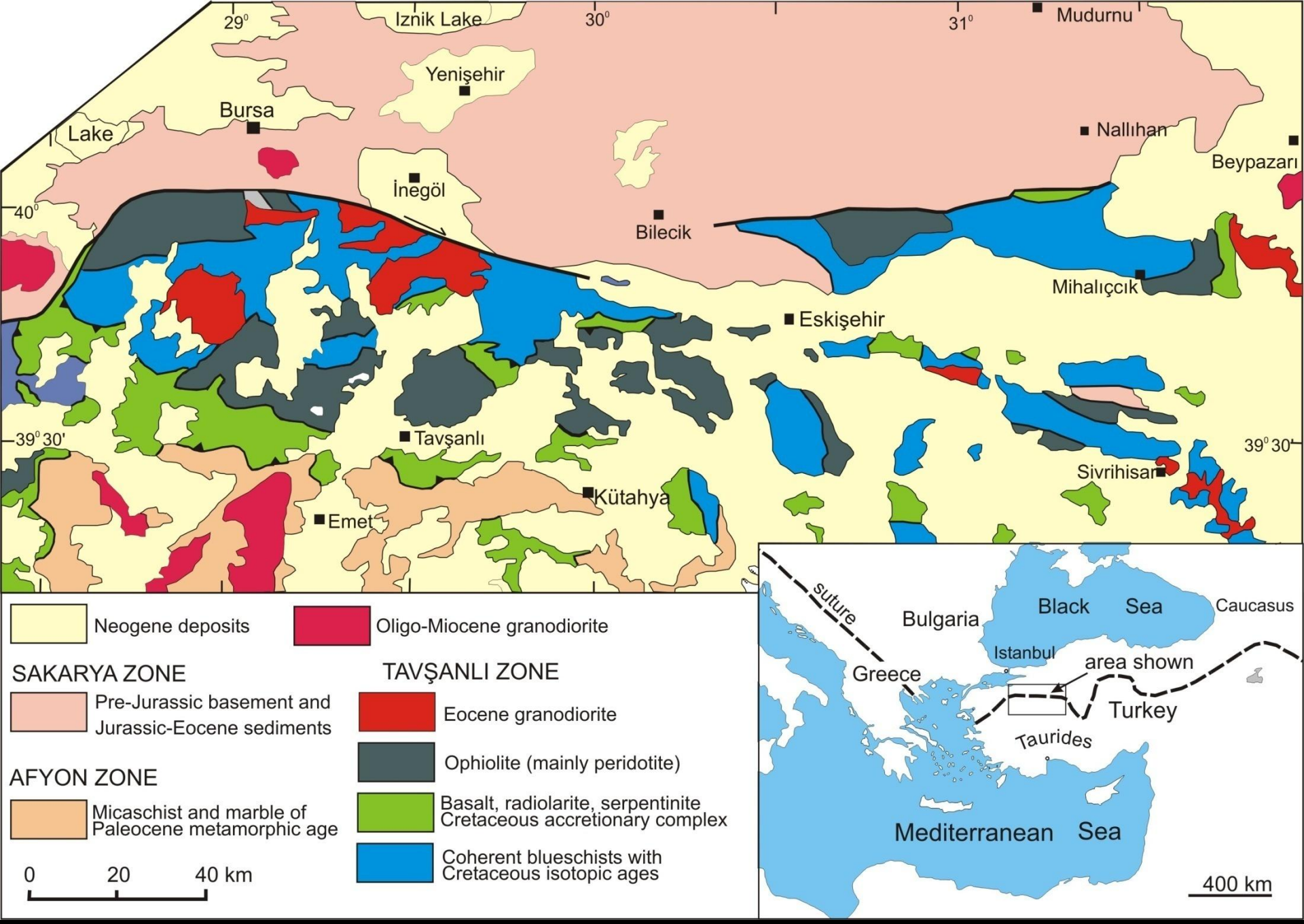

Hornblende from the garnet-amphibolite
4415
101.1±3.8 Ma
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
0.02
0.04
0.06
0.08
0.1
39Ar/40Ar

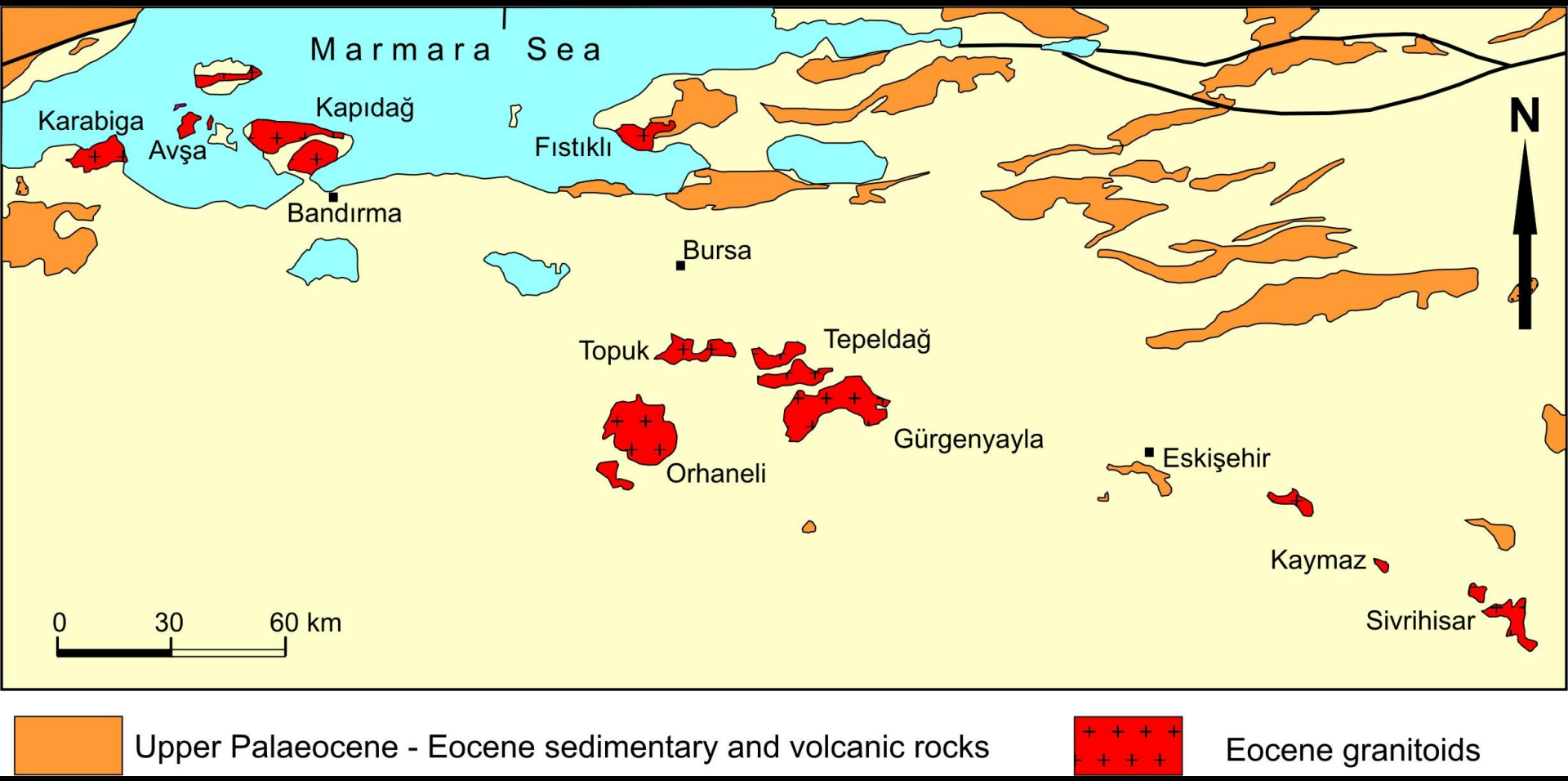
Mavişistler ve ofiyolit ne zaman yanyana geldi?

