GEOLOGY OF THE EASTERN PONTIDES

Aral Okay

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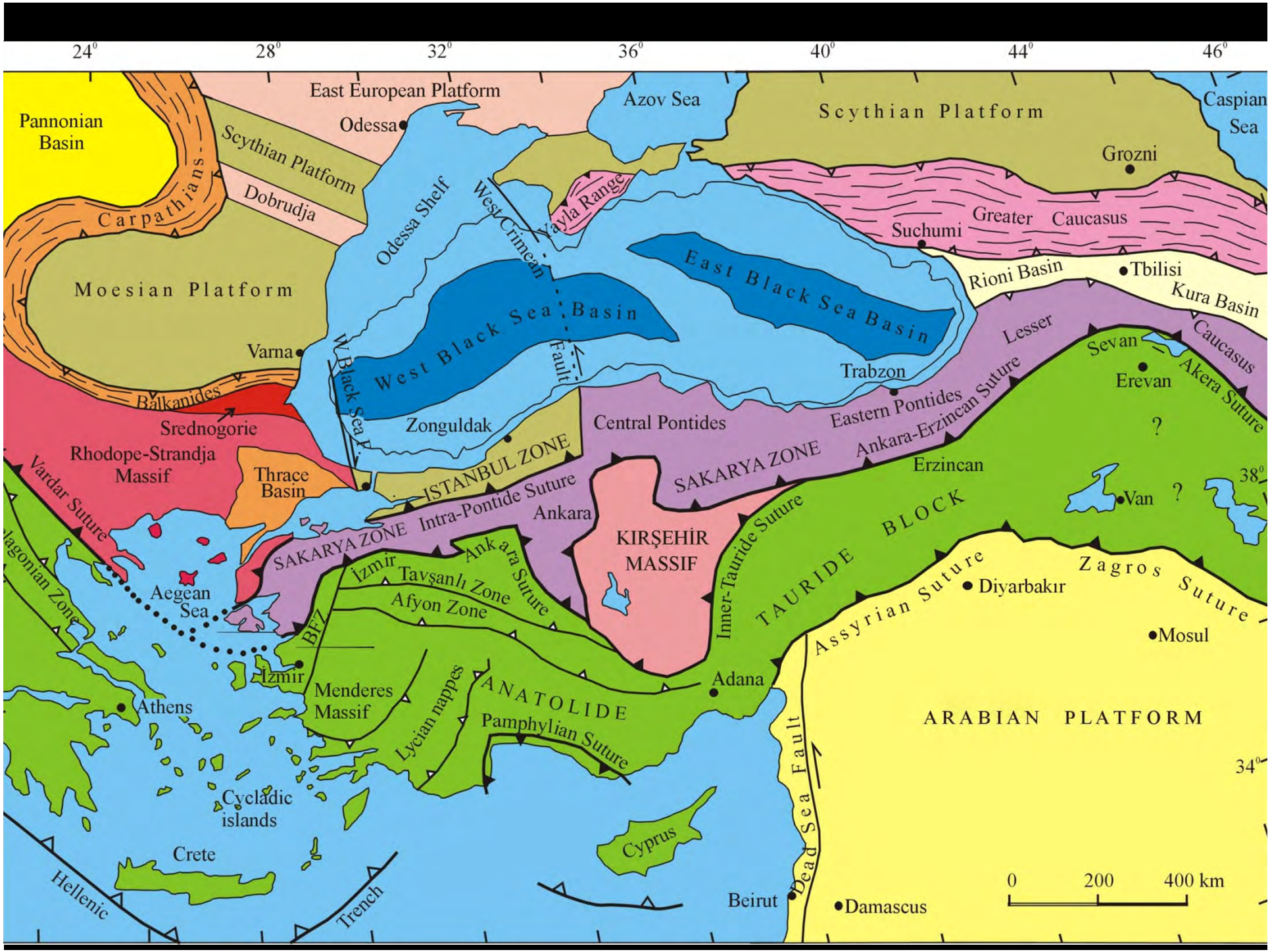
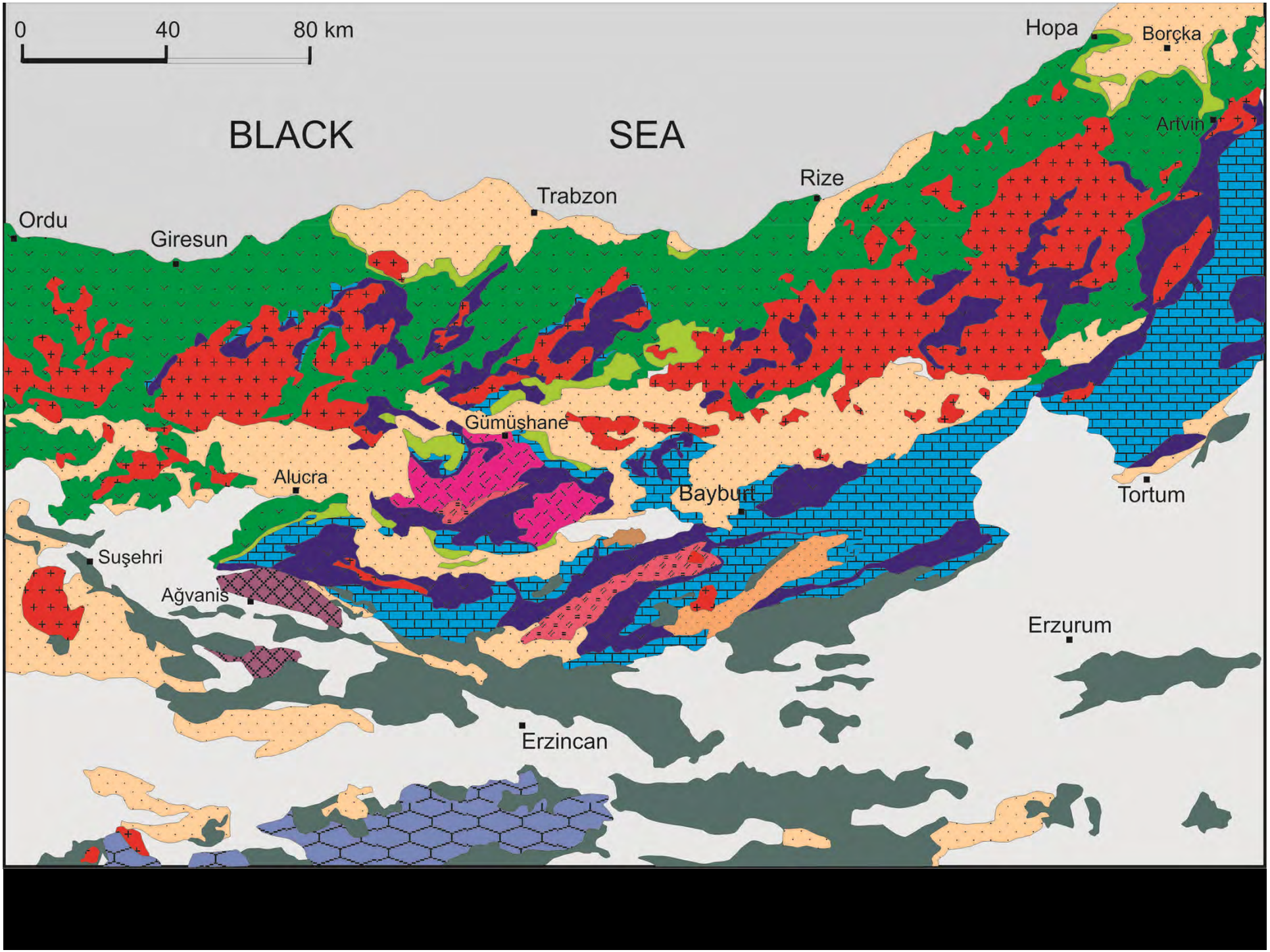
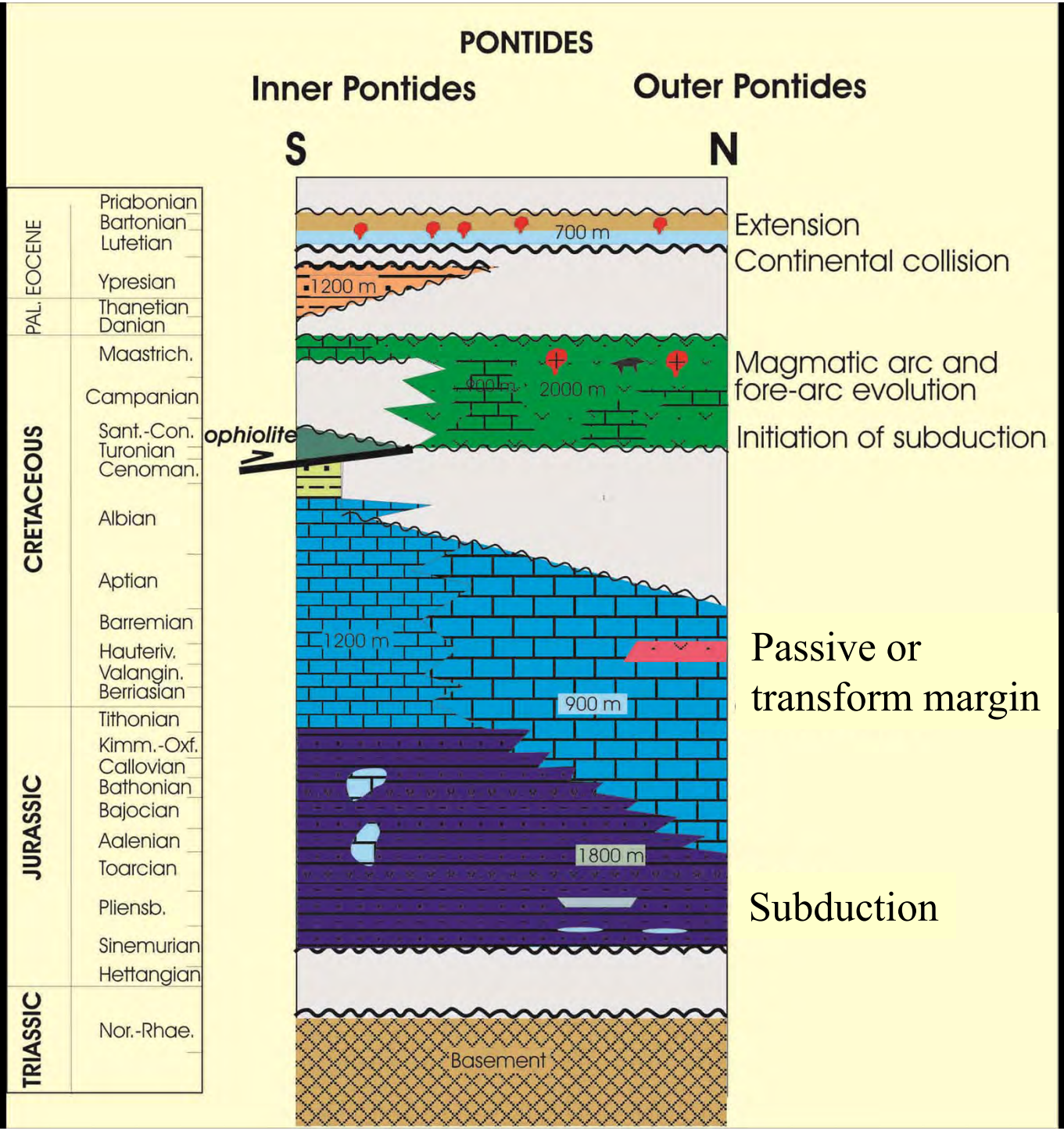
ve Avrasya Yerbilimleri Enstitüsü, Ayazağa 80626, İstanbul


LAURASIA
GONDWANA
AFRICA
Mediterranean
ARABIAN SHIELD
Zagros suture
Tibet
Makran
Himalaya
Oman
LAND
INDIAN SHIELD
Laurasia outside the Alpide orogen
Alpide Laurasia
Gondwana-Land outside the Alpide orogen
Alpide Gondwana-Land

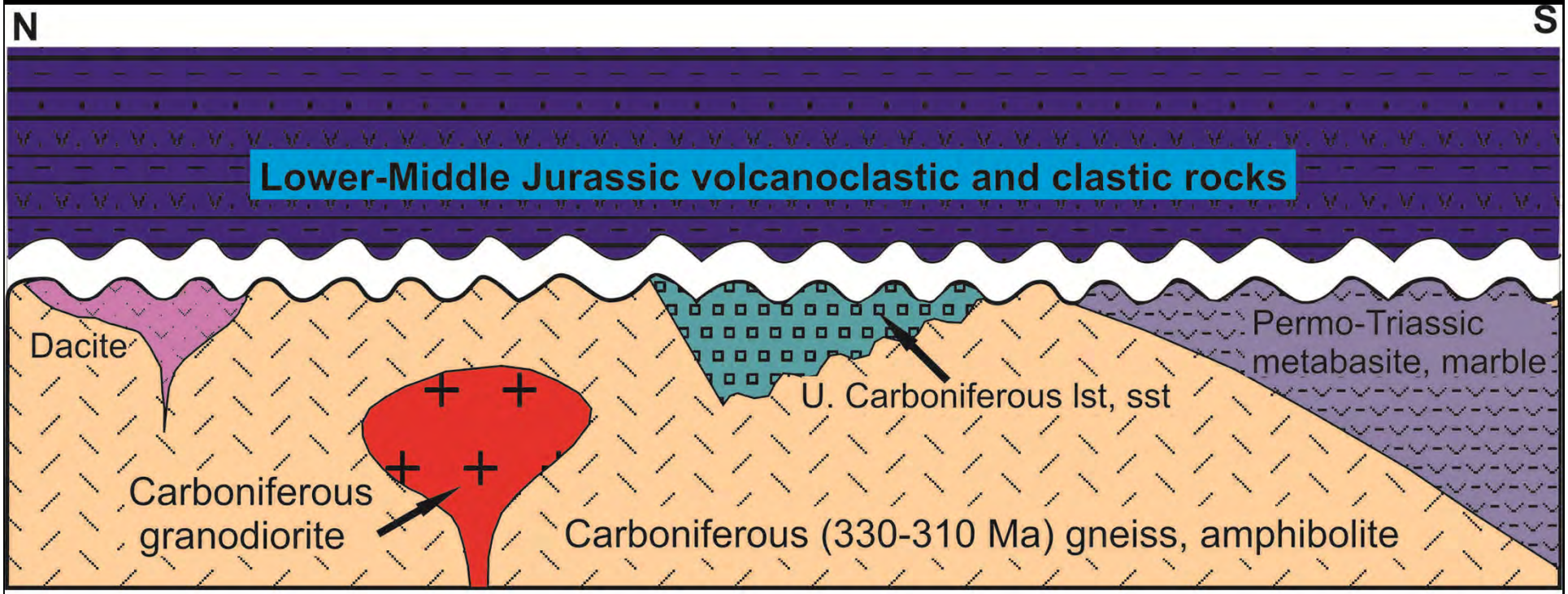

24°
28°
32°
36°
40°
44°
46°
Pannonian Basin
East European Platform
Odessa
Azov Sea
Scythian Platform
Caspian Sea
Grozni
Scythian Platform
Dobrudja
Carpathians
Odessa Shelf
West Crimean
Yayla Range
Greater Caucasus
Suchumi
Moesian Platform
East Black Sea Basin
Rioni Basin
Tbilisi
Kura Basin
West Black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


0
40
80 km
BLACK
SEA
Hopa
Borçka
Artvin
Rize
Trabzon
Ordu
Giresun
Gümüşhane
Alucra
Bayburt
Tortum
Suşehri
Ağvanis
Erzurum
Erzincan

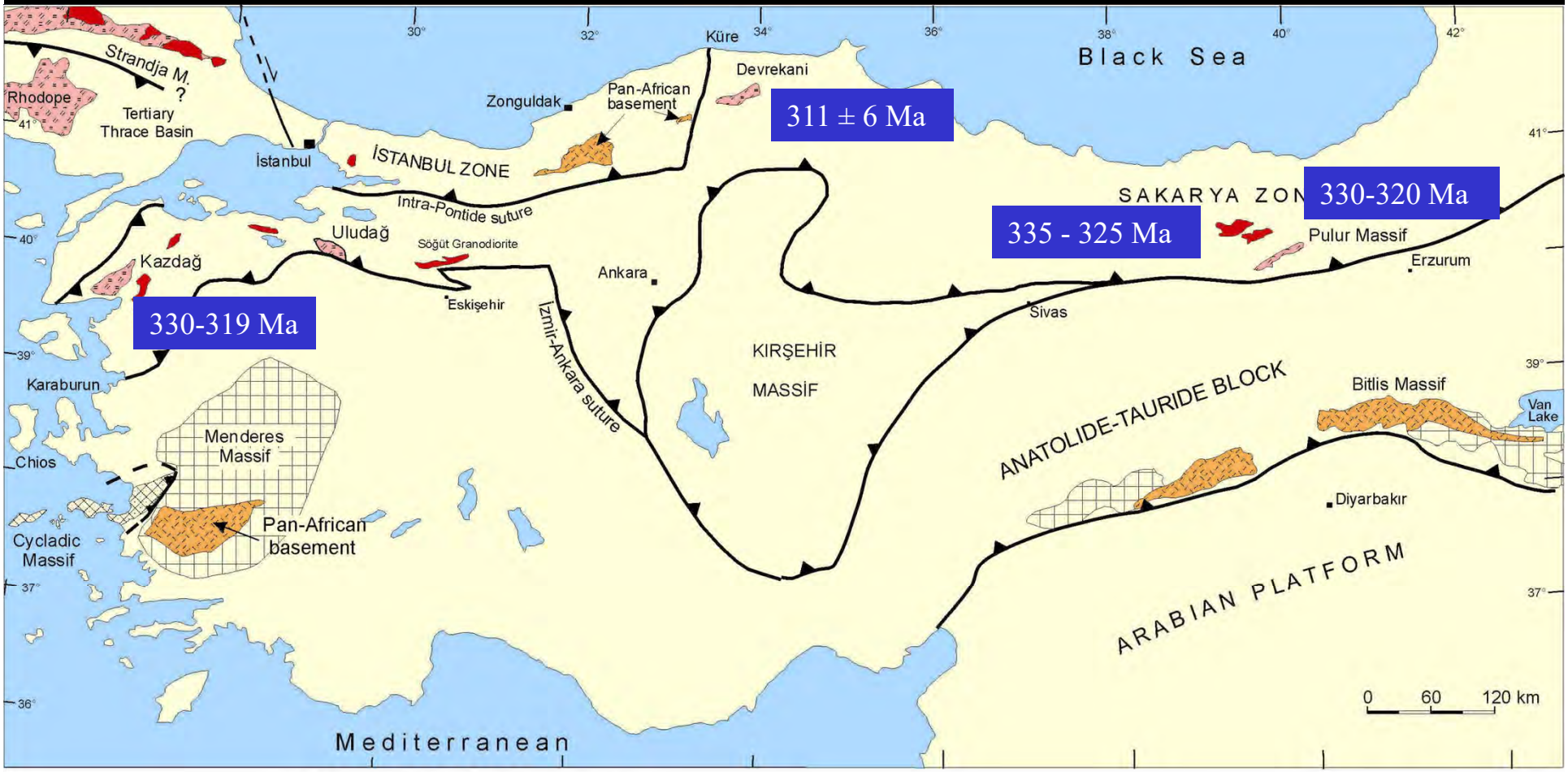

PONTIDES
Inner Pontides
Outer Pontides
S
N
PAL. EOCENE
Priabonian
Bartonian
Lutetian
Ypresian
Thanetian
Danian
CRETACEOUS
Maastrich.
Campanian
Sant.-Con.
Turonian
Cenoman.
Albian
Aptian
Barremian
Hauteriv.
Valangin.
Berriasian
JURASSIC
Tithonian
Kimm.-Oxf.
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Pliensb.
Sinemurian
Hettangian
TRIASSIC
Nor.-Rhae.
ophiolite
700 m
1200 m
2000 m
1200 m
900 m
1800 m
Basement
Extension
Continental collision
Magmatic arc and
fore-arc evolution
Initiation of subduction
Passive or
transform margin
Subduction