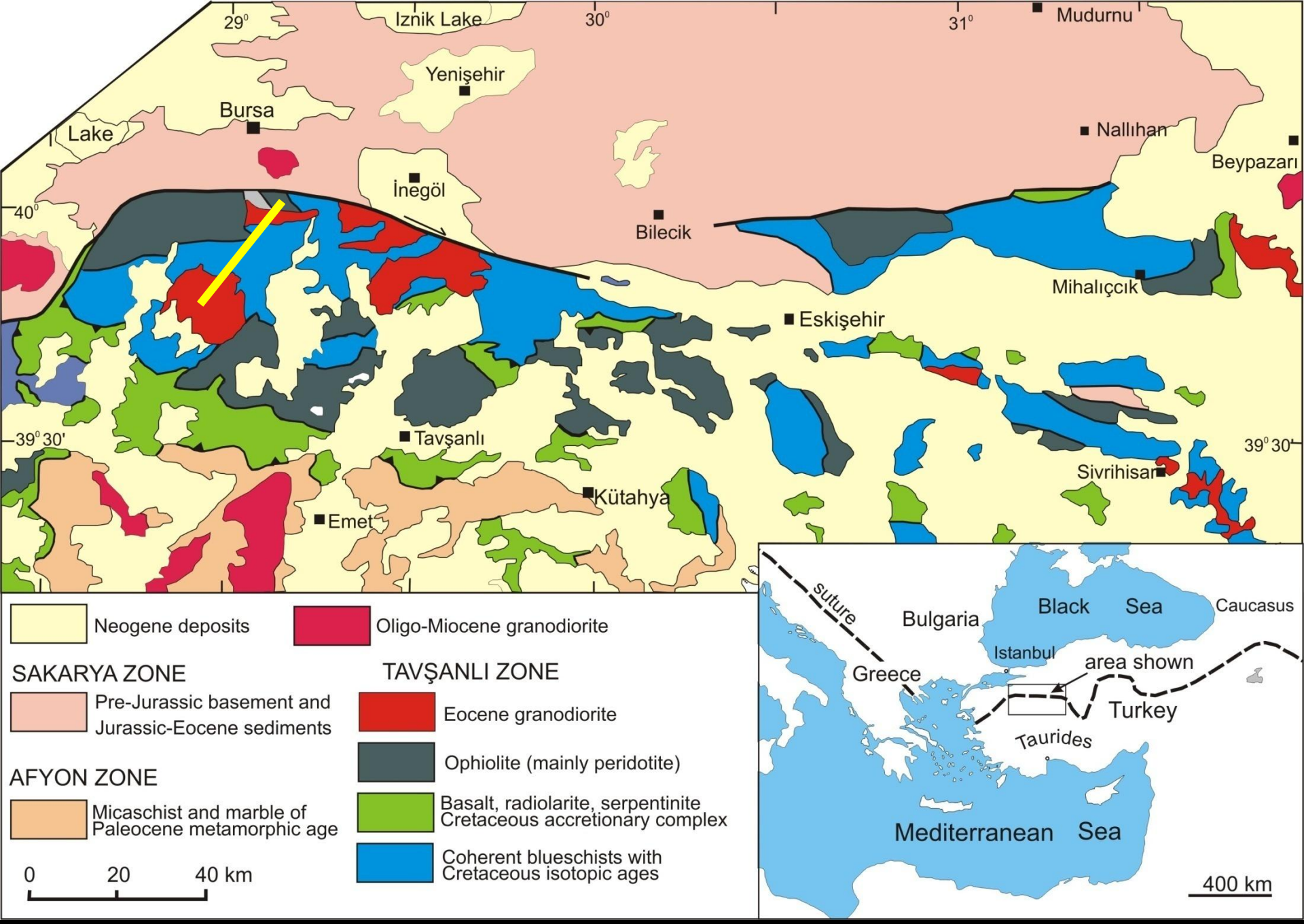
Eosen Granodiyoritleri

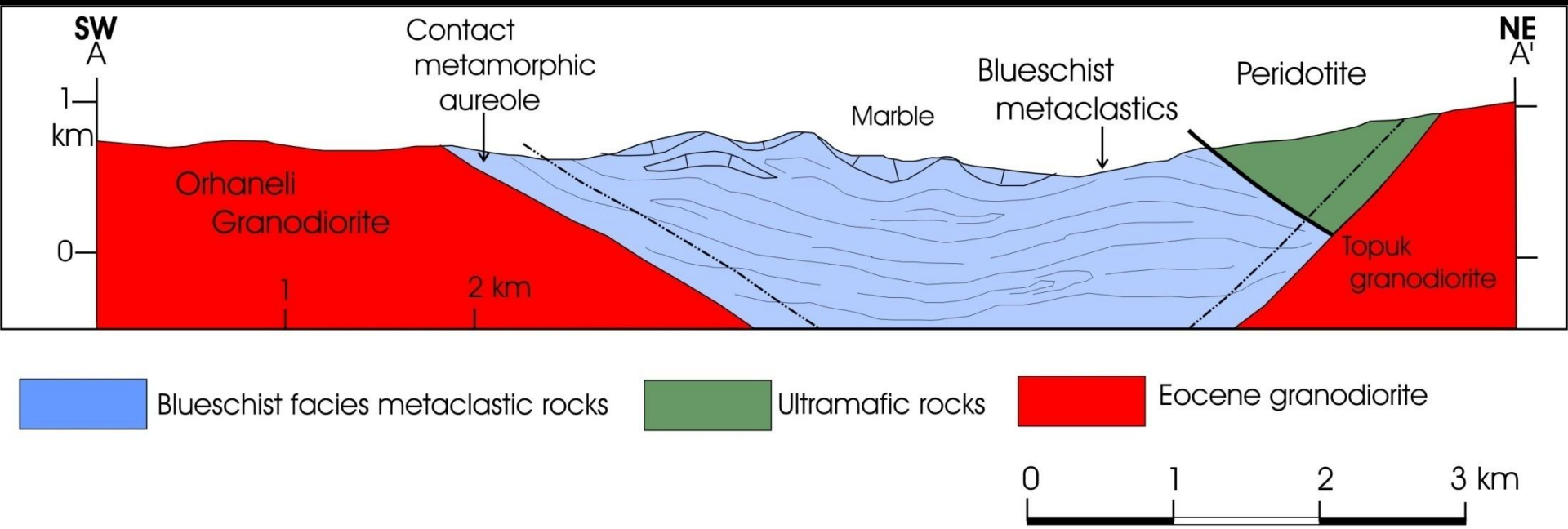
Mavişist ve ofiyolit birimlerini kesen çarpışma sonrası sokulumlar


N
S
SAKARYA ZONE
TAVŞANLI ZONE
Suture
Peridotite
Ovacık melange
Orhaneli unit
coherent blueschist terrain
microgabbro
dykes
Cretaceous
accretionary complex
Jurassic limestone
Karakaya Complex
metabasite,
metachert
marble
Nilüfer Unit
Eocene granodiorite
~10 km


29°
Iznik Lake
30°
31°
Mudurnu
Yenişehir
Bursa
Lake
Nallıhan
Beypazarı
İnegöl
40°
Bilecik
Mihalıççık
Eskişehir
39° 30'
Tavşanlı
39° 30'
Sivrihisar
Kütahya
Emet
Neogene deposits
Oligo-Miocene granodiorite
SAKARYA ZONE
Pre-Jurassic basement and Jurassic-Eocene sediments
AFYON ZONE
Micaschist and marble of Paleocene metamorphic age
TAVŞANLI ZONE
Eocene granodiorite
Ophiolite (mainly peridotite)
Basalt, radiolarite, serpentinite Cretaceous accretionary complex
Coherent blueschists with Cretaceous isotopic ages
0 20 40 km
suture
Bulgaria
Black Sea
Caucasus
Istanbul
area shown
Greece
Turkey
Taurides
Mediterranean Sea
400 km

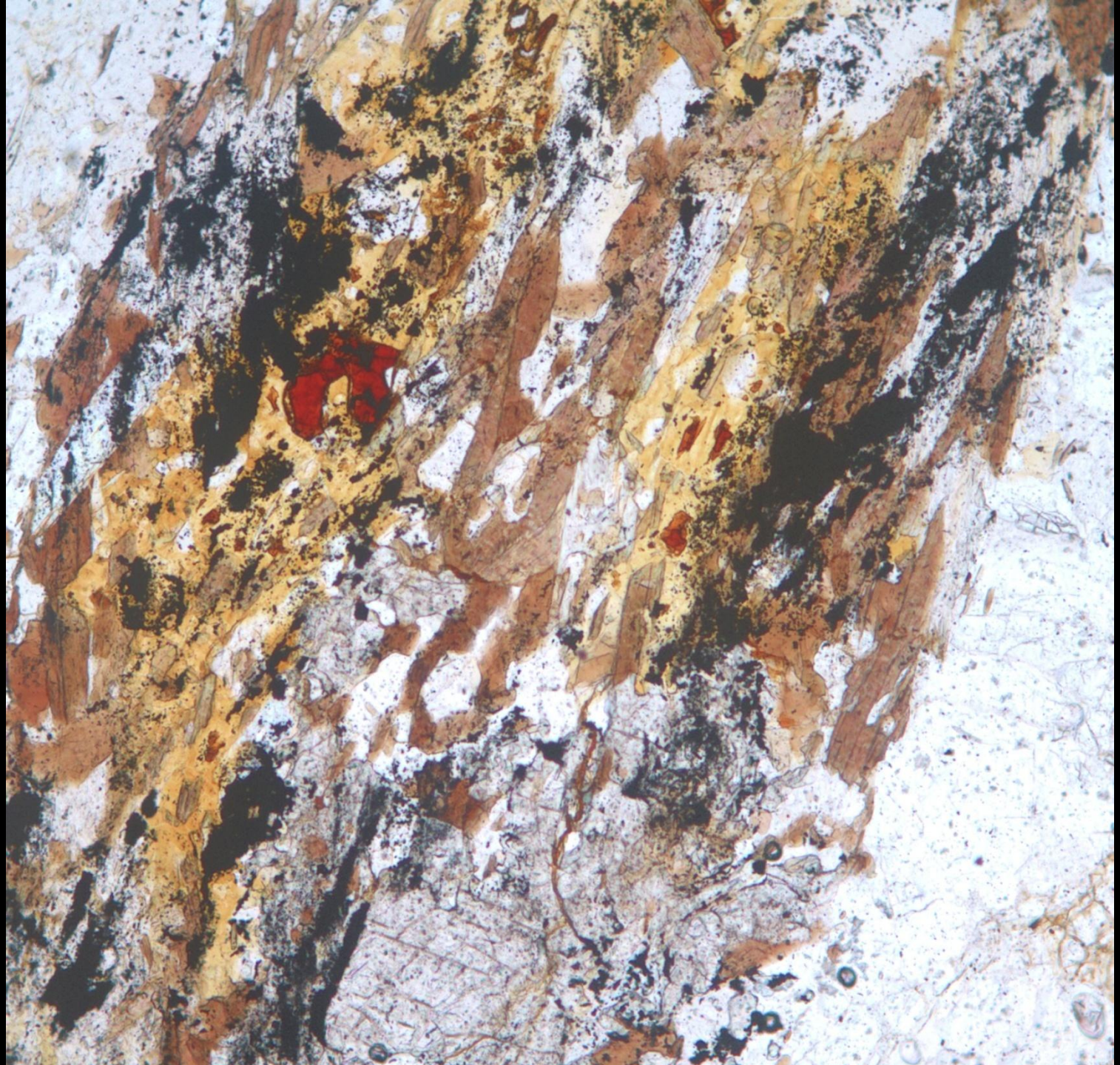

Marmara Sea
Karabiga
Avşa
Kapıdağ
Fıstıklı
Bandırma
Bursa
Topuk
Tepeldağ
Gürgenyayla
Orhaneli
Eskişehir
Kaymaz
Sivrihisar
N
0
30
60 km
Upper Palaeocene - Eocene sedimentary and volcanic rocks
Eocene granitoids

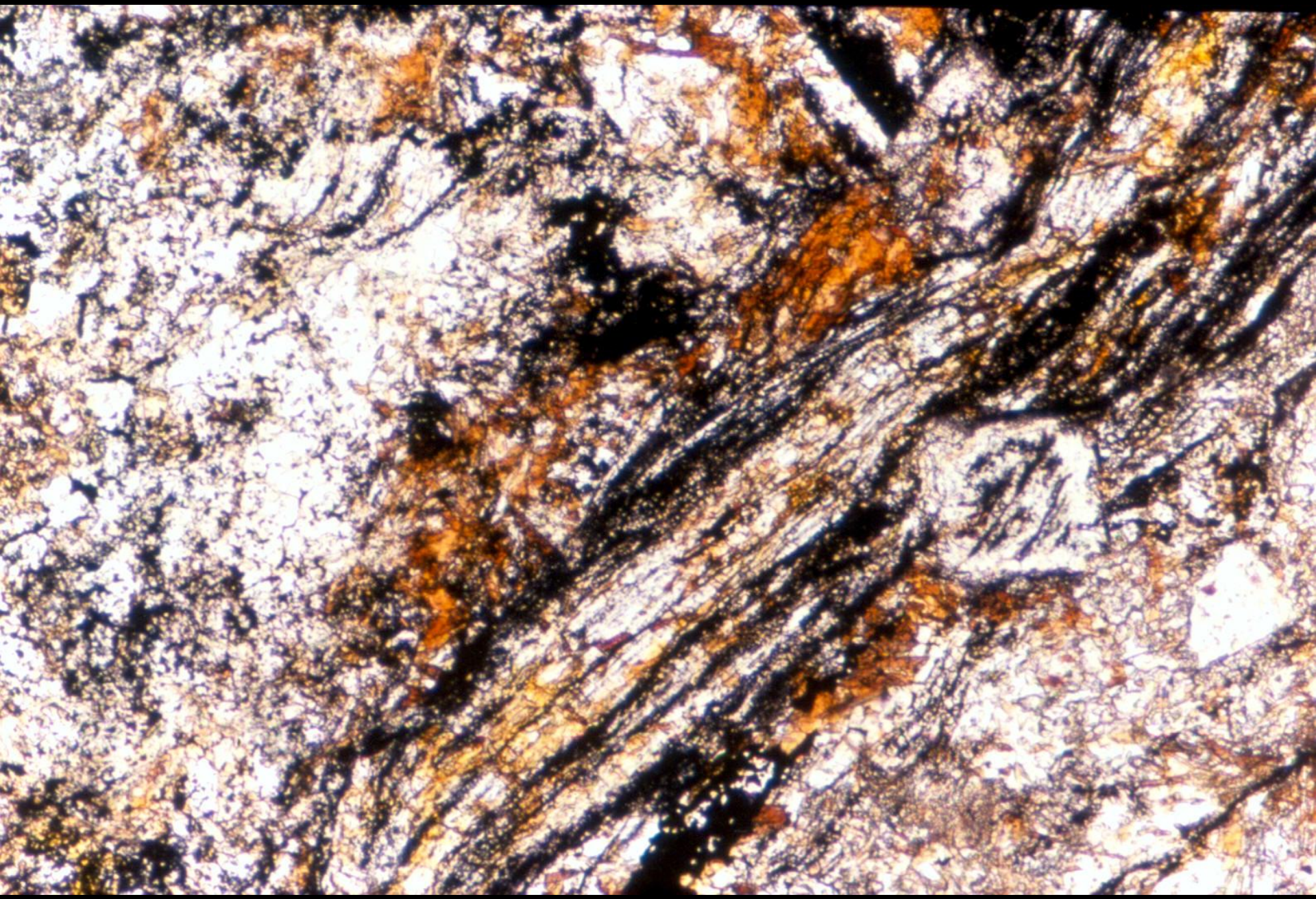

29°
Iznik Lake
30°
31°
Mudurnu
Yenişehir
Bursa
Lake
Nallıhan
Beypazarı
İnegöl
40°
Bilecik
Mihalıççık
Eskişehir
39° 30'
Tavşanlı
39° 30'
Sivrihisar
Kütahya
Emet
Neogene deposits
Oligo-Miocene granodiorite
SAKARYA ZONE
Pre-Jurassic basement and Jurassic-Eocene sediments
AFYON ZONE
Micaschist and marble of Paleocene metamorphic age
TAVŞANLI ZONE
Eocene granodiorite
Ophiolite (mainly peridotite)
Basalt, radiolarite, serpentinite Cretaceous accretionary complex
Coherent blueschists with Cretaceous isotopic ages
0 20 40 km
suture
Bulgaria
Black Sea
Caucasus
Istanbul
area shown
Greece
Turkey
Taurides
Mediterranean Sea
400 km