PRE-JURASSIC BASEMENT OF THE EASTERN PONTIDES

EVIDENCE FOR HERCYNIAN AND CIMMERIAN OROGENIES

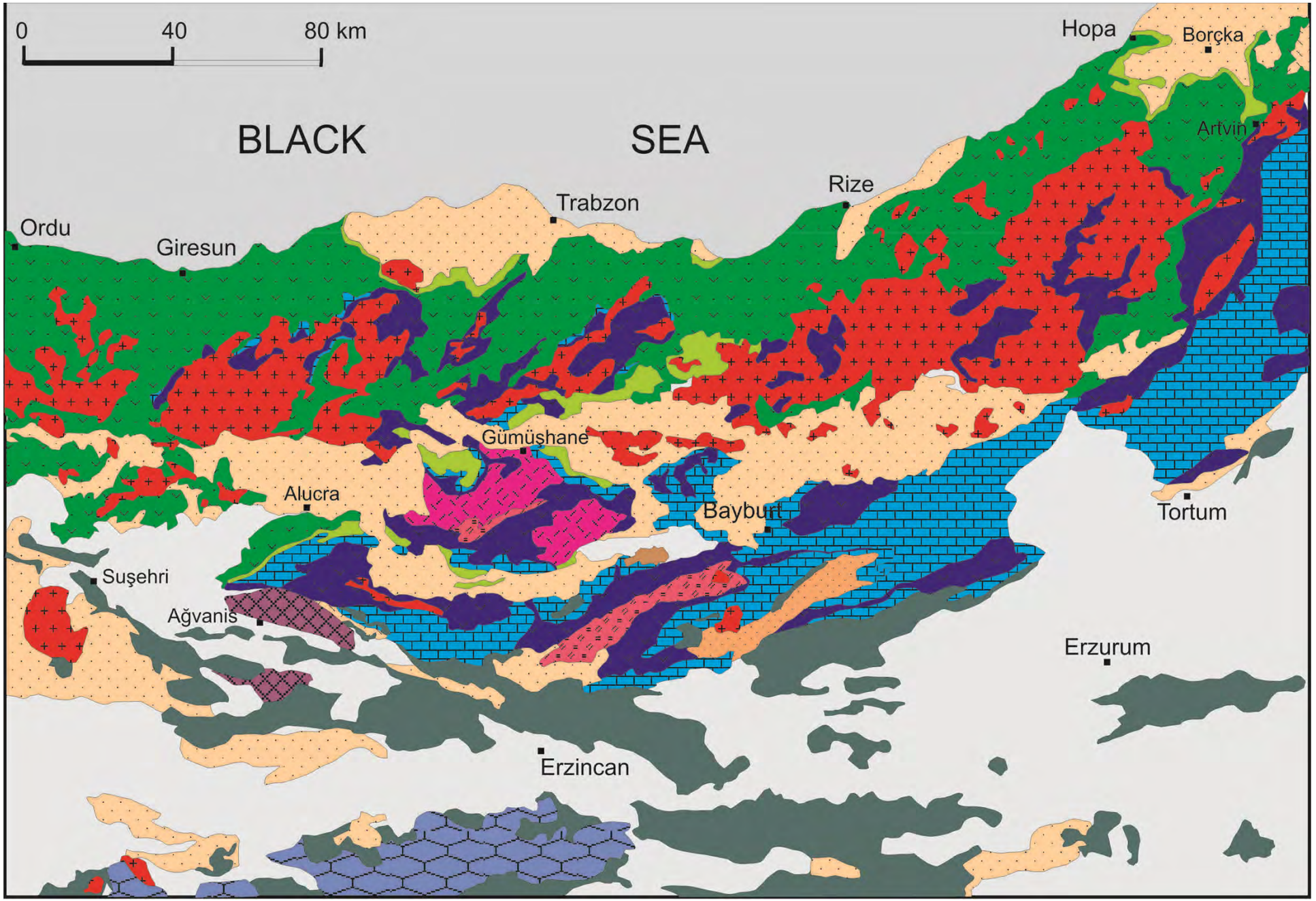


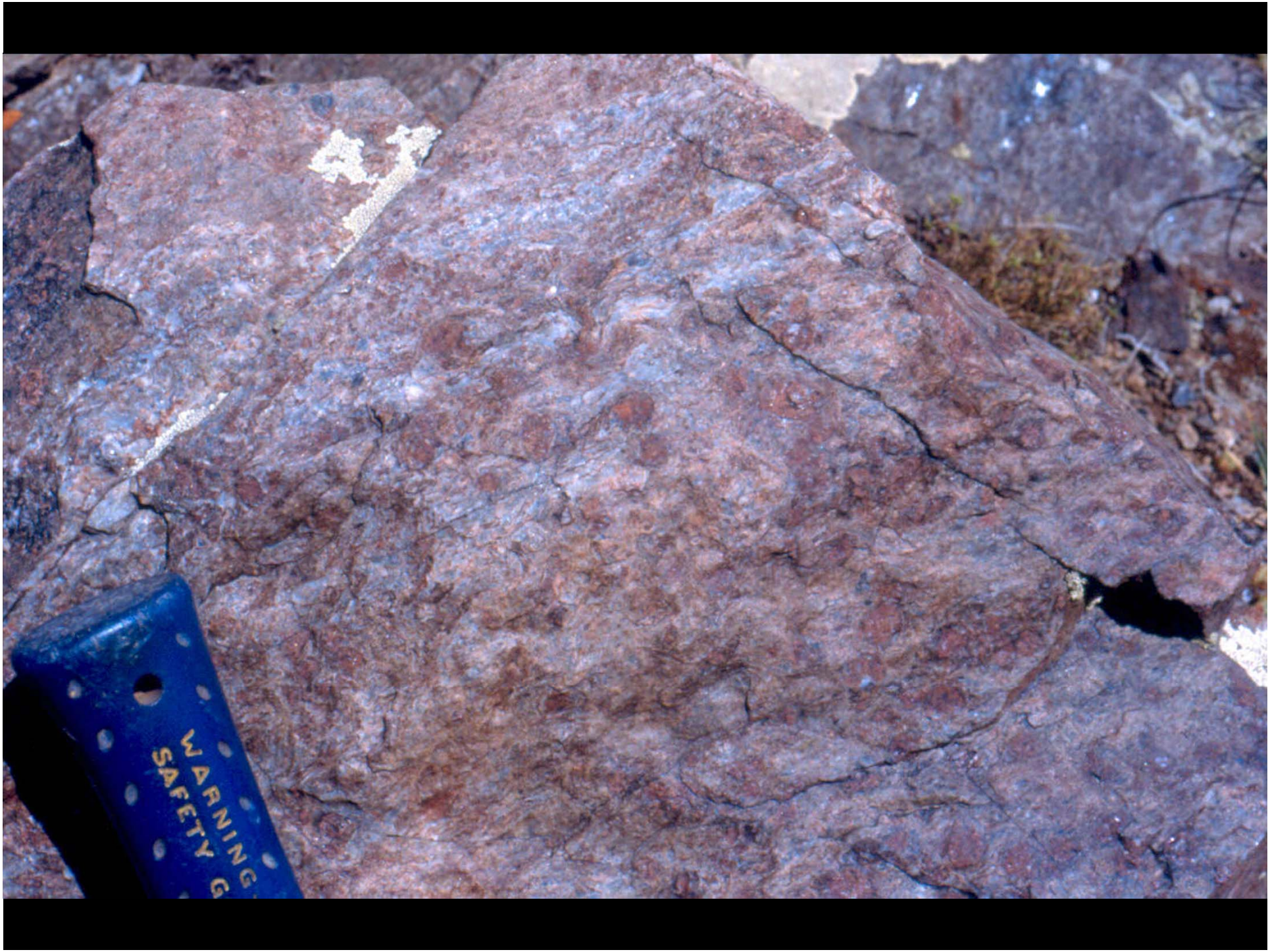
Pre-Jurassic basement units in the Eastern Pontides

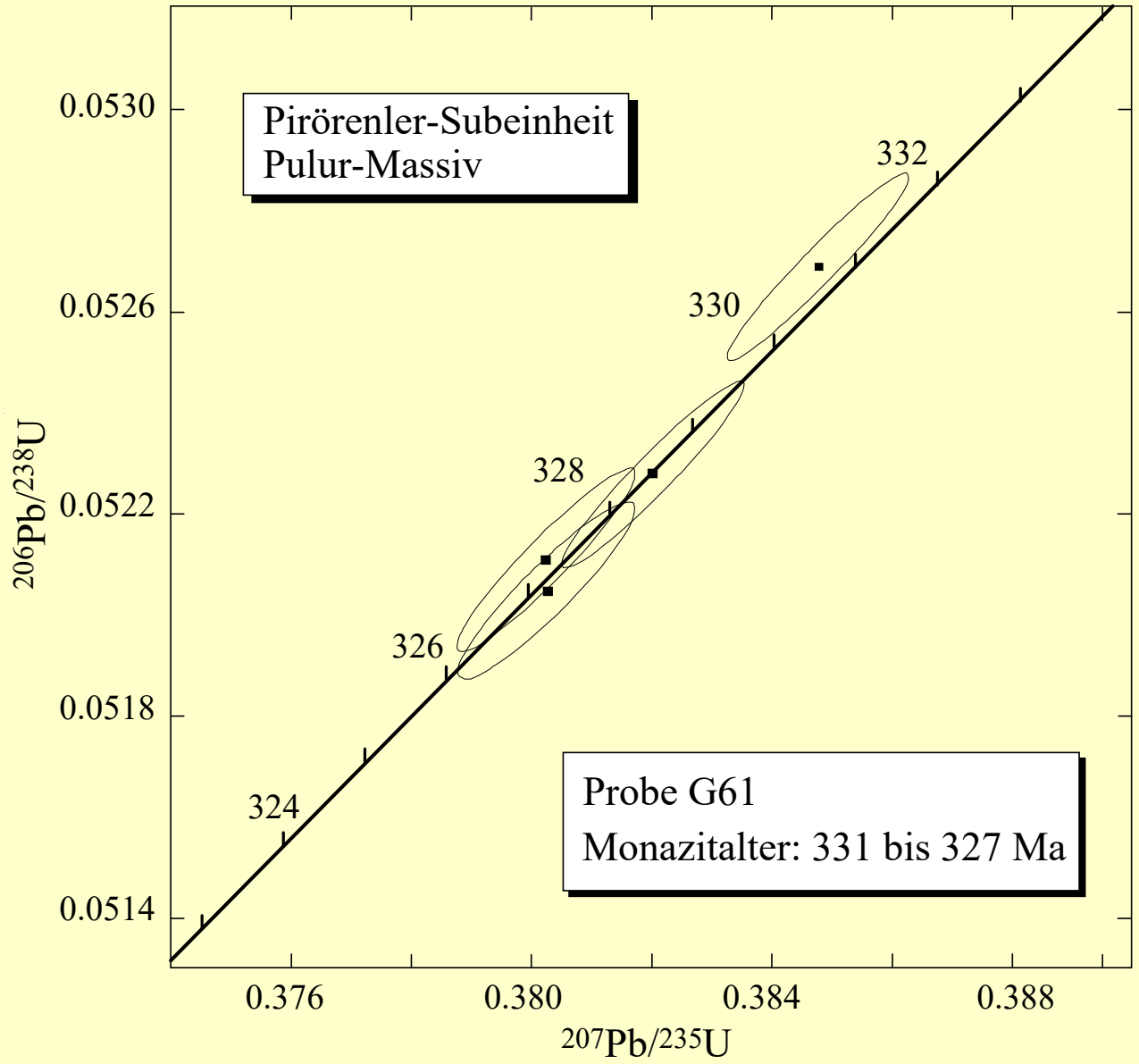

Black Sea
Mediterranean
Strandja M.
Rhodope
Tertiary
Thrace Basin
İstanbul
Zonguldak
Küre
Devrekani
Pan-African
basement
311 ± 6 Ma
İSTANBUL ZONE
Intra-Pontide suture
SAKARYA ZON
330-320 Ma
335 - 325 Ma
Pulur Massif
Erzurum
Uludağ
Söğüt Granodiorite
Kazdağ
Ankara
Eskişehir
330-319 Ma
İzmir-Ankara suture
Sivas
KIRŞEHİR
MASSİF
Karaburun
Menderes
Massif
Chios
Cycladic
Massif
Pan-African
basement
ANATOLIDE-TAURIDE BLOCK
Bitlis Massif
Van
Lake
Diyarbakır
ARABIAN PLATFORM
0 60 120 km
Crystalline basement
Pre-Jurassic granites
Variscan gneiss, amphibolite, marble
Pan-African gneiss, micaschist

PULUR MASSIVE

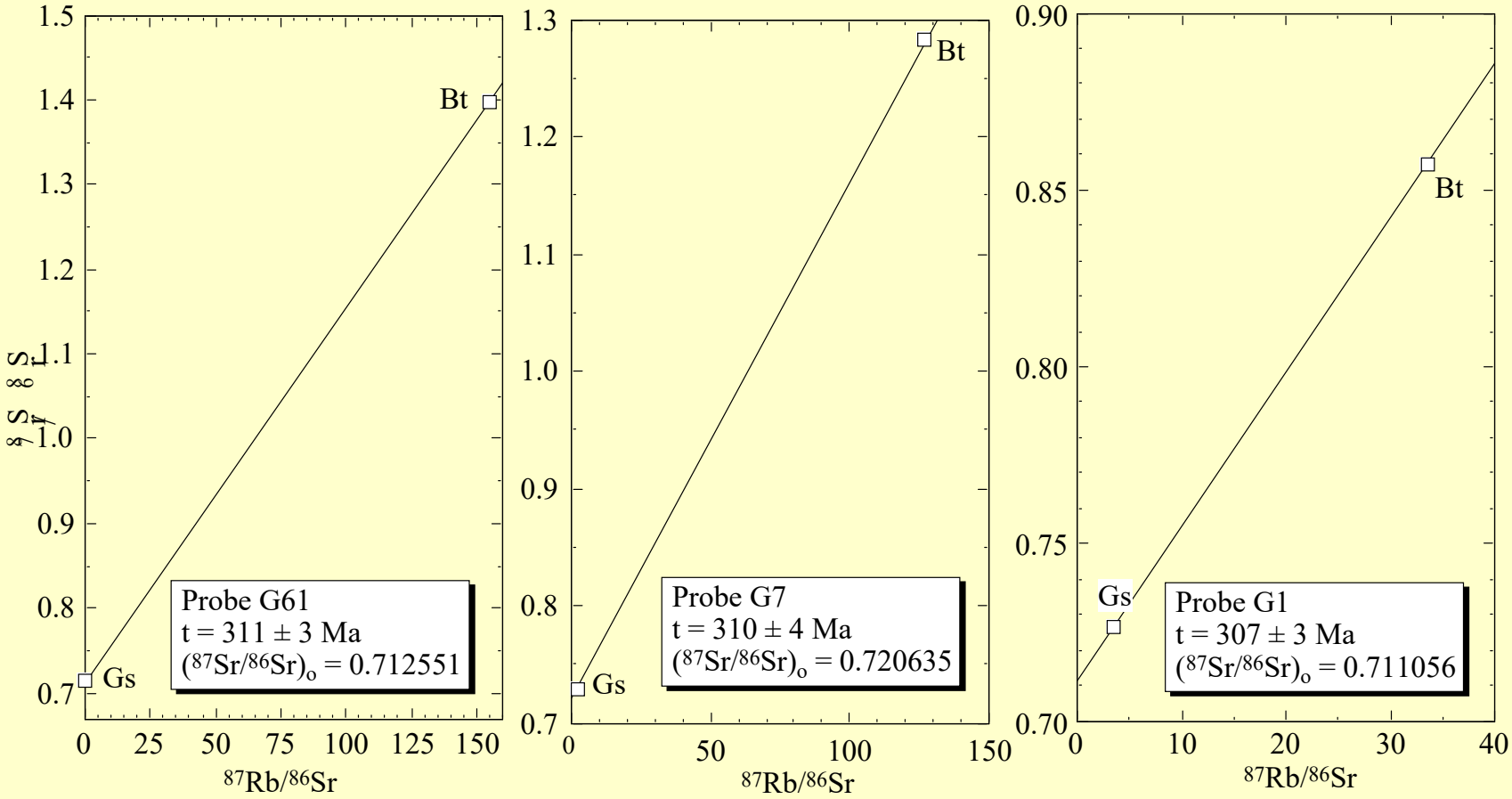
A HERCYNIAN METAMORPHIC BASEMENT OF EARLY CARBONIFEROUS AGE


0
40
80 km
BLACK
SEA
Hopa
Borçka
Artvin
Rize
Trabzon
Ordu
Giresun
Gümüşhane
Alucra
Bayburt
Tortum
Suşehri
Ağvanis
Erzurum
Erzincan

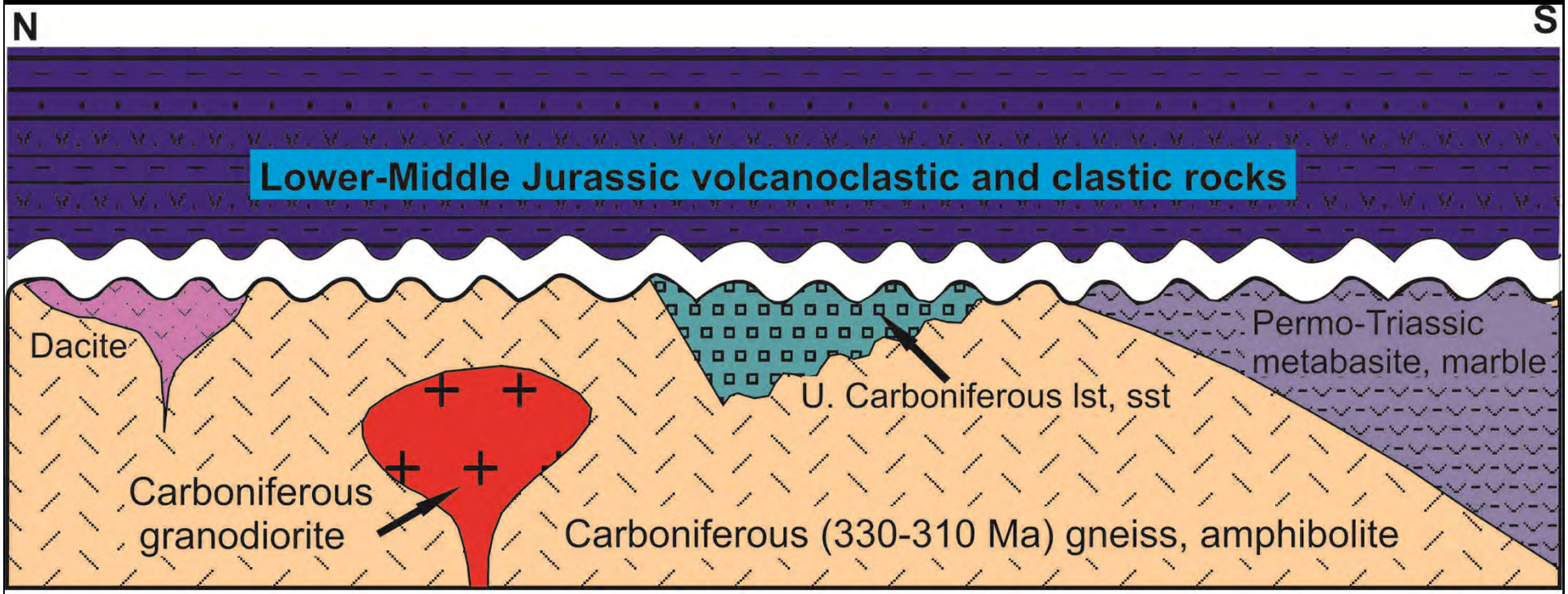

WARNING
SAFETY



U/Pb monazite ages from the Pulur Massif (Topuz, 1999)



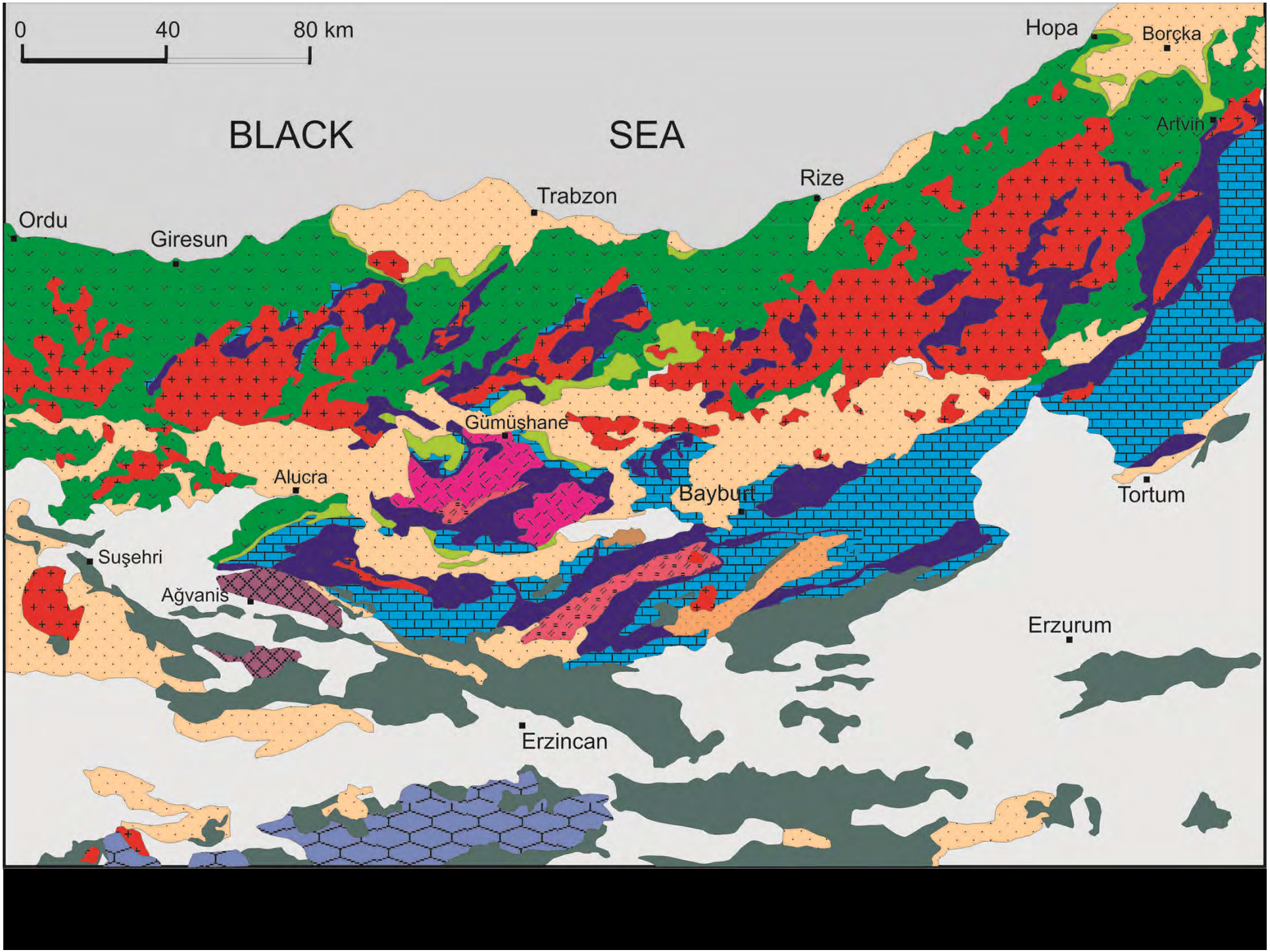
Rb/Sr biotite ages from the Pulur Massif (Topuz, 1999)



Pre-Jurassic basement units in the Eastern Pontides

PULUR CARBONIFEROUS SEQUENCE

MOLASSE DEPOSITS OF LATEST CARBONIFEROUS AGE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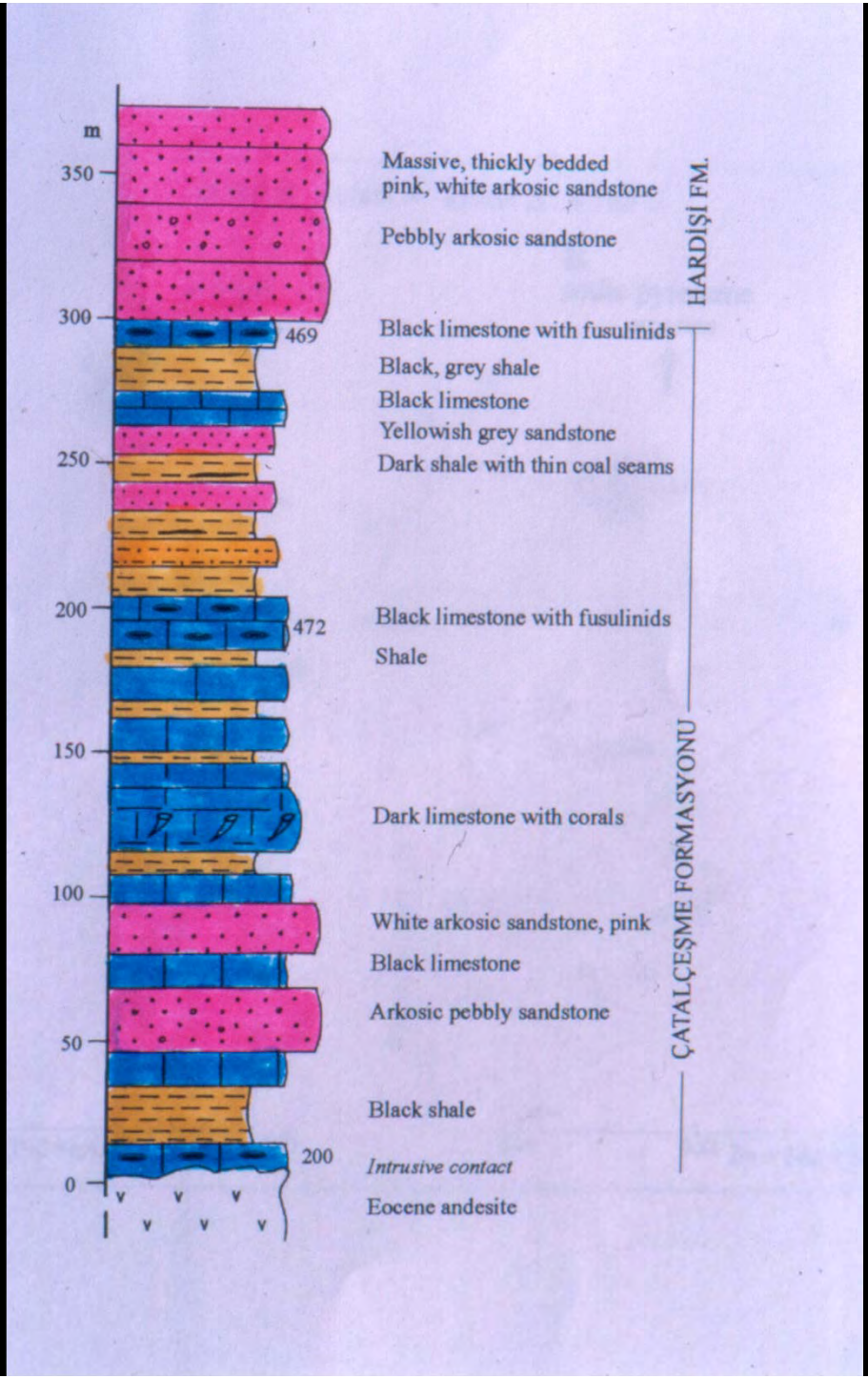
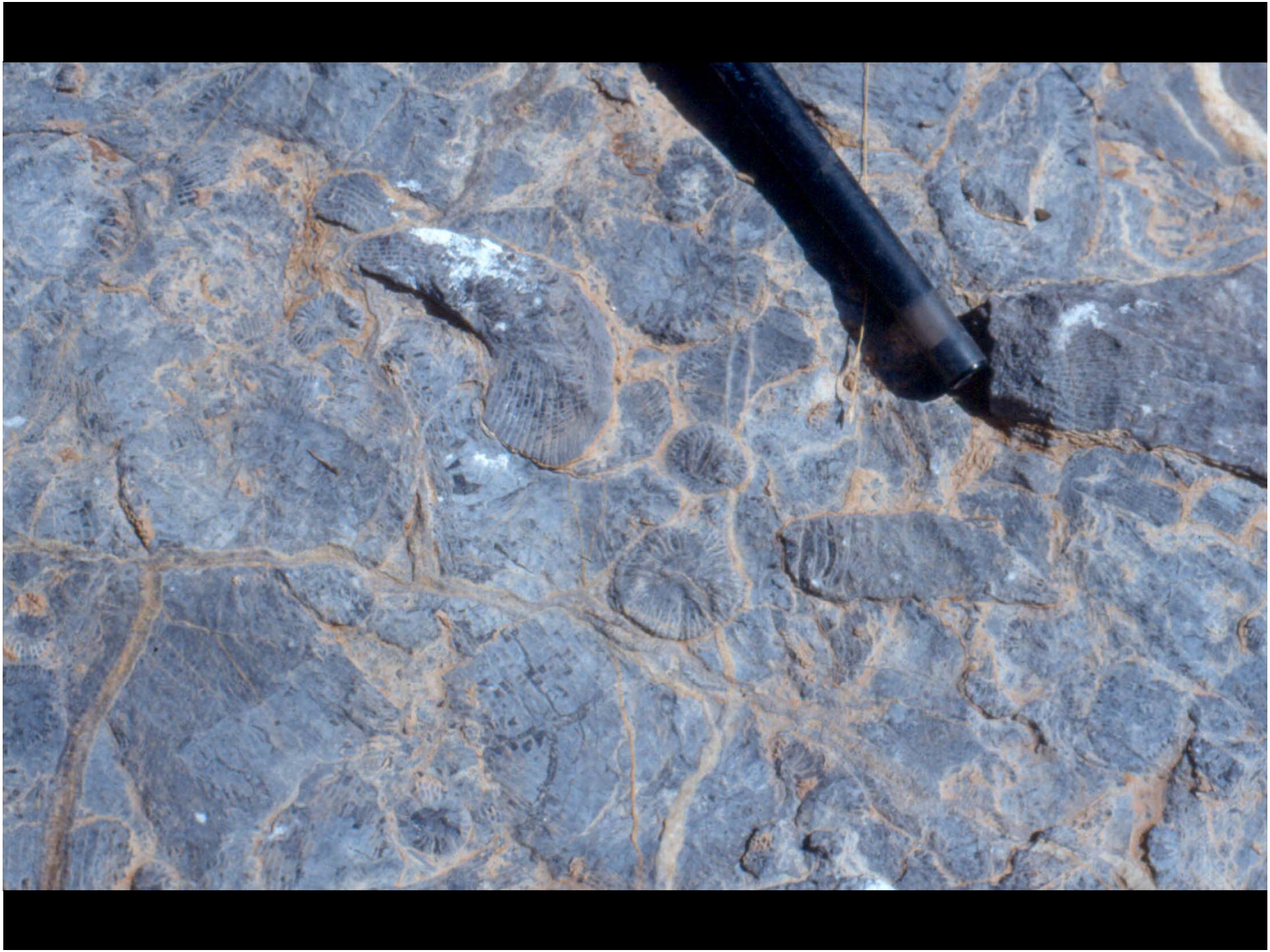
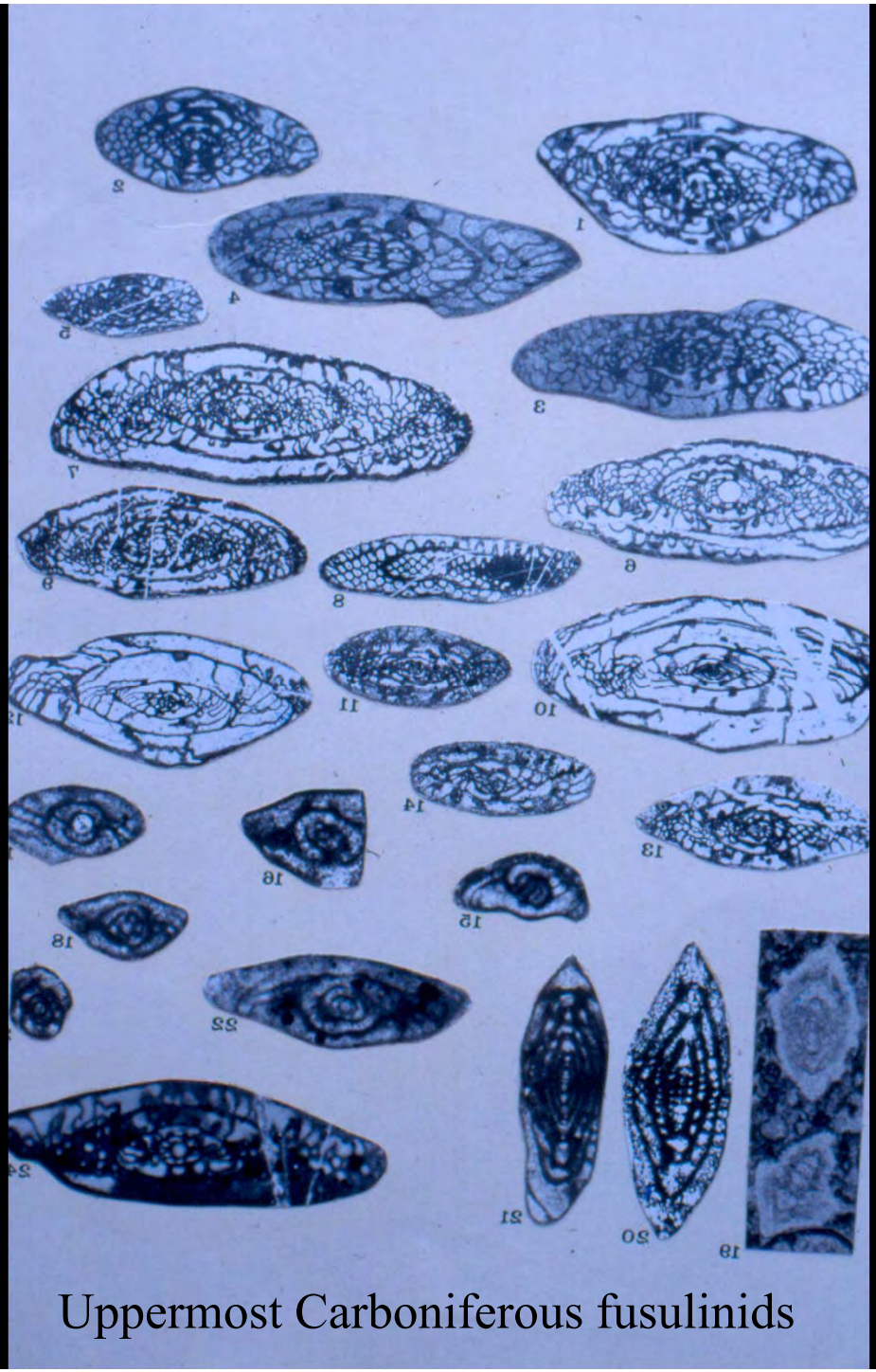
Rize
Trabzon
Ordu
Giresun
Gümüşhane
Alucra
Bayburt
Tortum
Suşehri
Ağvanis
Erzurum
Erzincan