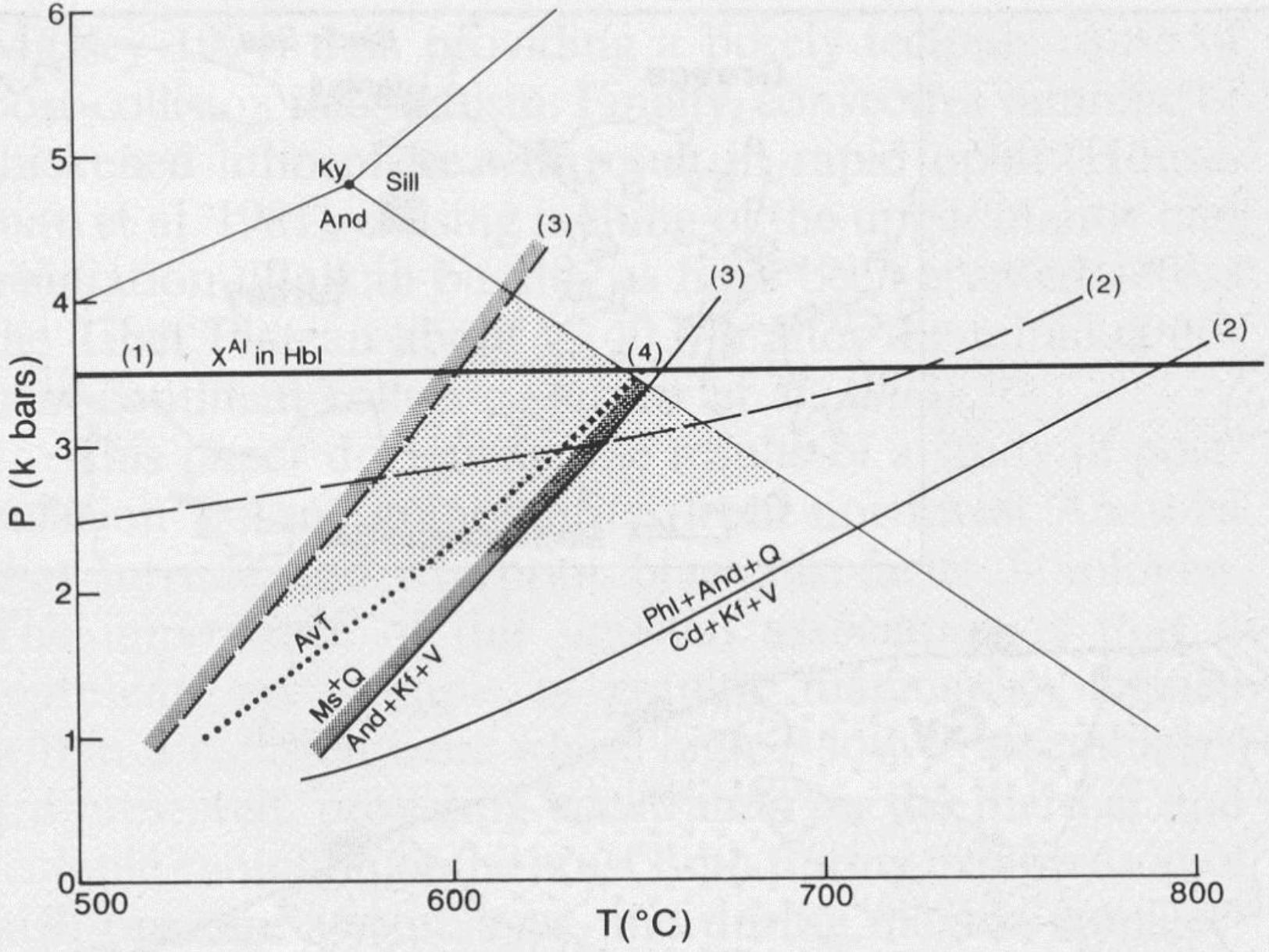


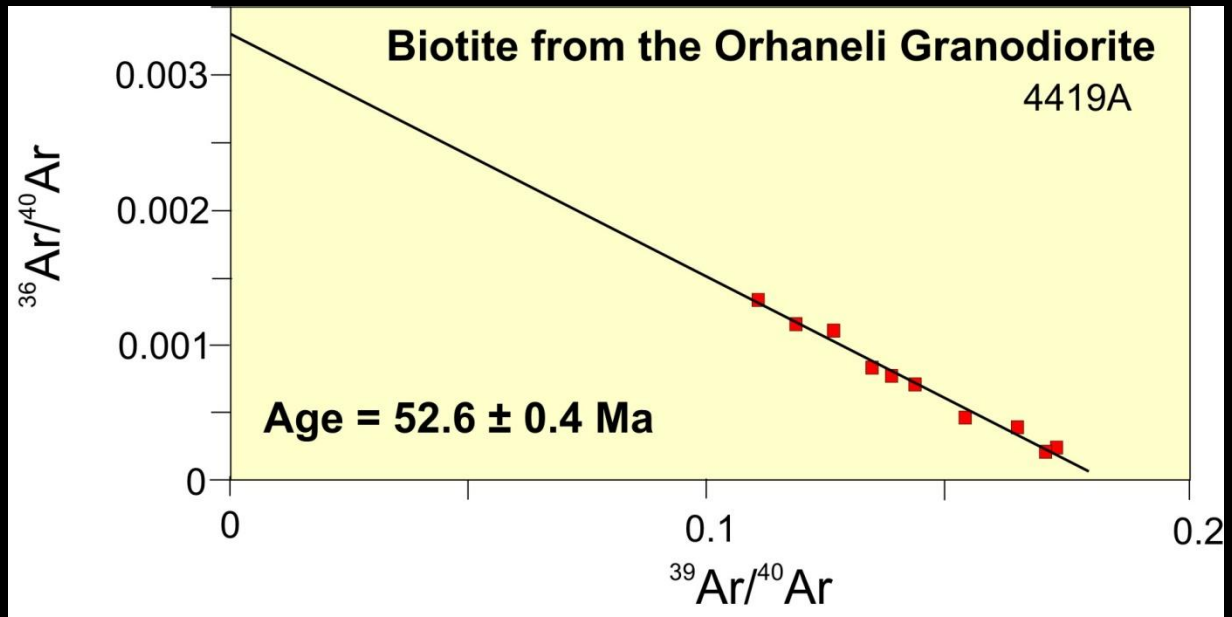
Geological cross-section from the Orhaneli region (Okay, 2002)

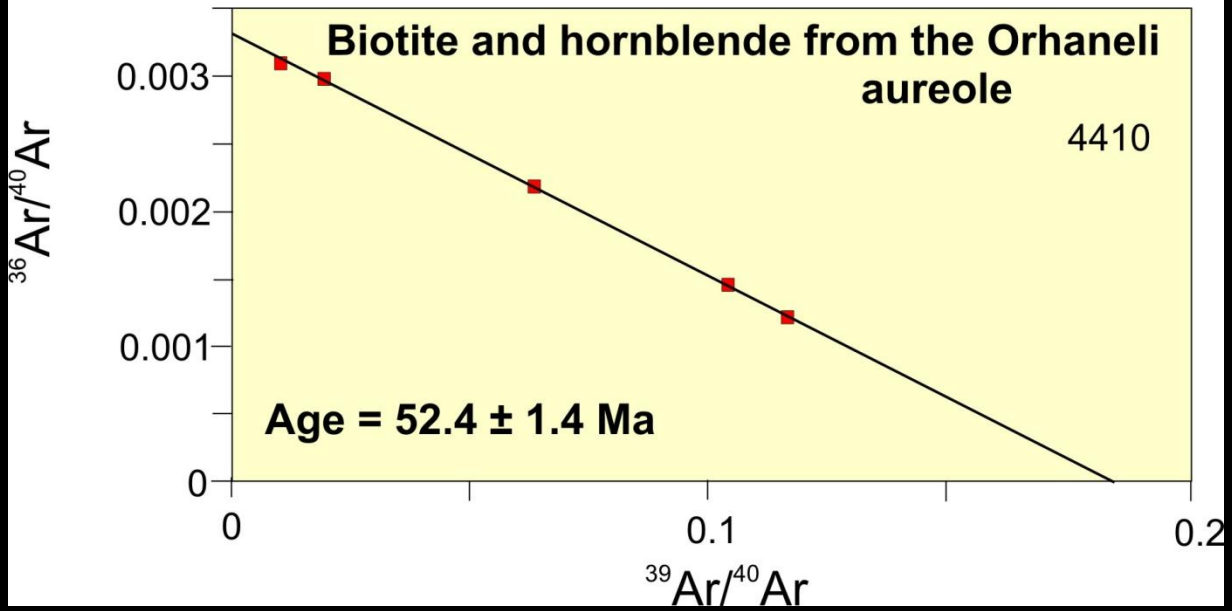

25¢



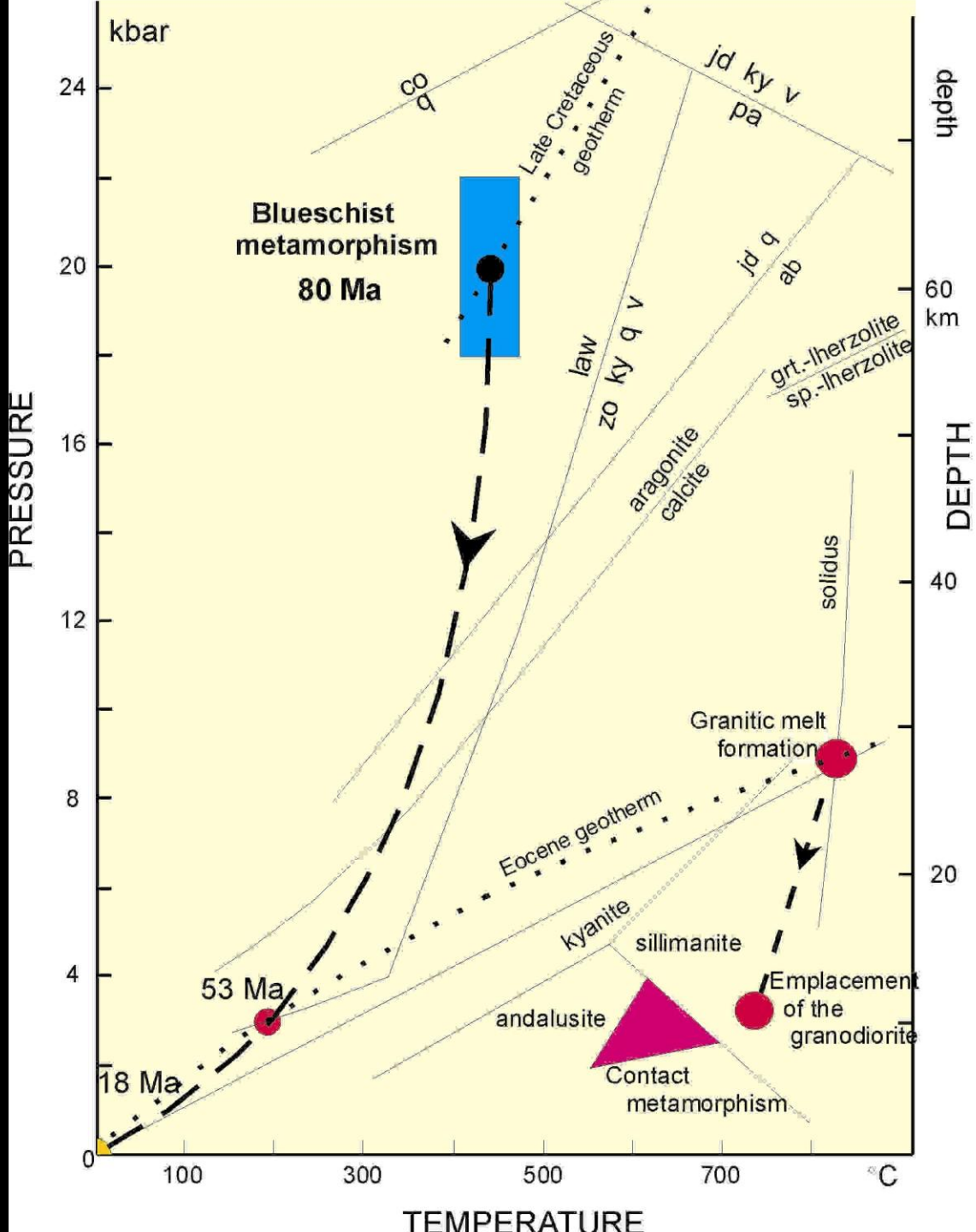



6
5
4
3
2
1
0
P (k bars)
500
600
700
800
T(°C)
Ky
Sill
And
(1)
X^{Al} in Hbl
(3)
(3)
(4)
(2)
(2)
AvT
Ms+Q
And+Kf+V
Phl+And+Q
Cd+Kf+V


Biotite from the Orhaneli Granodiorite
4419A
Age = 52.6 ± 0.4 Ma
0.003
0.002
0.001
0
0
0.1
0.2
$^{36}Ar/^{40}Ar$
$^{39}Ar/^{40}Ar$


Biotite and hornblende from the Orhaneli aureole
4410
Age = 52.4 ± 1.4 Ma
0.003
0.002
0.001
0
0
0.1
0.2
$^{36}Ar/^{40}Ar$
$^{39}Ar/^{40}Ar$

Erken Eosen’de (53 Ma) mavişist-ofiyolit tektonik istifi bugünkü konumundaydı ve yer sathından derinliği 10 km’ye geçmiyordu.