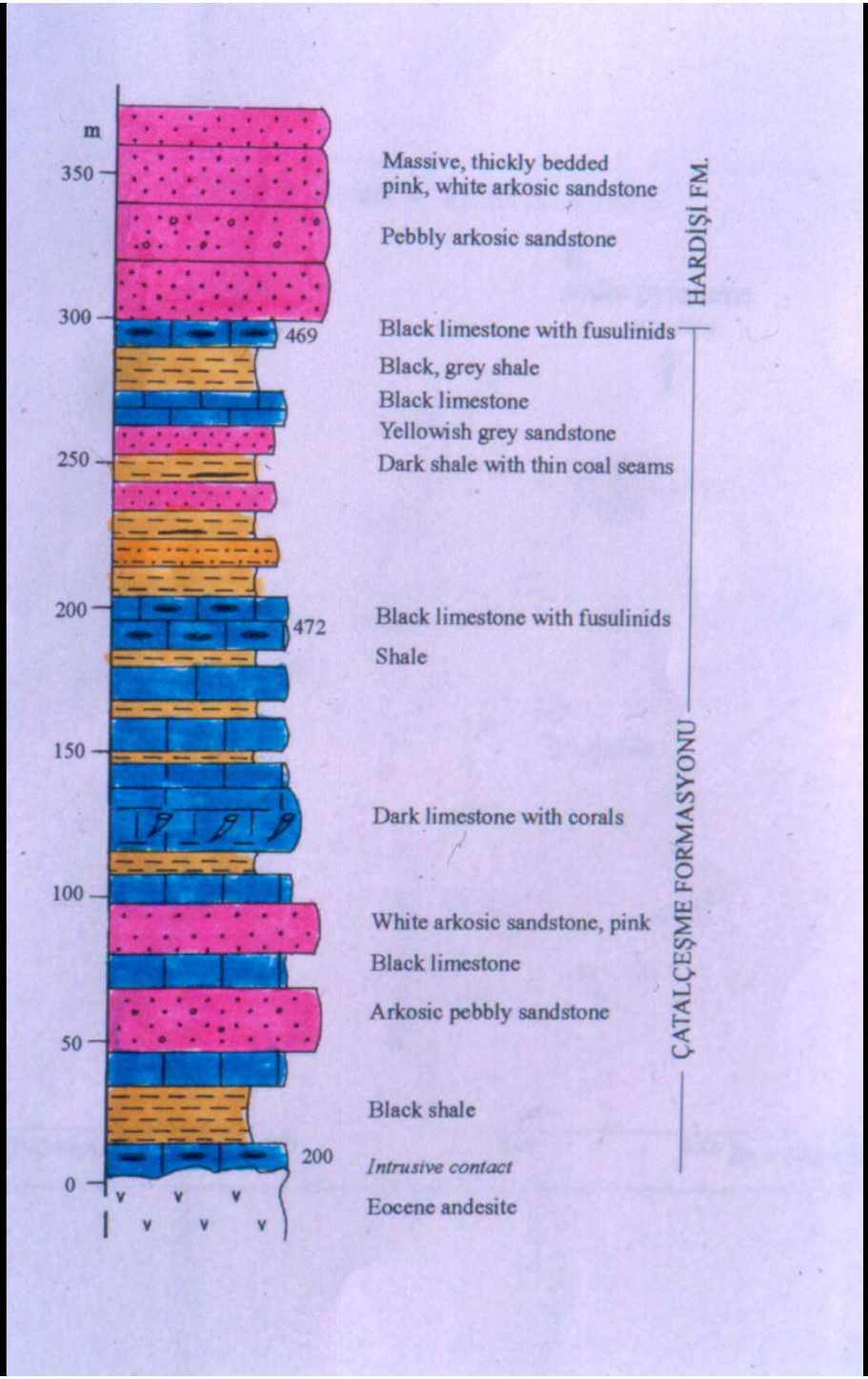

m
350
300
250
200
150
100
50
0
469
472
200
Massive, thickly bedded pink, white arkosic sandstone
Pebbly arkosic sandstone
Black limestone with fusulinids
Black, grey shale
Black limestone
Yellowish grey sandstone
Dark shale with thin coal seams
Black limestone with fusulinids
Shale
Dark limestone with corals
White arkosic sandstone, pink
Black limestone
Arkosic pebbly sandstone
Black shale
Intrusive contact
Eocene andesite
HARDİŞİ FM.
ÇATALÇEŞME FORMASYONU


2008
KURUŞ
15





Uppermost Carboniferous fusulinids


m
350
300
250
200
150
100
50
0
469
472
200
Massive, thickly bedded pink, white arkosic sandstone
Pebbly arkosic sandstone
Black limestone with fusulinids
Black, grey shale
Black limestone
Yellowish grey sandstone
Dark shale with thin coal seams
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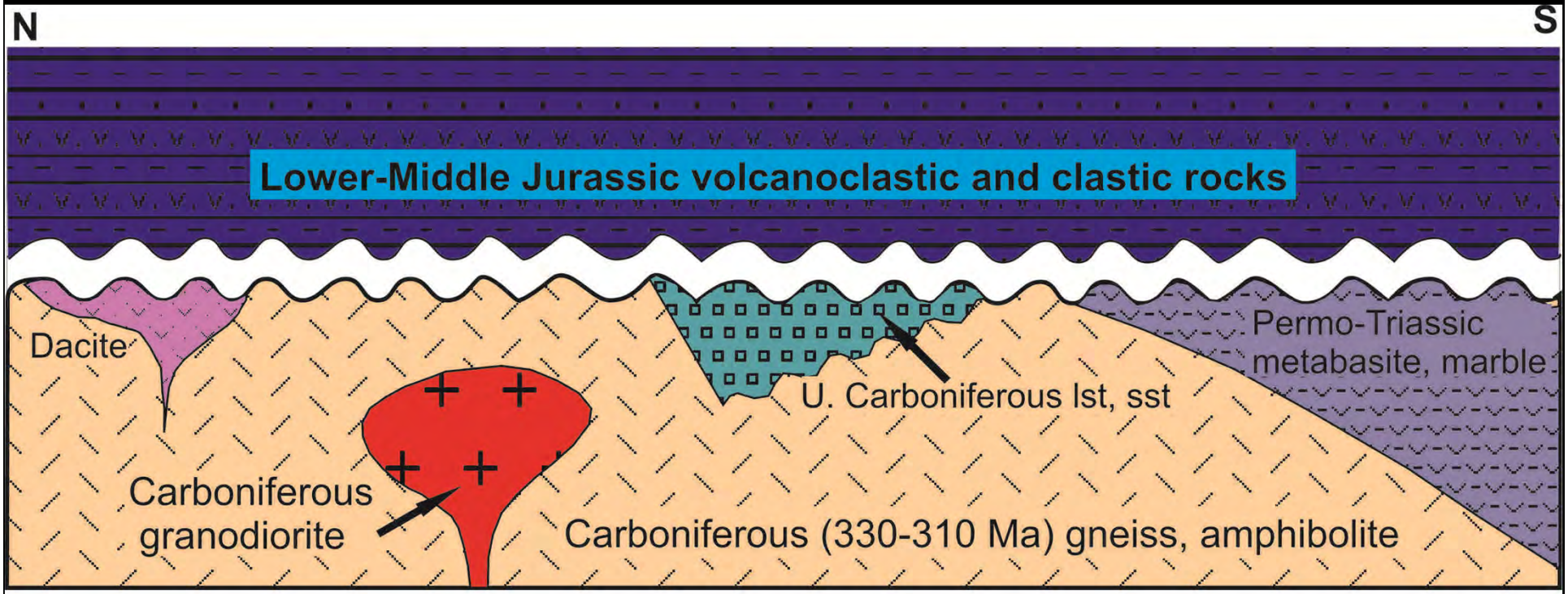
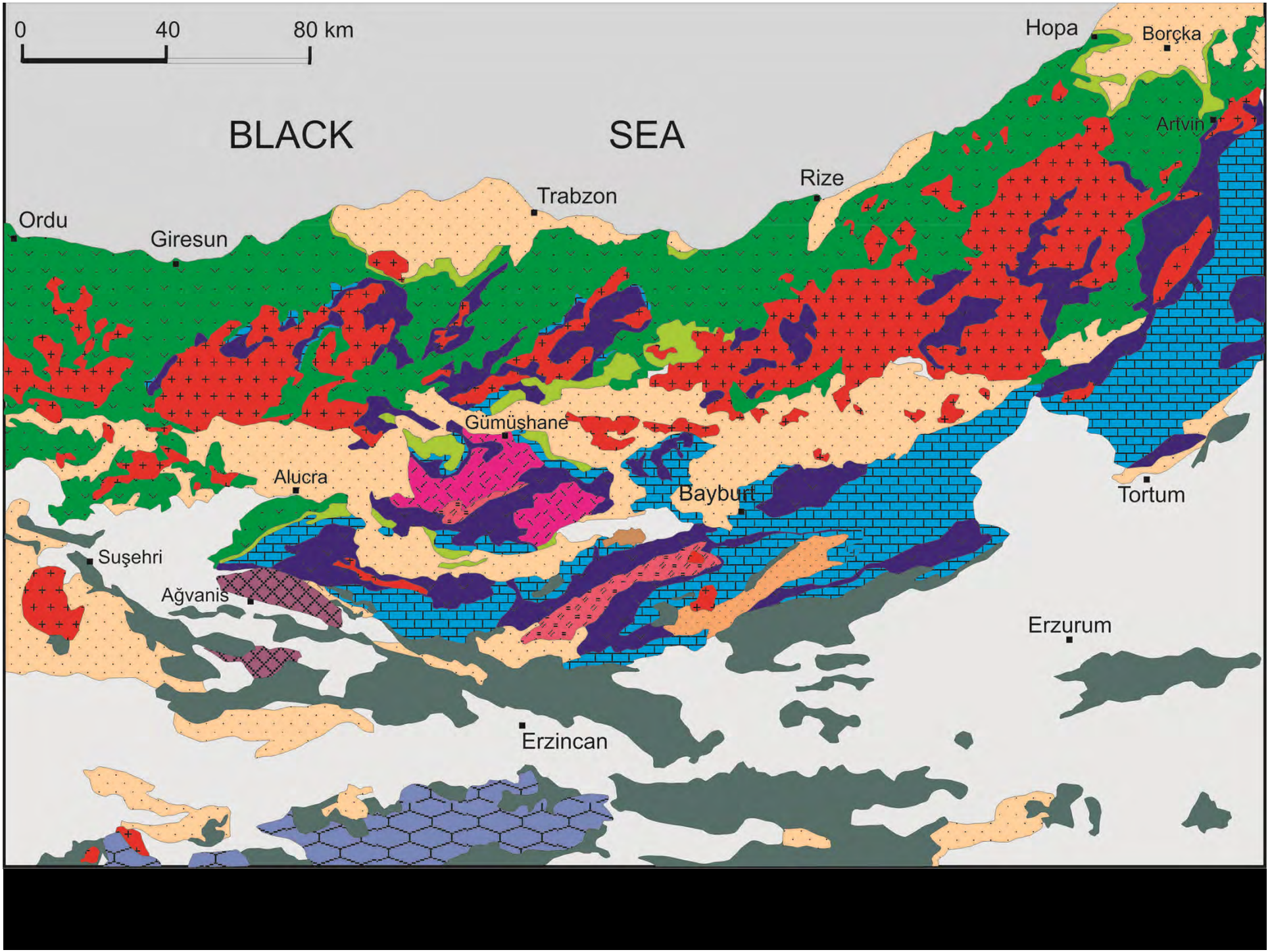
Shale
Dark limestone with corals
White arkosic sandstone, pink
Black limestone
Arkosic pebbly sandstone
Black shale
Intrusive contact
Eocene andesite
HARDİŞİ FM.
ÇATALÇEŞME FORMASYONU

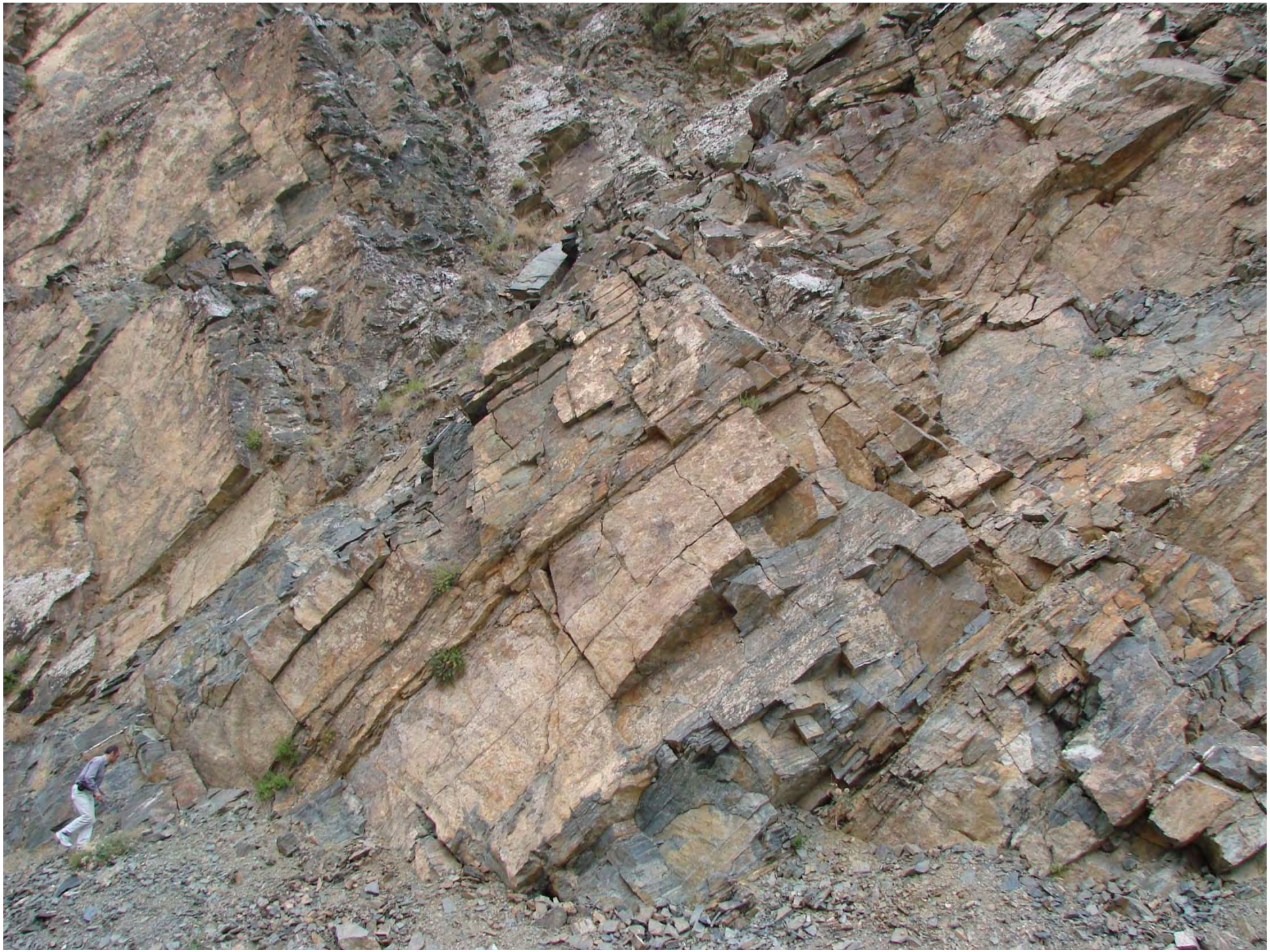


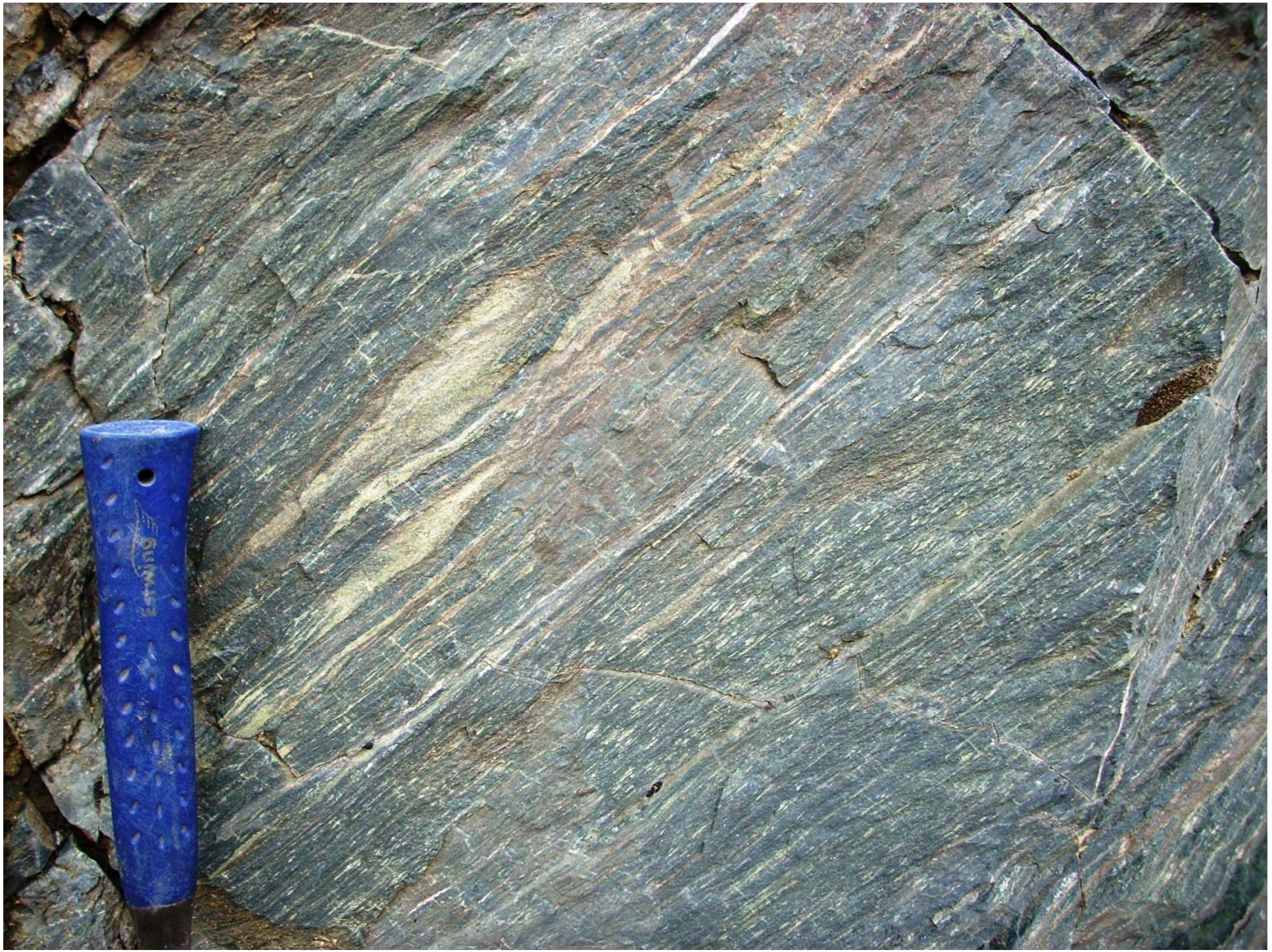
Pre-Jurassic basement units in the Eastern Pontides