Pressure-temperature diagram showing *P-T-t* path followed by the blueschists of the Tavşanlı Zone (Okay et al., 1998).

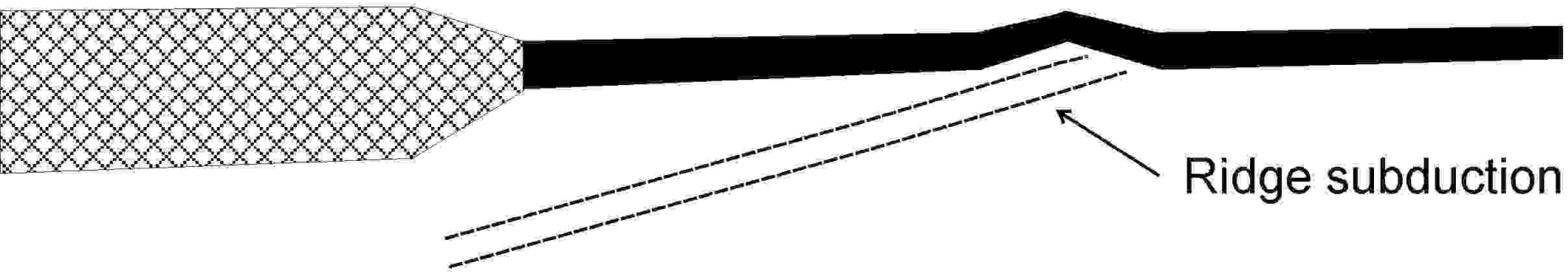
Genel tektonik evrim

Albian

N

Pontides

İzmir-Ankara ocean

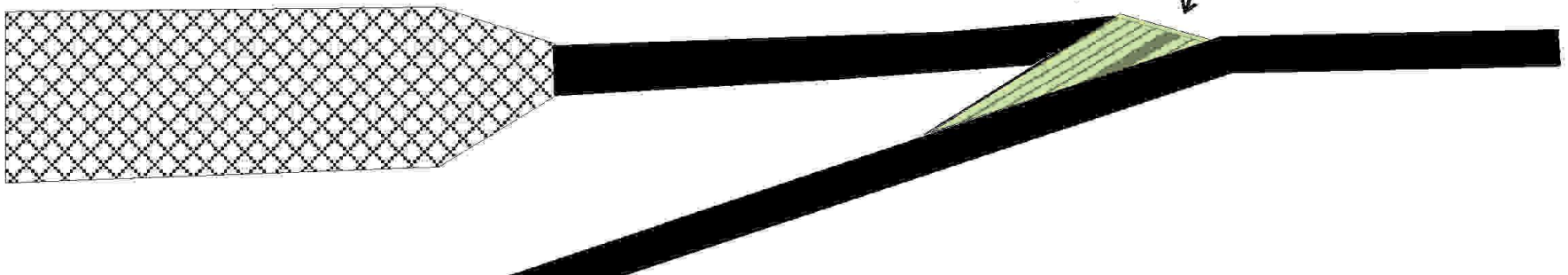


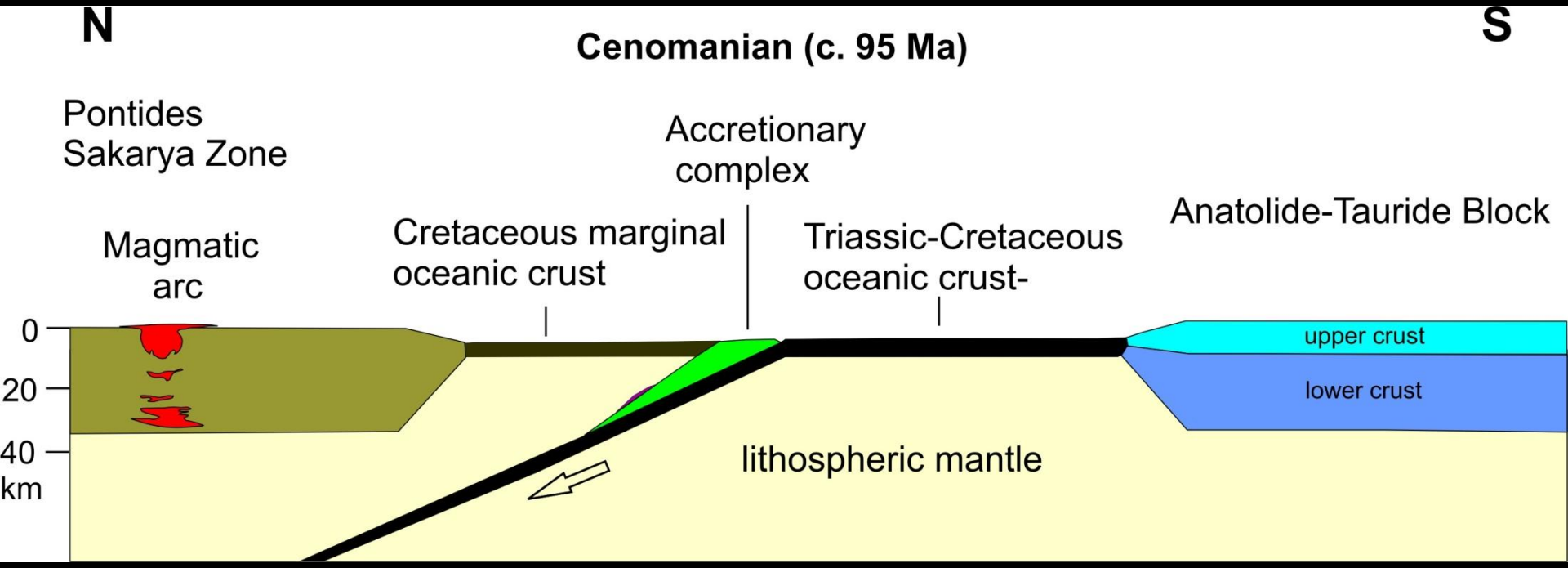
Ridge subduction

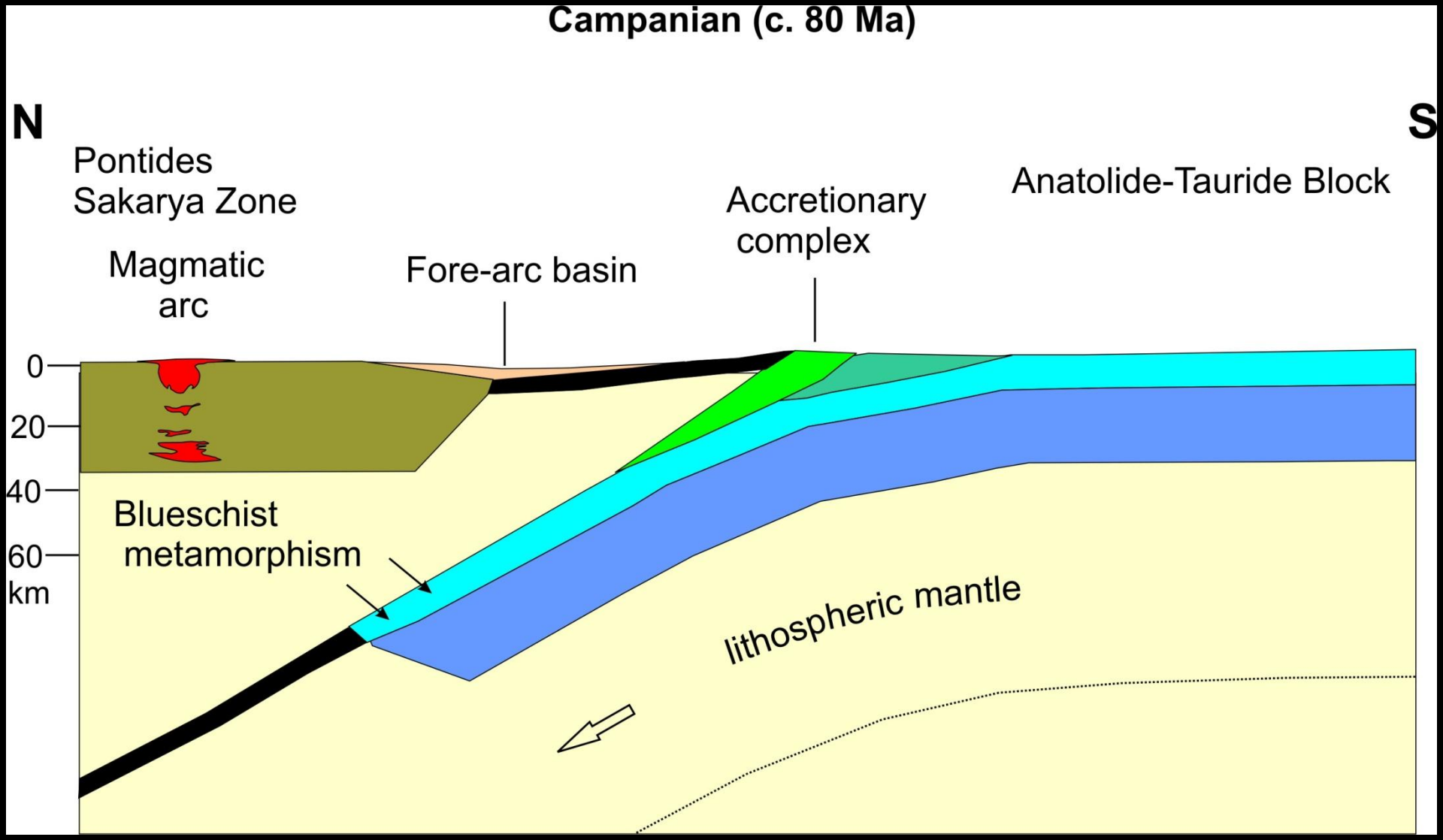
Cenomanian

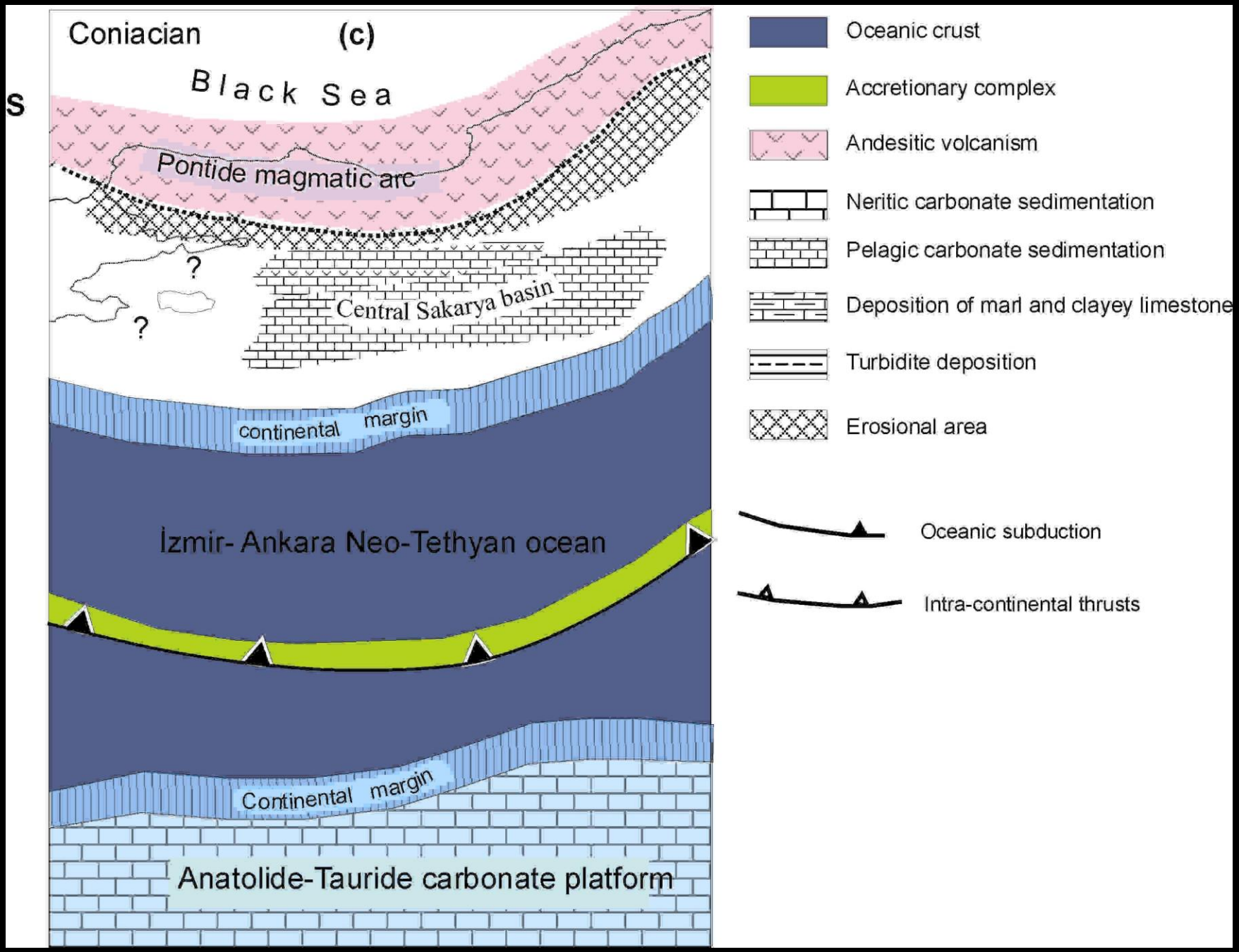
Early Cretaceous oceanic crust

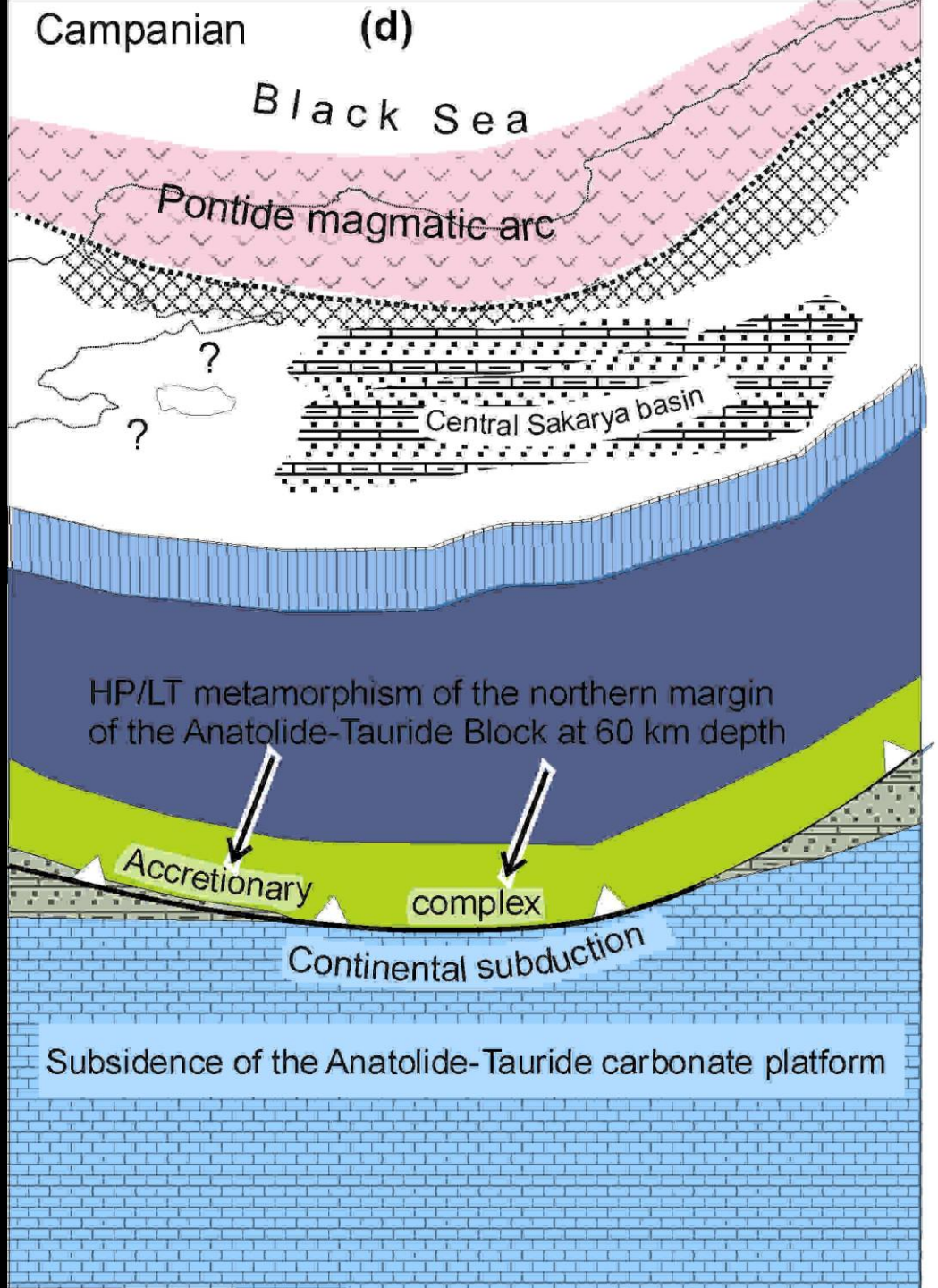
Accretionary complex

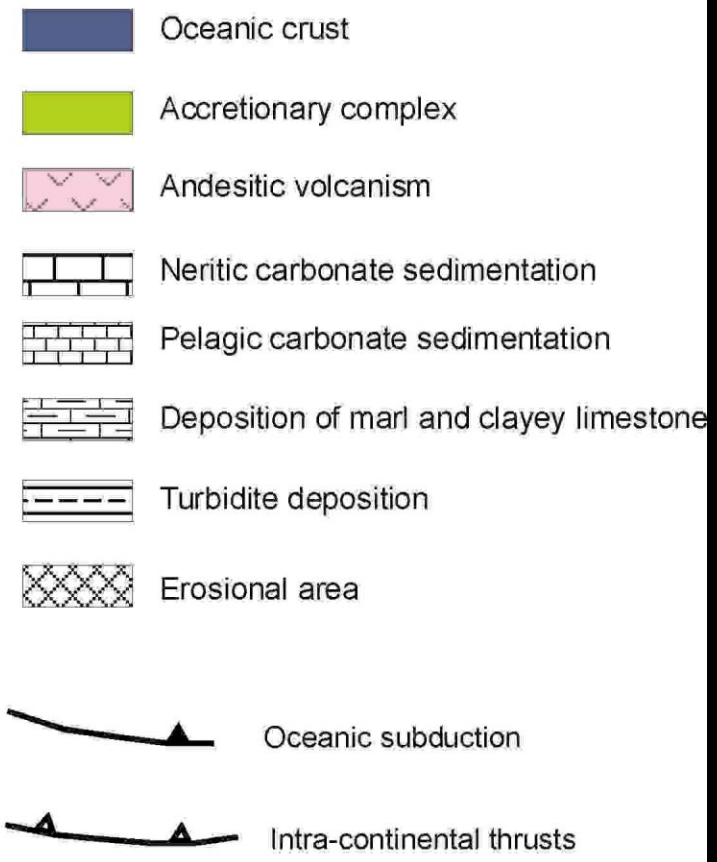


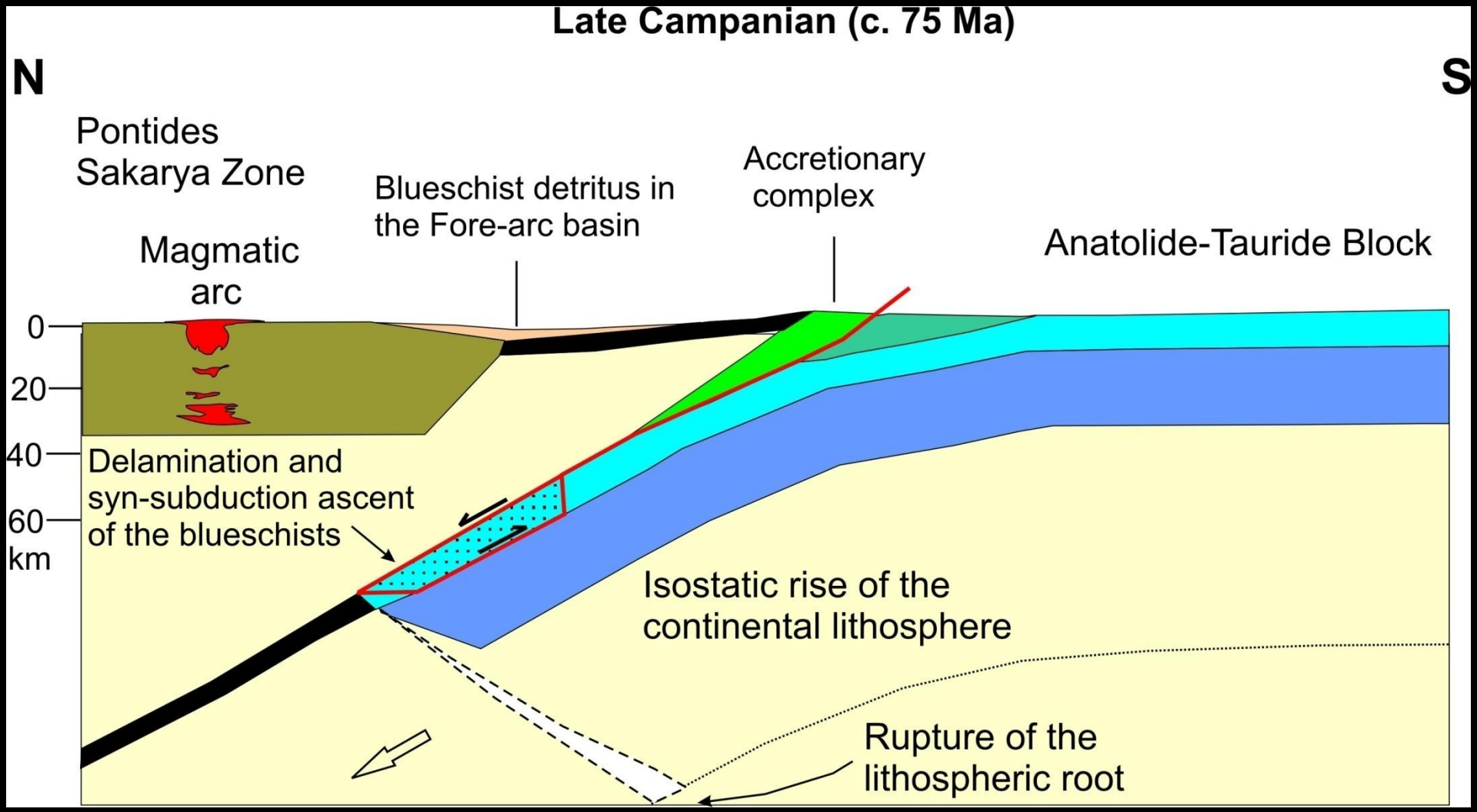

N
S
Cenomanian (c. 95 Ma)
Pontides
Sakarya Zone
Accretionary
complex
Anatolide-Tauride Block
Magmatic