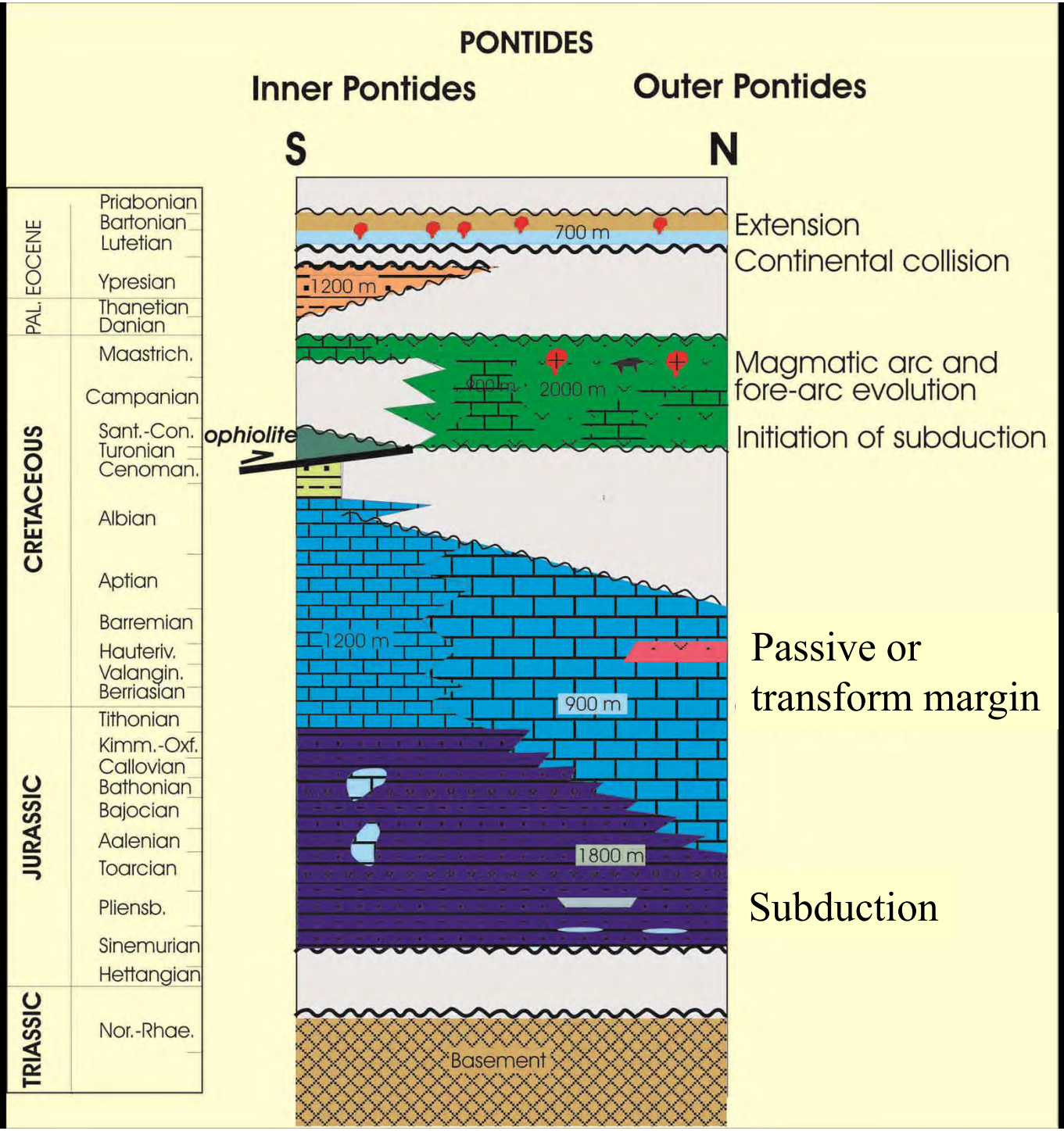
AĞVANİS MASSIF

METABASITE-PHYLLITE-MARBLE
LOWER KARAKAYA COMPLEX
(NİLÜFER UNIT)
LATE TRIASSIC METAMORPHISM


0
40
80 km
BLACK
SEA
Hopa
Borçka
Artvin
Rize
Trabzon
Ordu
Giresun
Gümüşhane
Alucra
Bayburt
Tortum
Suşehri
Ağvanis
Erzurum
Erzincan






PONTIDES
Inner Pontides
Outer Pontides
S
N
PAL. EOCENE
Priabonian
Bartonian
Lutetian
Ypresian
Thanetian
Danian
CRETACEOUS
Maastrich.
Campanian
Sant.-Con.
Turonian
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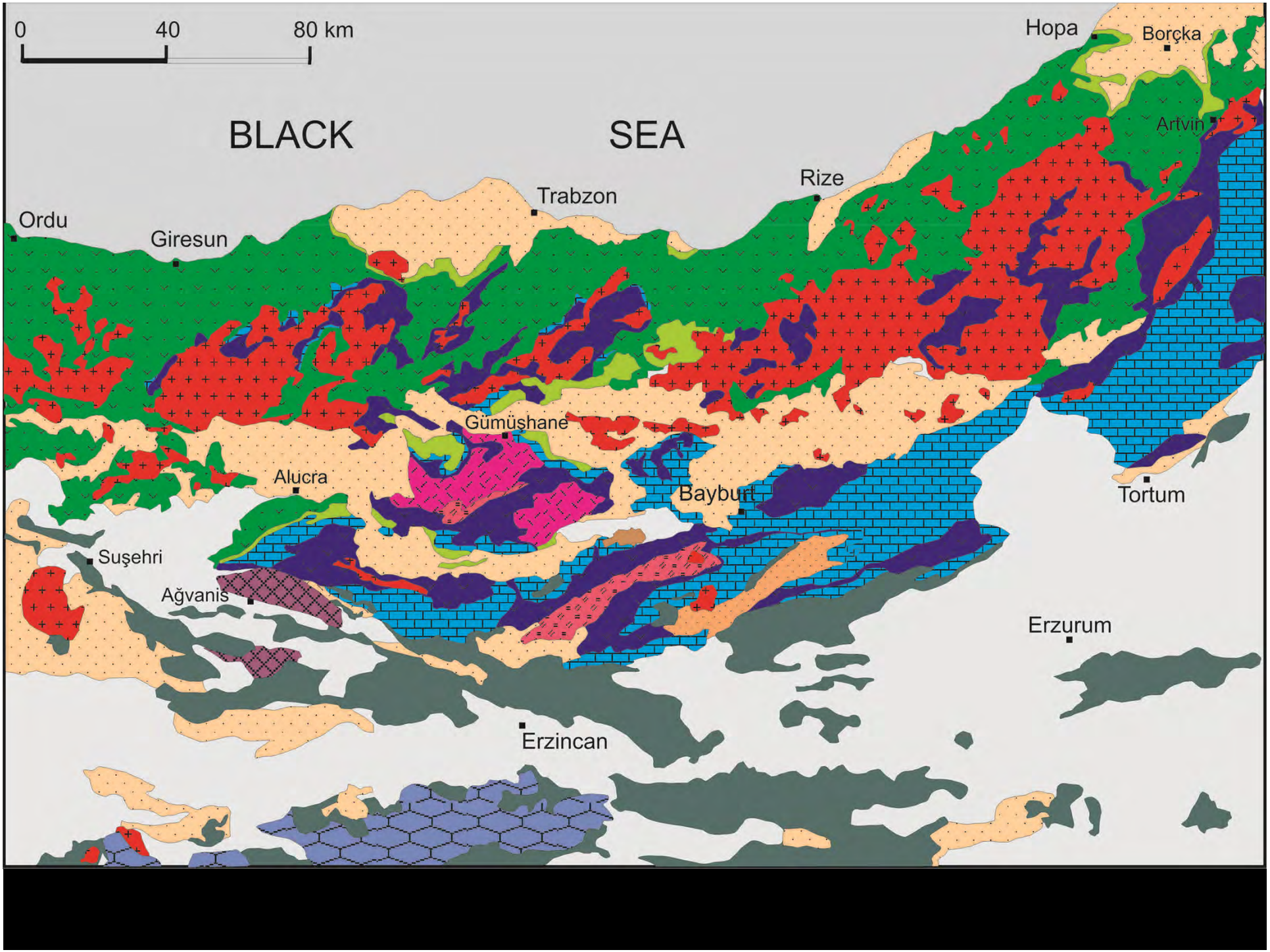
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Pliensb.
Sinemurian
Hettangian
TRIASSIC
Nor.-Rhae.
ophiolite
700 m
1200 m
2000 m
1200 m
900 m
1800 m
Basement
Extension
Continental collision
Magmatic arc and
fore-arc evolution
Initiation of subduction
Passive or
transform margin
Subduction

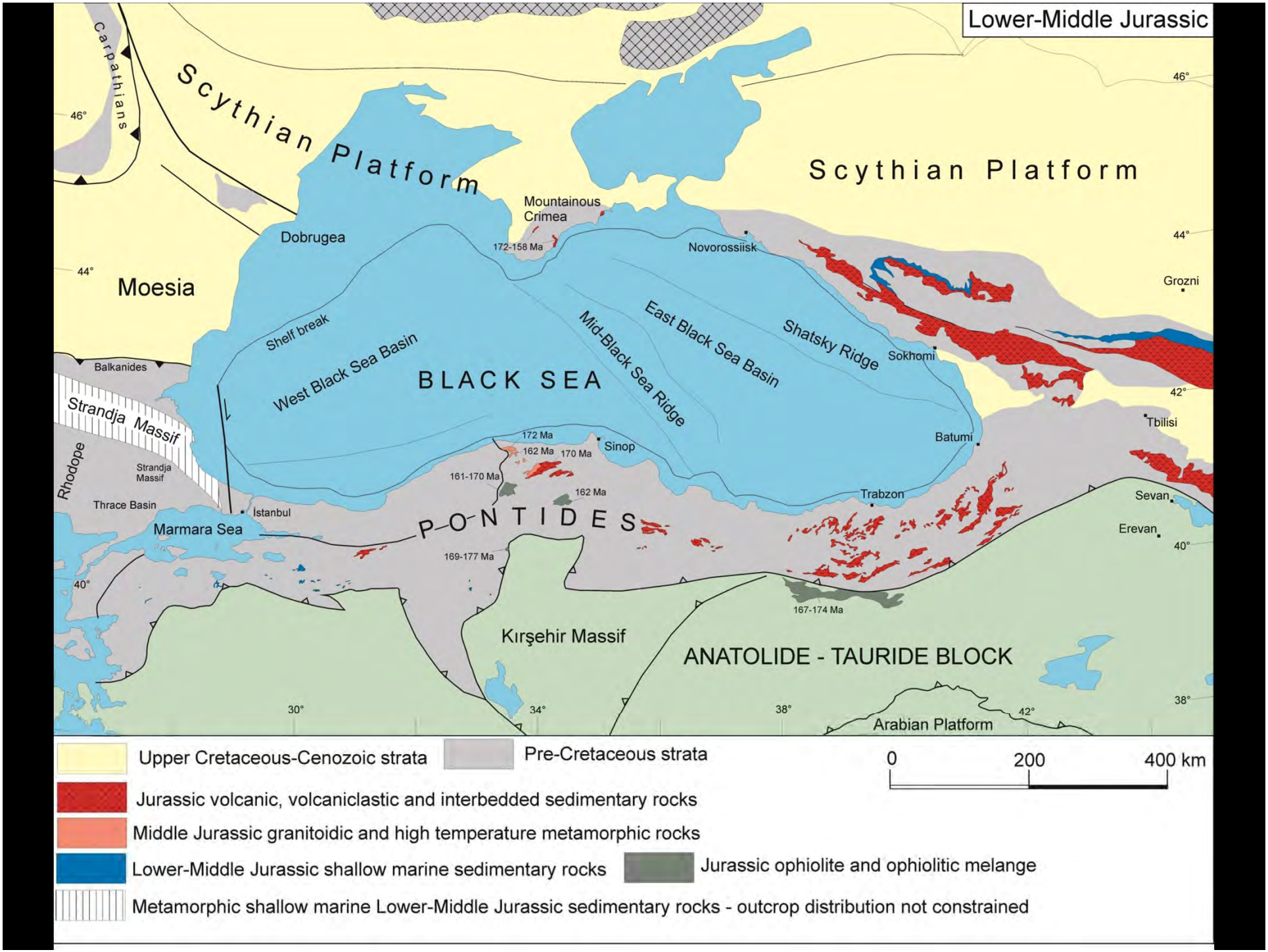
LOWER-MIDDLE-UPPER JURASSIC CLASTIC AND VOLCANICLASTIC ROCKS

KELKİT (ŞENKÖY) FORMATION

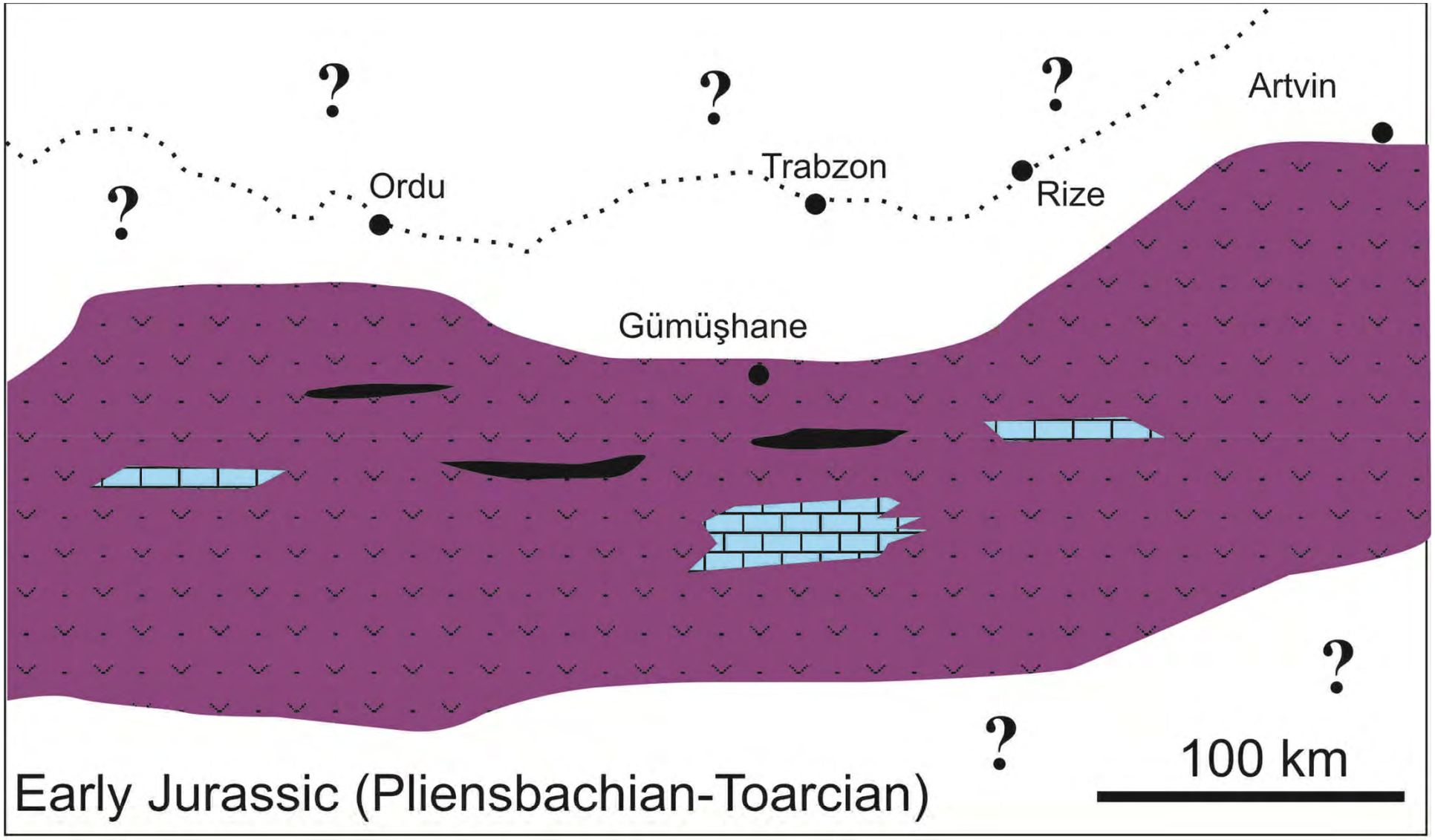
BASE OF THE PONTIDE SEDIMENTARY SEQUENCE

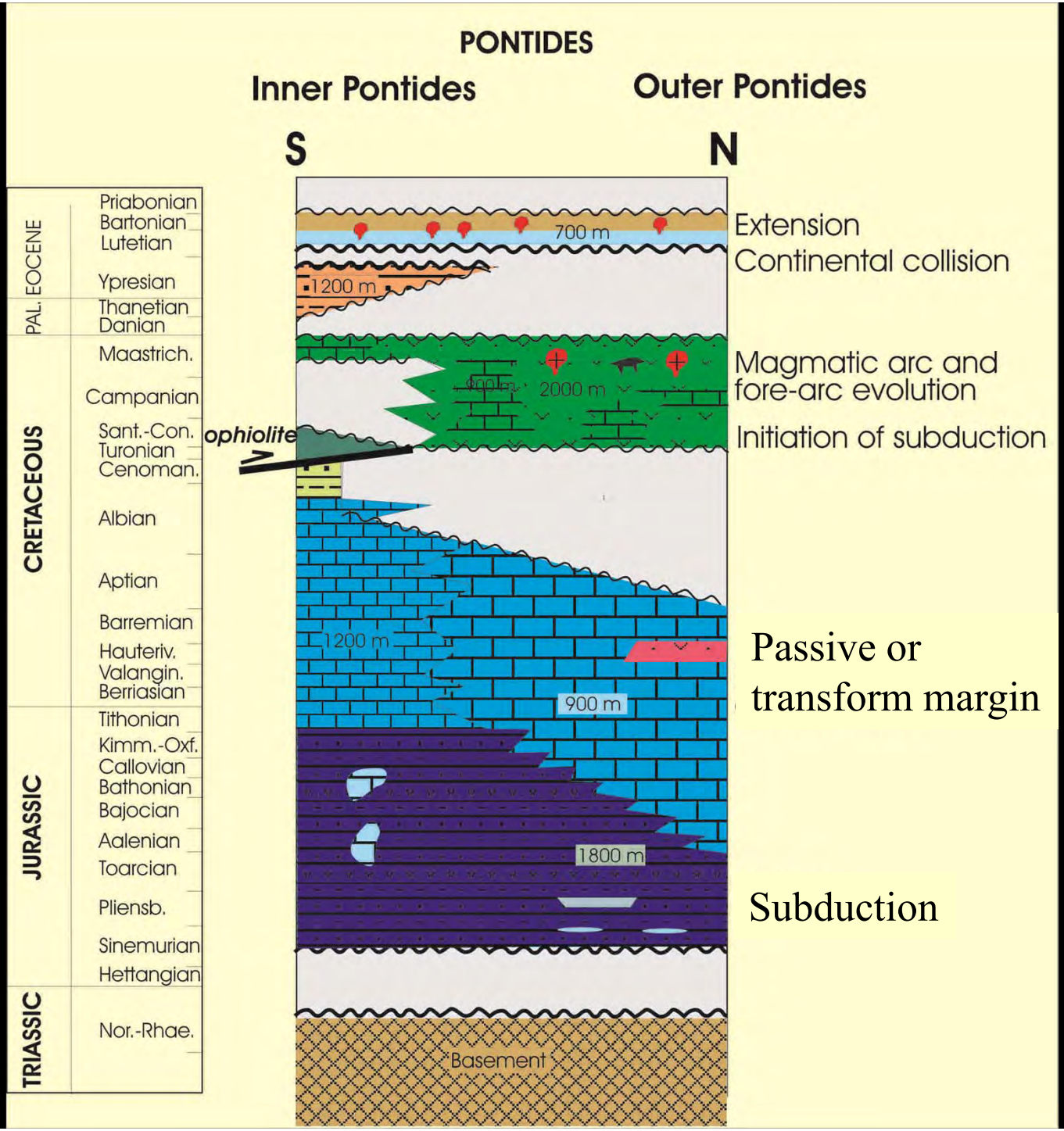
RIFT MAGMATISM OR SUBDUCTION MAGMATISM?


0
40
80 km
BLACK
SEA
Hopa
Borçka
Artvin
Rize
Trabzon
Ordu
Giresun
Gümüşhane
Alucra
Bayburt
Tortum
Suşehri
Ağvanis
Erzurum
Erzincan


Lower-Middle Jurassic
Carpathians
Scythian Platform
Scythian Platform
Mountainous Crimea
172-158 Ma
Dobrugea
Novorossiisk
Moesia
Grozni
Shelf break
West Black Sea Basin
BLACK SEA
Mid-Black Sea Ridge
East Black Sea Basin
Shatsky Ridge
Sokhomi
Balkanides
Strandja Massif
Rhodope
Strandja Massif
172 Ma
162 Ma
170 Ma
Sinop
Batumi
Tbilisi
161-170 Ma
162 Ma
Thrace Basin
Istanbul
Trabzon
Sevan
Marmara Sea
PONTIDES
Erevan
169-177 Ma
167-174 Ma
Kırşehir Massif
ANATOLIDE - TAURIDE BLOCK
Arabian Platform
46°
44°
42°
40°
38°
30°
34°
42°
Upper Cretaceous-Cenozoic strata
Pre-Cretaceous strata
0
200
400 km
Jurassic volcanic, volcaniclastic and interbedded sedimentary rocks
Middle Jurassic granitoidic and high temperature metamorphic rocks
Lower-Middle Jurassic shallow marine sedimentary rocks
Jurassic ophiolite and ophiolitic melange
Metamorphic shallow marine Lower-Middle Jurassic sedimentary rocks - outcrop distribution not constrained


N50
Pentel PEN
PERMANENT MARKER


Artvin
Trabzon
Ordu
Rize
Gümüşhane
100 km
Early Jurassic (Pliensbachian-Toarcian)
Basaltic, andesitic tuff, volcanoclastic sandstone, shale
Limestone (ammonitico rosso type)
Coal


PONTIDES
Inner Pontides
Outer Pontides
S
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PAL. EOCENE
Priabonian
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Maastrich.
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Passive or
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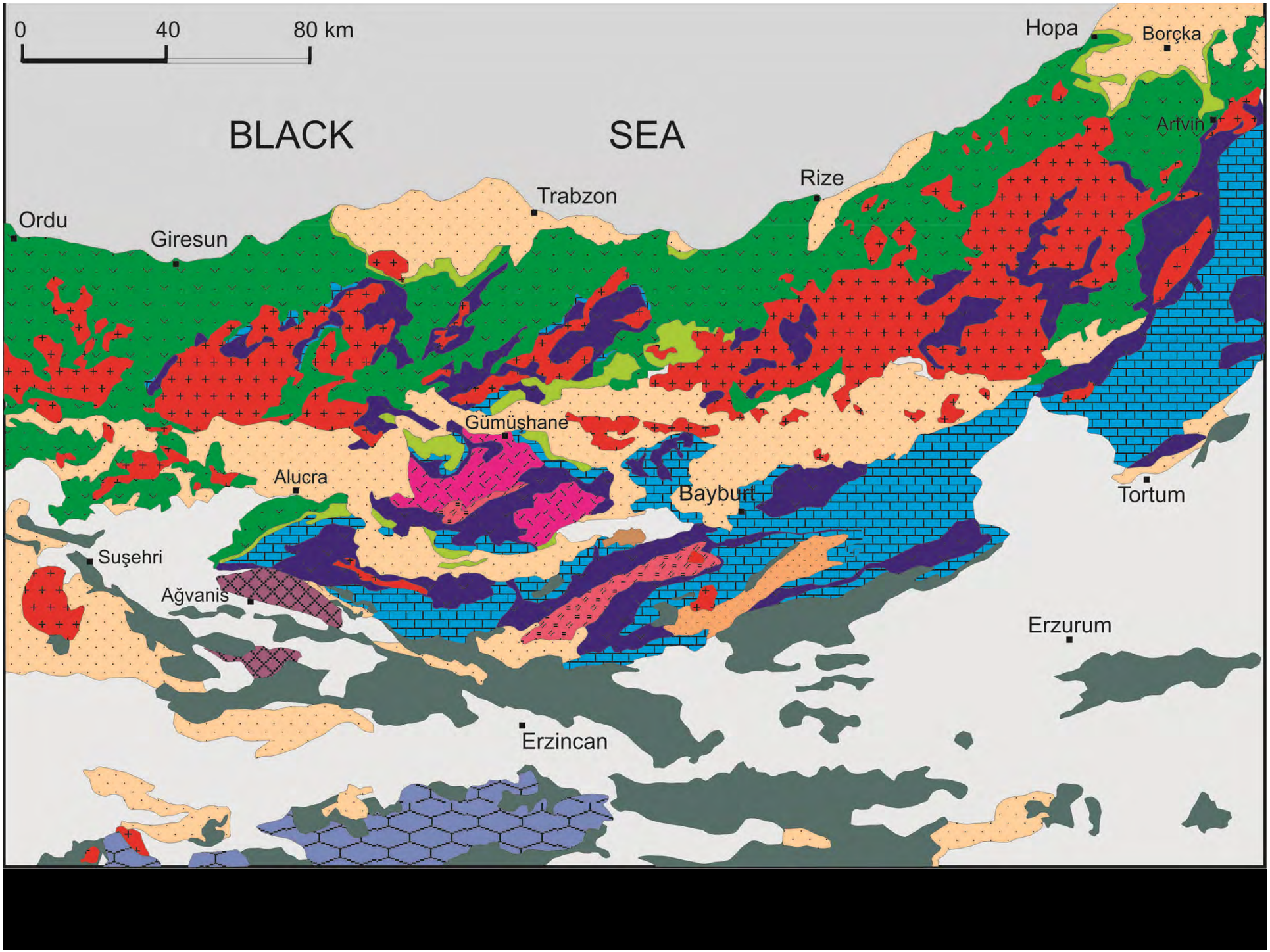
Subduction

UPPER JURASSIC – LOWER CRETACEOUS CARBONATES

BERDİGA LIMESTONE

EQUIVALENT OF THE BILECİK LIMESTONE OF THE WESTERN SAKARYA ZONE AND THE İNALTI FORMATION IN THE CENTRAL PONTIDES


0
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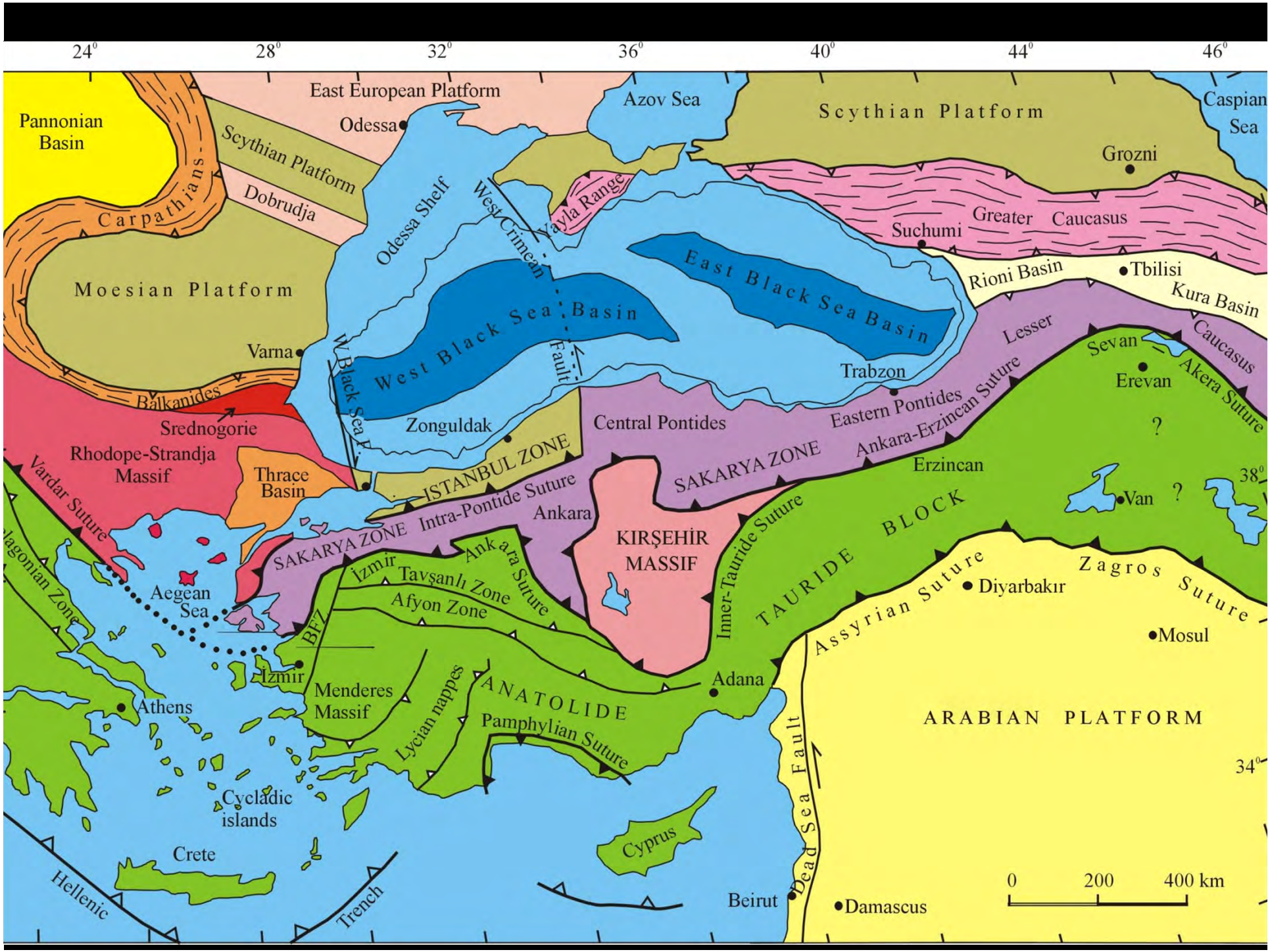
24°
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Dobrudja
Carpathians
Odessa Shelf
West Crimean
Yayla Range
Greater Caucasus
Suchumi
Moesian Platform
East Black Sea Basin
Rioni Basin
Tbilisi
Kura Basin
West Black Sea Basin
Fault
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Varna
Trabzon
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Ankara
38°
Van
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TAURIDE BLOCK
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Assyrian Suture
Diyarbakır
Afyon Zone
BFZ
Mosul
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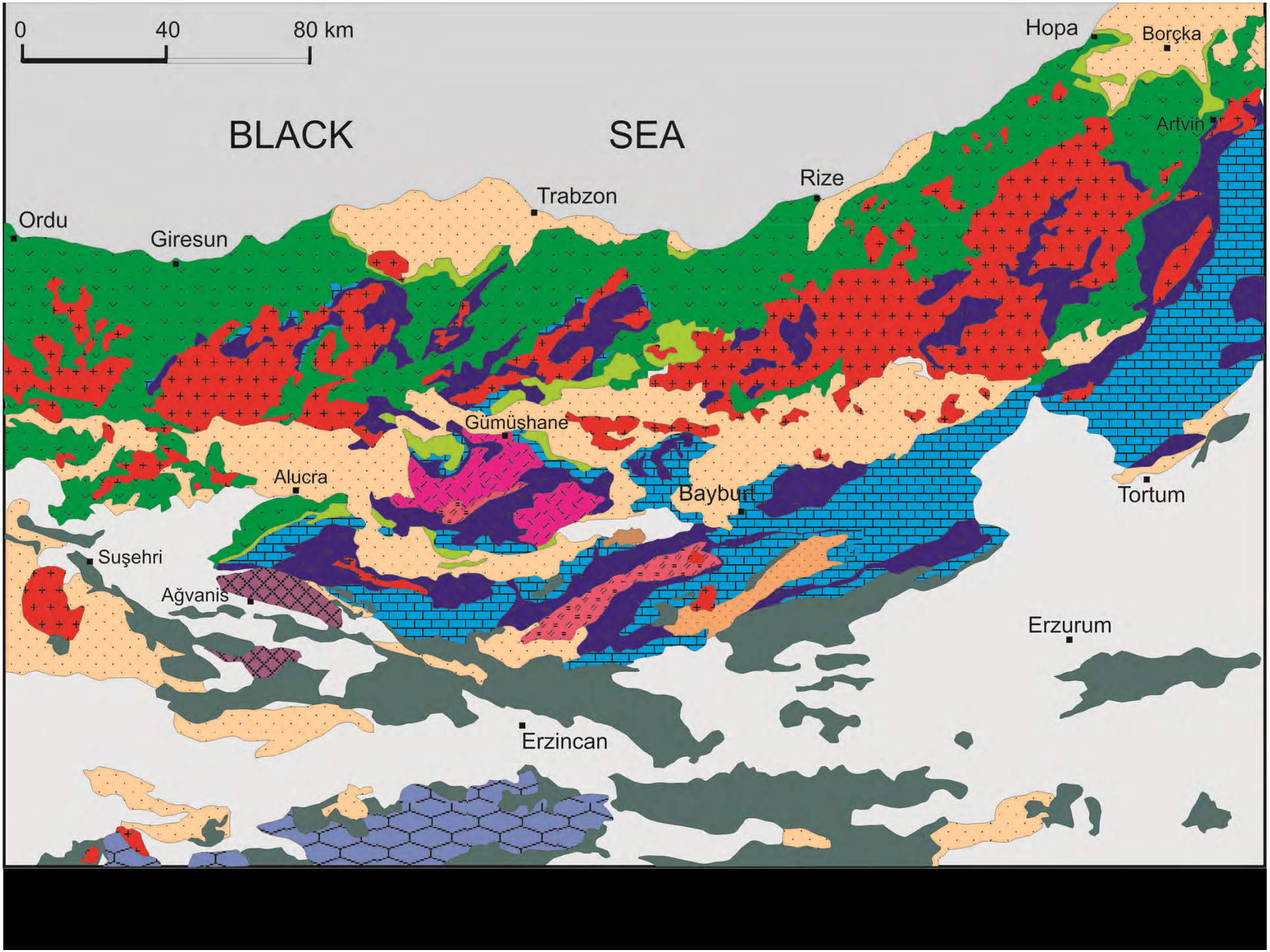
Menderes Massif
Lycian nappes
ANATOLIDE
Adana
Athens
Pamphylian Suture
ARABIAN PLATFORM
Cycladic islands
Dead Sea Fault
34°
Cyprus
Crete
Hellenic Trench
Beirut
Damascus
0
200
400 km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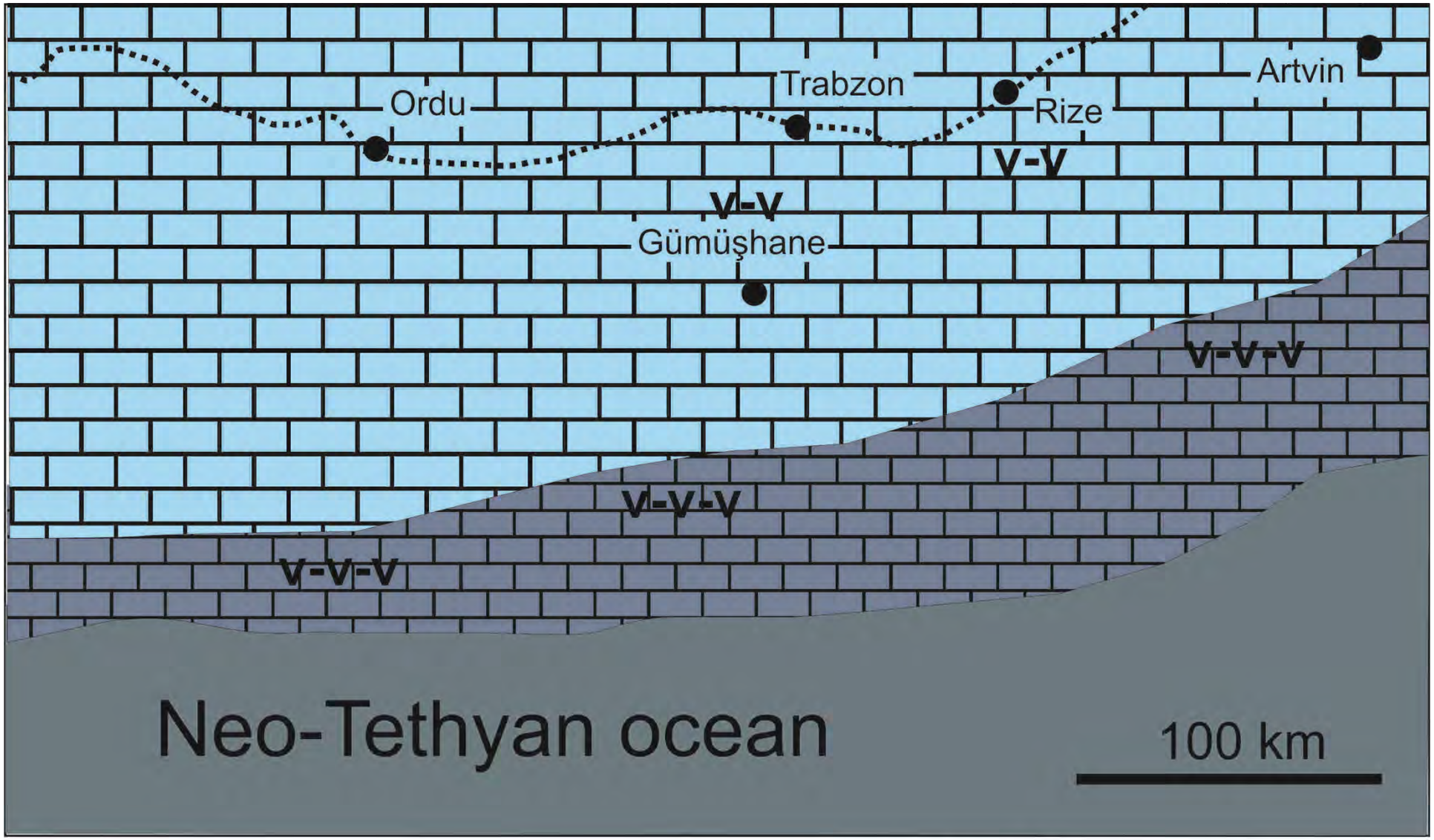
Alucra
Bayburt
Tortum
Suşehri
Ağvanis
Erzurum
Erzincan