arc
Cretaceous marginal
oceanic crust
Triassic-Cretaceous
oceanic crust-
0
20
40
km
upper crust
lower crust
lithospheric mantle

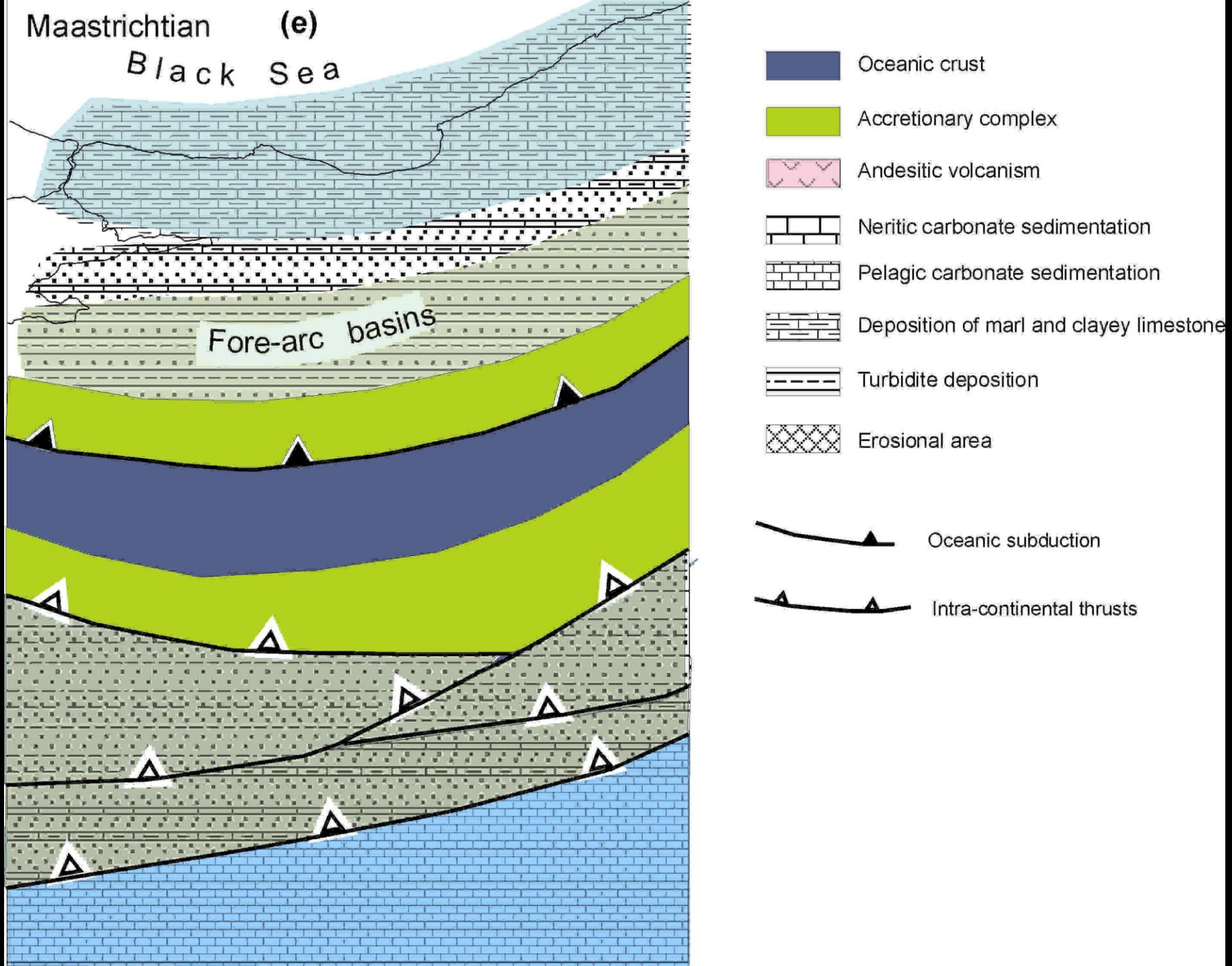

Campanian (c. 80 Ma)
N
S
Pontides
Sakarya Zone
Anatolide-Tauride Block
Accretionary
complex
Magmatic
arc
Fore-arc basin
0
20
40
60
km
Blueschist
metamorphism
lithospheric mantle