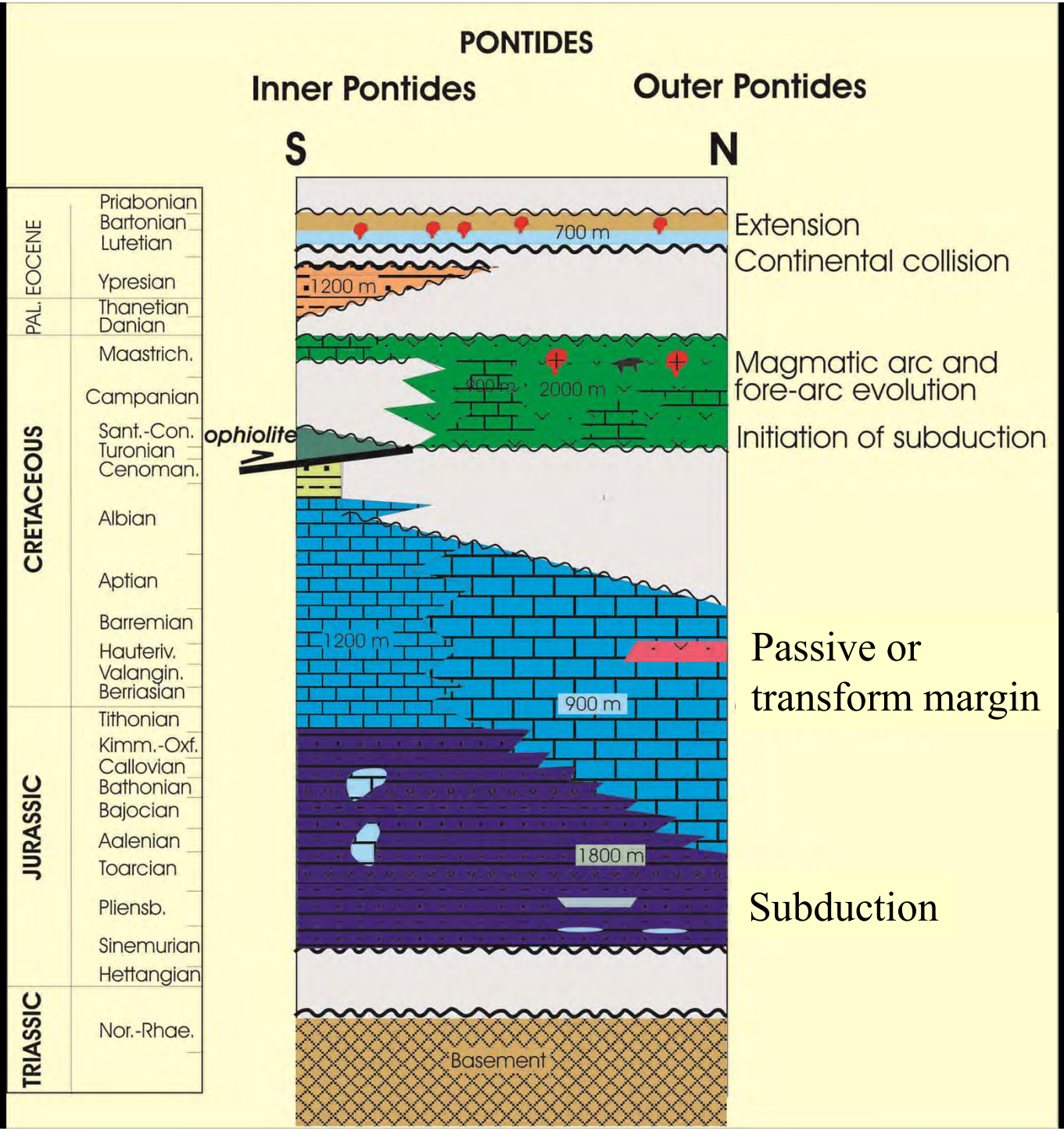
Tortum water-fall



Early Cretaceous

Neritic limestone

Pelagic limestone, calciturbidite


PONTIDES
Inner Pontides
Outer Pontides
S
N
PAL. EOCENE
Priabonian
Bartonian
Lutetian
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CRETACEOUS
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Albian
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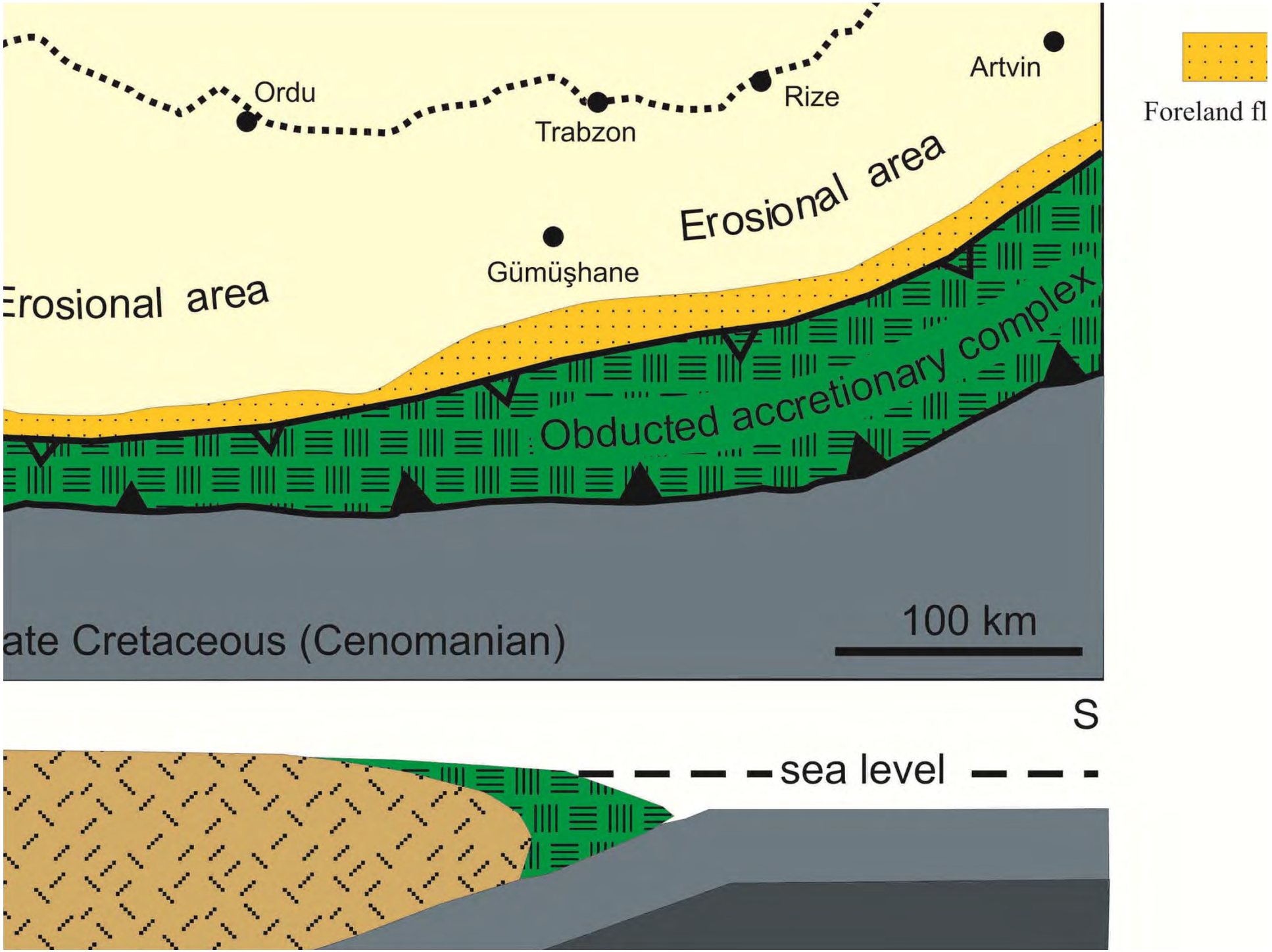
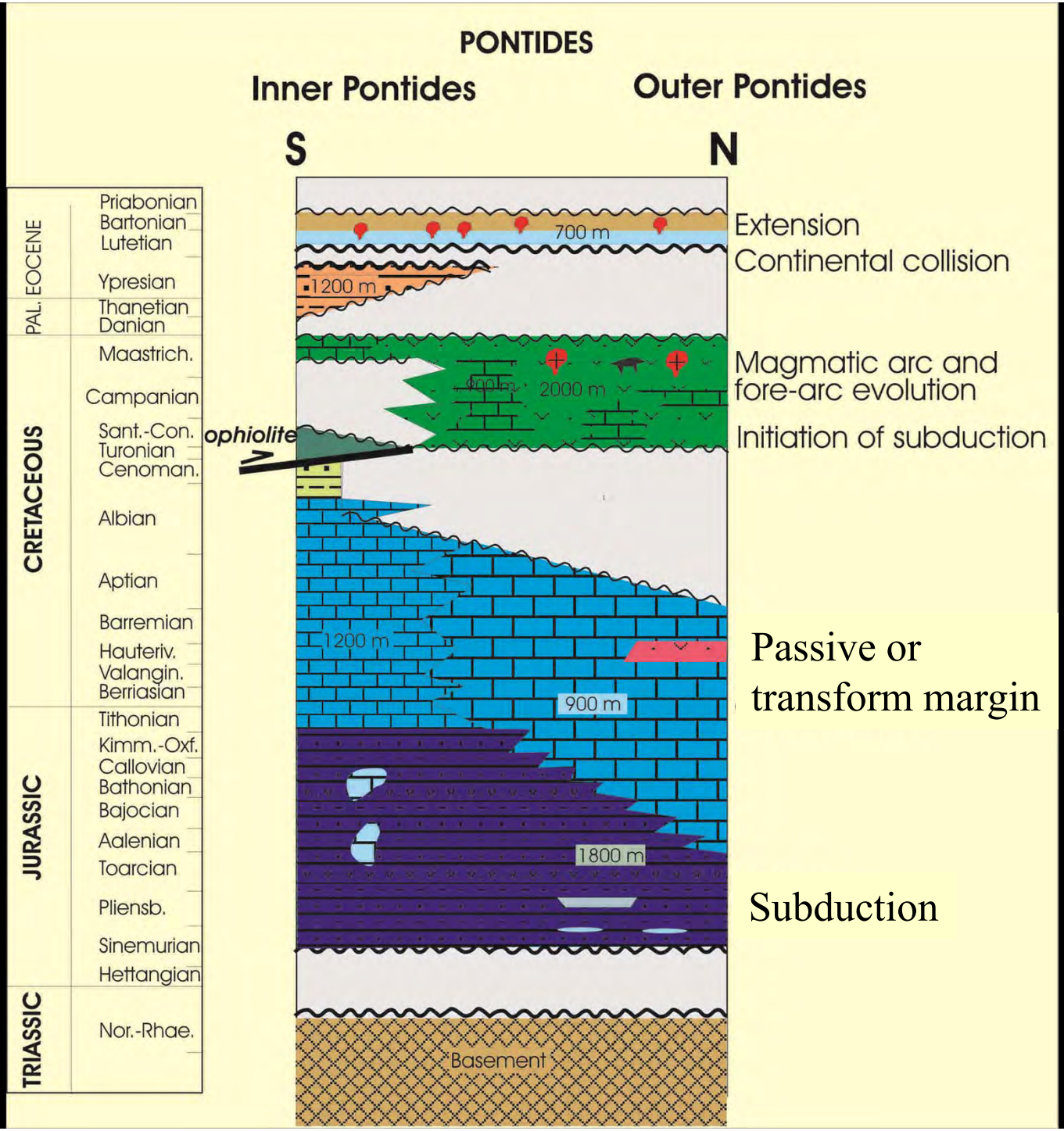
Kimm.-Oxf.
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Pliensb.
Sinemurian
Hettangian
TRIASSIC
Nor.-Rhae.
ophiolite
700 m
1200 m
2000 m
1200 m
900 m
1800 m
Basement
Extension
Continental collision
Magmatic arc and
fore-arc evolution
Initiation of subduction
Passive or
transform margin
Subduction

CENOMANIAN - TURONIAN

NORTHWARD EMPLACEMENT OF OPHIOLITE AND ASSOCIATED UPLIFT AND EROSION


Ordu
Trabzon
Rize
Artvin
Gümüşhane
Erosional area
Erosional area
Obducted accretionary complex
ate Cretaceous (Cenomanian)
100 km
Foreland fl
S
sea level