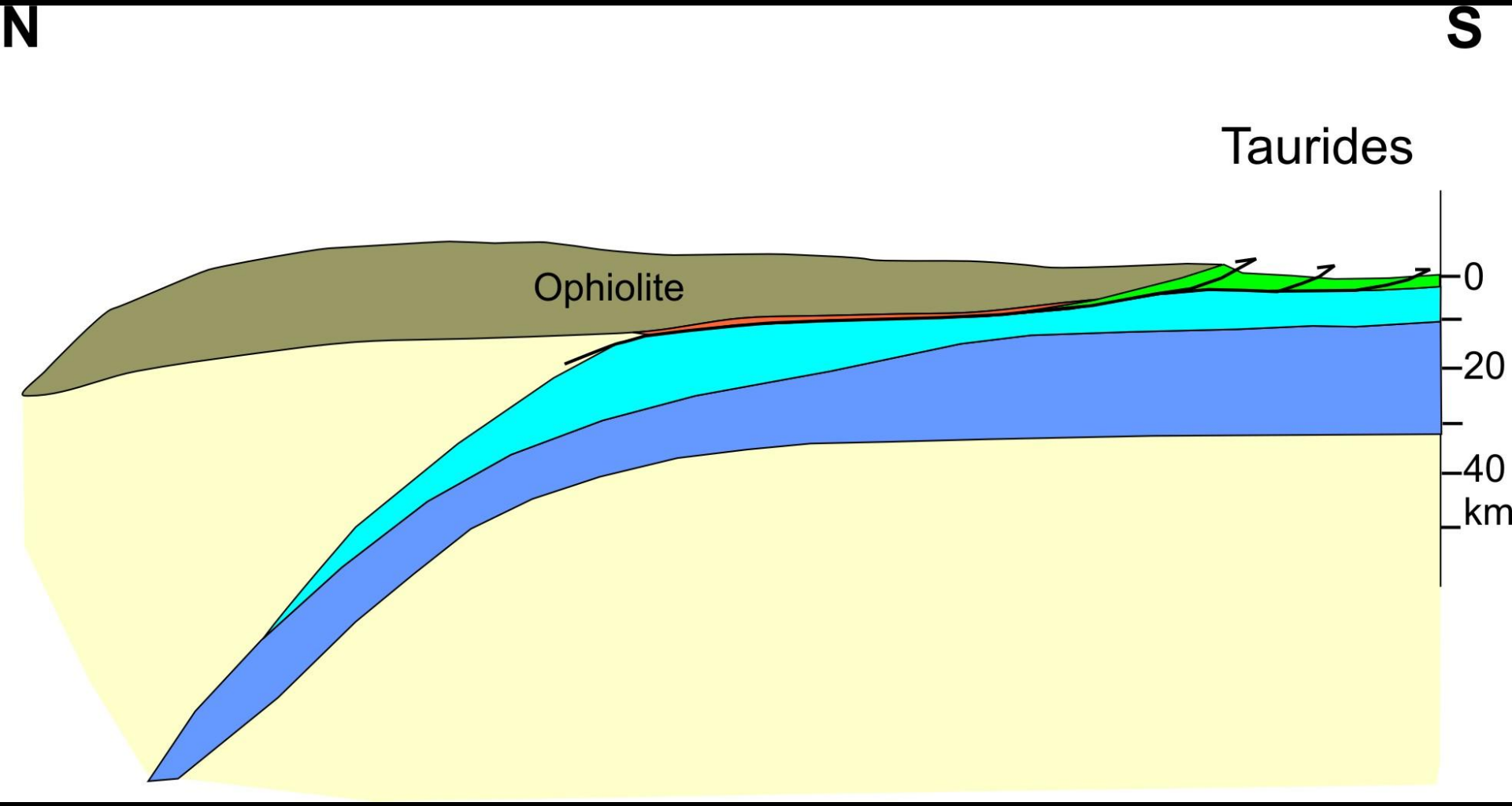

Coniacian
(c)
Black Sea
Pontide magmatic arc
?
?
Central Sakarya basin
continental margin
İzmir- Ankara Neo-Tethyan ocean
Continental margin
Anatolide-Tauride carbonate platform
Oceanic crust
Accretionary complex
Andesitic volcanism
Neritic carbonate sedimentation
Pelagic carbonate sedimentation
Deposition of marl and clayey limestone
Turbidite deposition
Erosional area
Oceanic subduction
Intra-continental thrusts

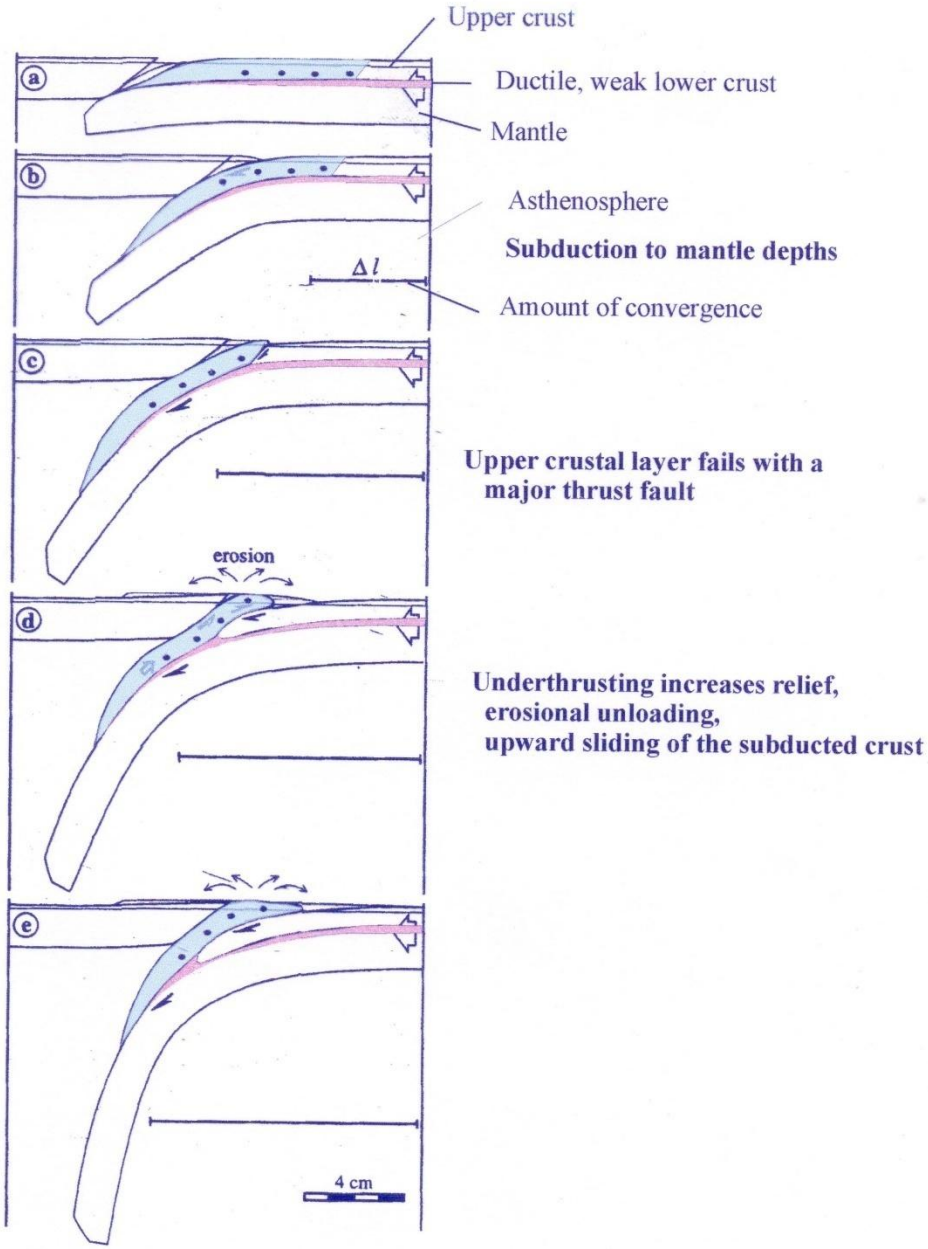

Campanian
(d)
Black Sea
Pontide magmatic arc
?
?
Central Sakarya basin
HP/LT metamorphism of the northern margin
of the Anatolide-Tauride Block at 60 km depth
Accretionary
complex
Continental subduction
Subsidence of the Anatolide-Tauride carbonate platform


Oceanic crust
Accretionary complex
Andesitic volcanism
Neritic carbonate sedimentation
Pelagic carbonate sedimentation
Deposition of marl and clayey limestone
Turbidite deposition
Erosional area
Oceanic subduction
Intra-continental thrusts


Late Campanian (c. 75 Ma)
N
S
Pontides
Sakarya Zone
Magmatic
arc
Blueschist detritus in
the Fore-arc basin
Accretionary
complex
Anatolide-Tauride Block
0
20
40
60
km
Delamination and
syn-subduction ascent
of the blueschists
Isostatic rise of the
continental lithosphere
Rupture of the
lithospheric root


Maastrichtian
(e)
Black Sea
Fore-arc basins
Oceanic crust
Accretionary complex
Andesitic volcanism
Neritic carbonate sedimentation
Pelagic carbonate sedimentation
Deposition of marl and clayey limestone
Turbidite deposition
Erosional area
Oceanic subduction
Intra-continental thrusts


N
S
Taurides
Ophiolite
0
20
40
km



Drawing of an analogue experiment of subduction of continental lithosphere (Chemenda et al., 1995). The model includes a strong upper crust, a weak ductile lower crust and a strong mantle part.

Some unanswered questions