PONTIDES
Inner Pontides
Outer Pontides
S
N
PAL. EOCENE
Priabonian
Bartonian
Lutetian
Ypresian
Thanetian
Danian
CRETACEOUS
Maastrich.
Campanian
Sant.-Con.
Turonian
Cenoman.
Albian
Aptian
Barremian
Hauteriv.
Valangin.
Berriasian
JURASSIC
Tithonian
Kimm.-Oxf.
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Pliensb.
Sinemurian
Hettangian
TRIASSIC
Nor.-Rhae.
ophiolite
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1200 m
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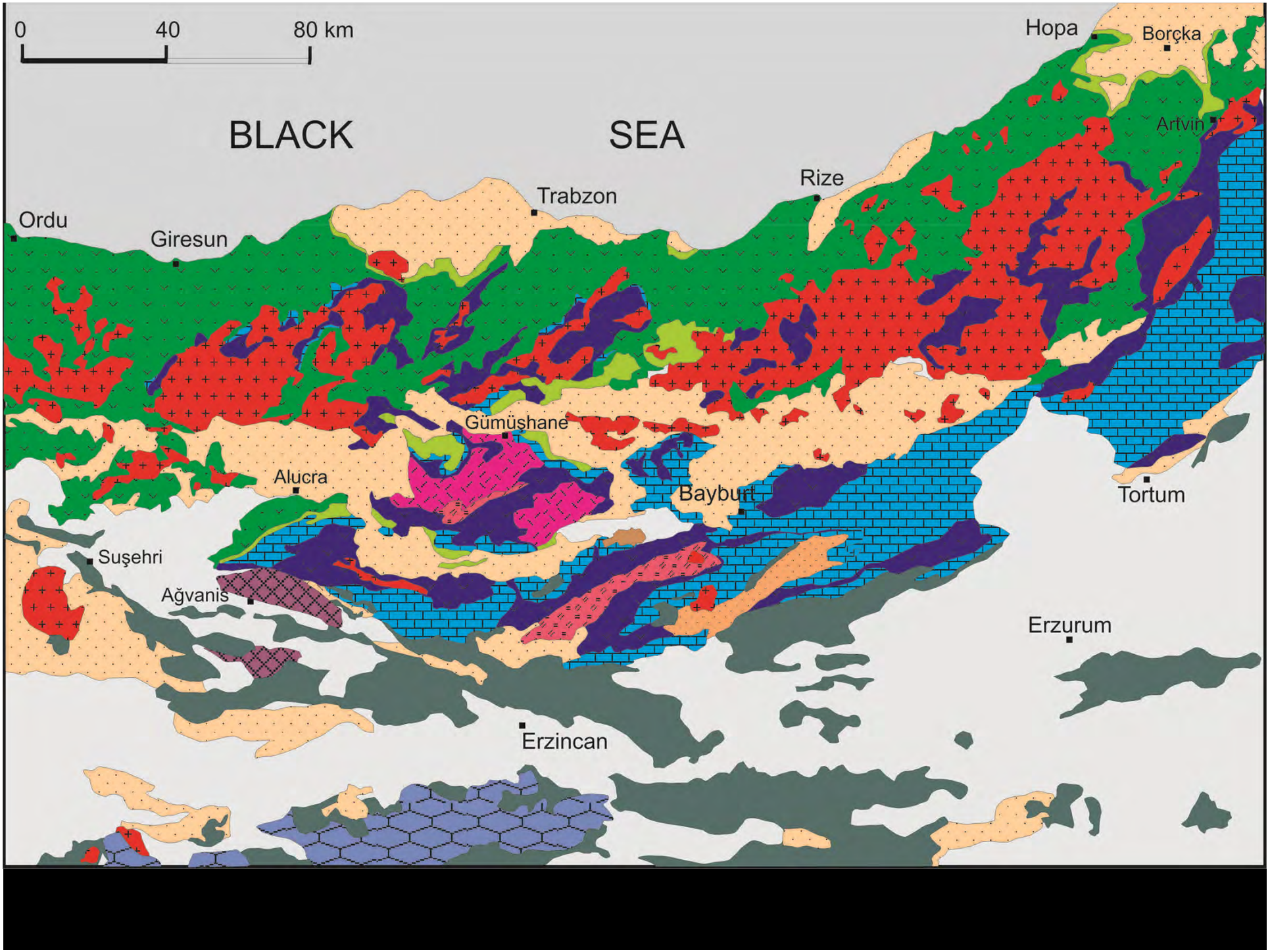
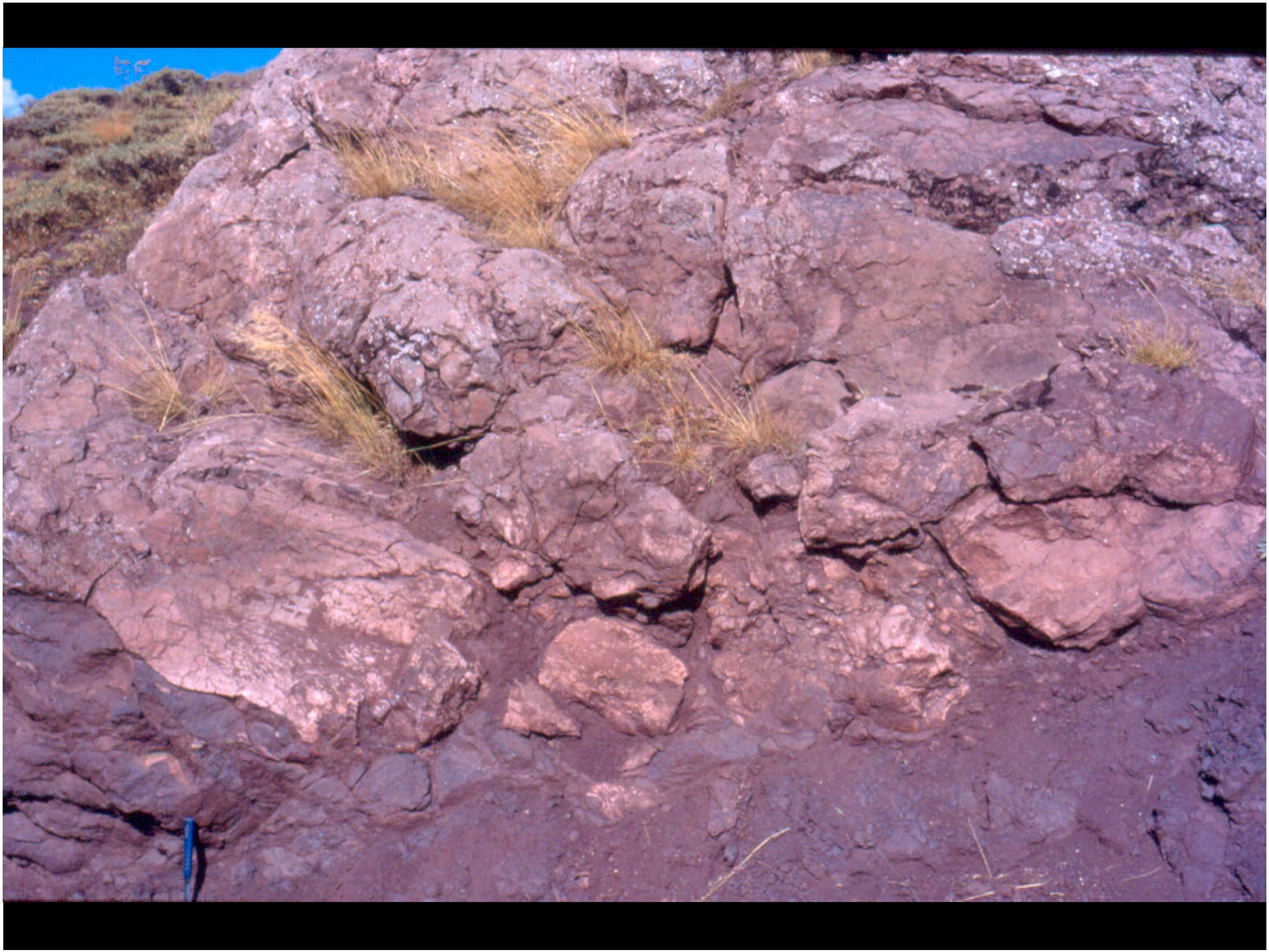
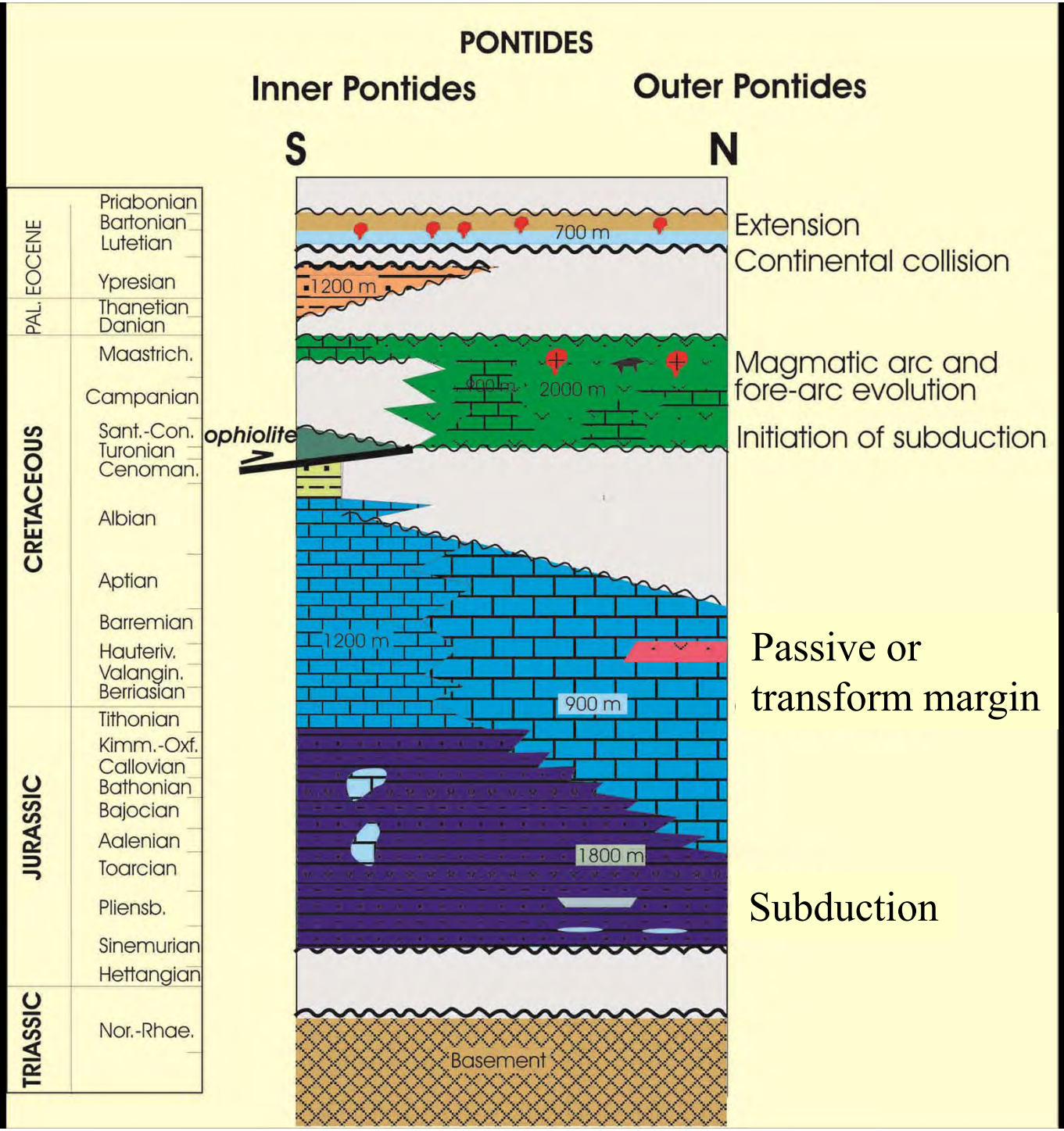
1800 m
Basement
Extension
Continental collision
Magmatic arc and
fore-arc evolution
Initiation of subduction
Passive or
transform margin
Subduction


0
40
80 km
BLACK
SEA
Hopa
Borçka
Artvin
Rize
Trabzon
Ordu
Giresun
Gümüşhane
Alucra
Bayburt
Tortum
Suşehri
Ağvanis
Erzurum
Erzincan



SENONIAN IN THE OUTER EASTERN PONTIDES –

DEVELOPMENT OF THE MAGMATIC ARC


PONTIDES
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Outer Pontides
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Bartonian
Lutetian
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Danian
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Basement
Extension
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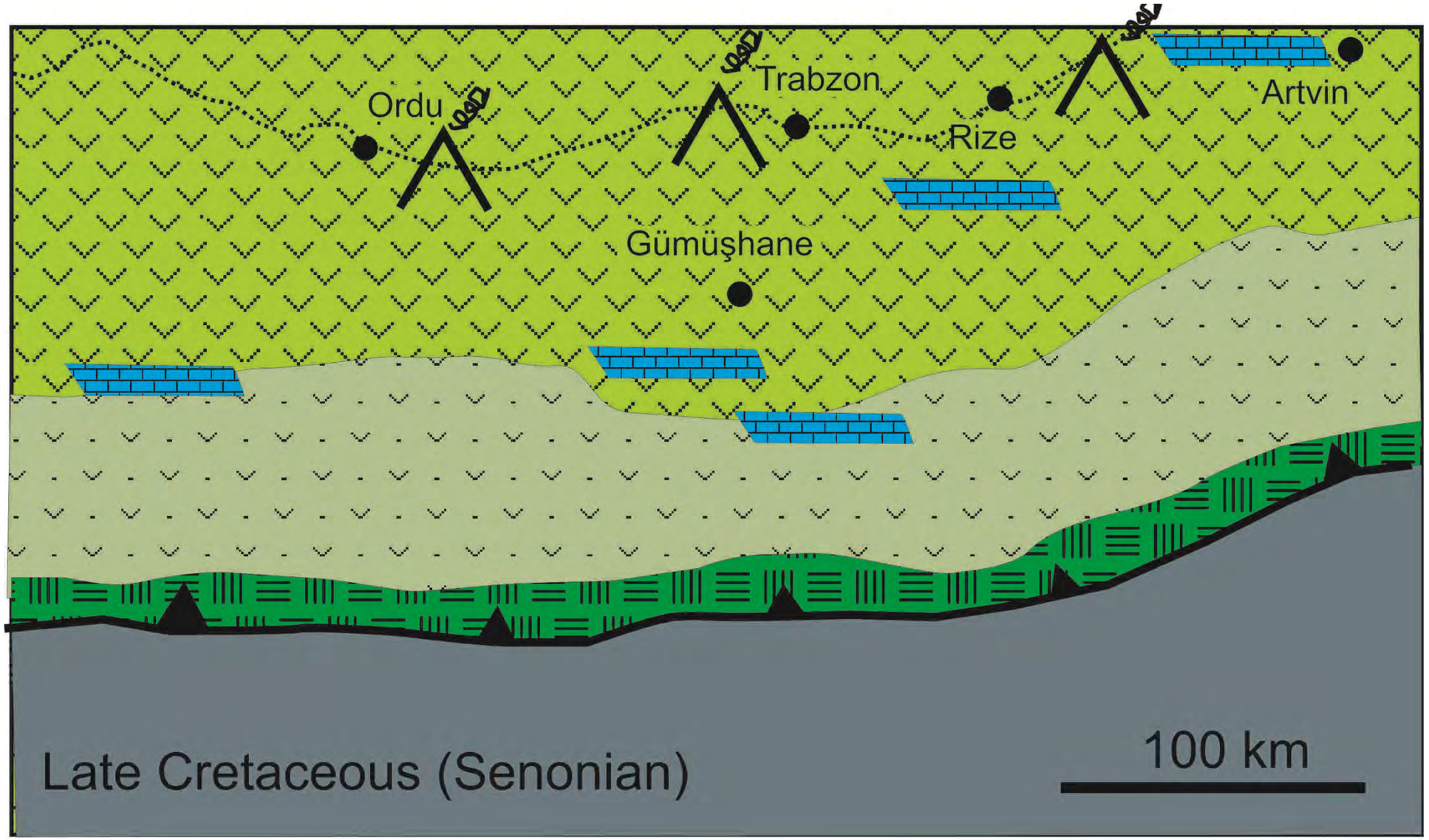
Magmatic arc and
fore-arc evolution
Initiation of subduction
Passive or
transform margin
Subduction

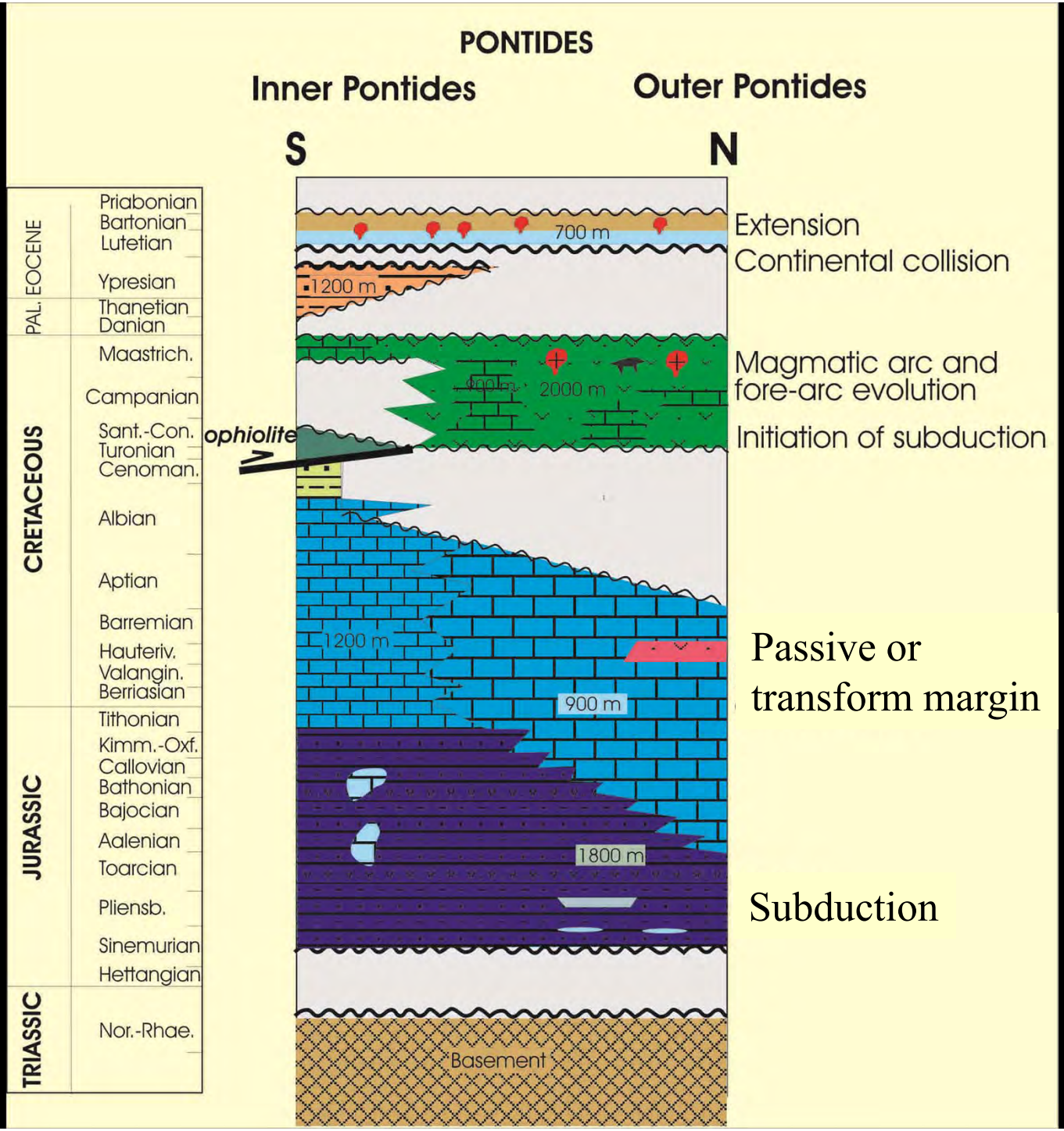


Dacitic, rhyolitic, andesitic, basaltic lava, agglomerate, tuff

Volcanoclastic sandstone, basaltic, andesitic agglomerate, tuff

Pelagic limestone

Accretionary complex


PONTIDES
Inner Pontides
Outer Pontides
S
N
PAL. EOCENE
Priabonian
Bartonian
Lutetian
Ypresian
Thanetian
Danian
CRETACEOUS
Maastrich.
Campanian
Sant.-Con.
Turonian
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Albian
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fore-arc evolution
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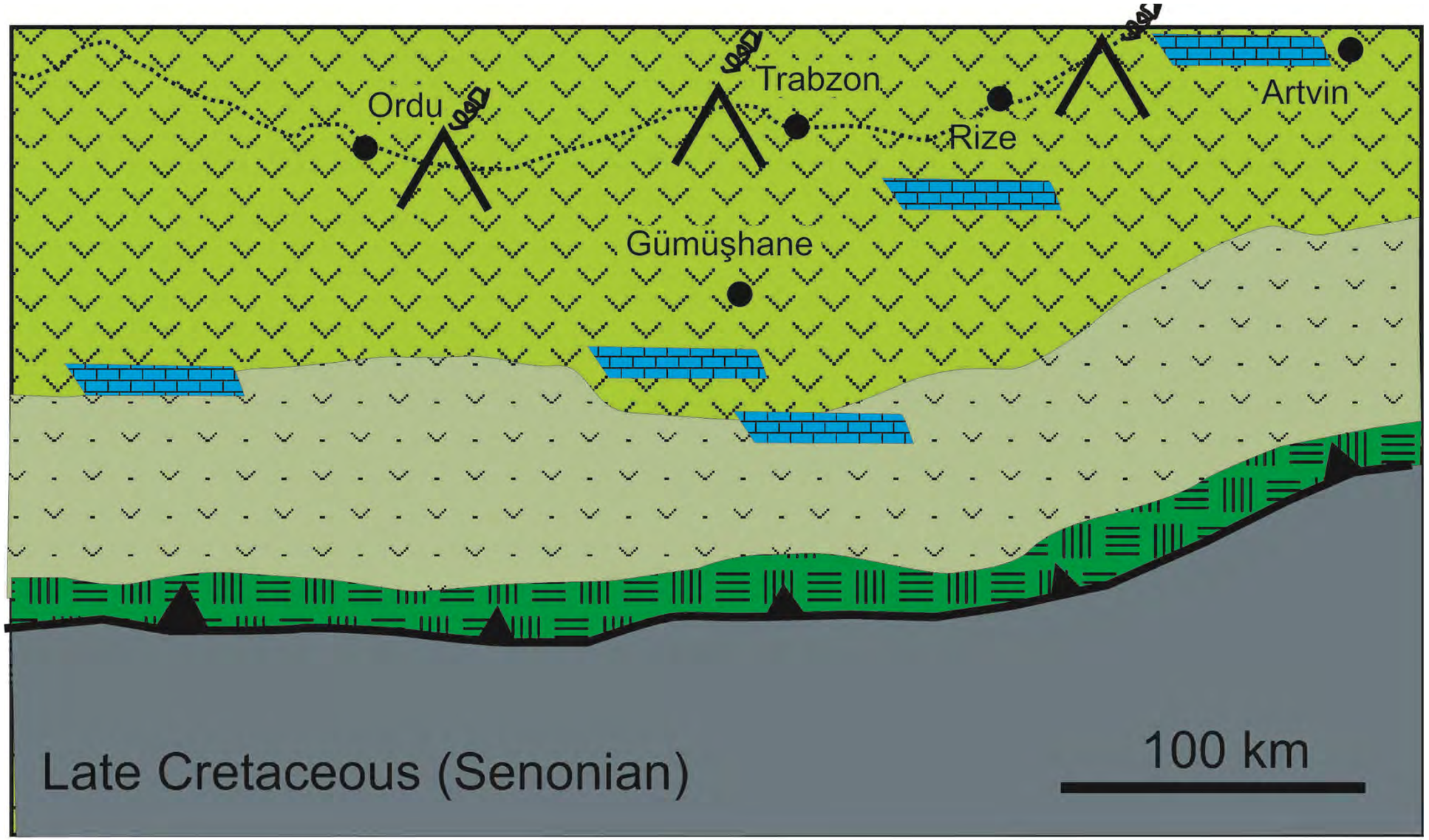

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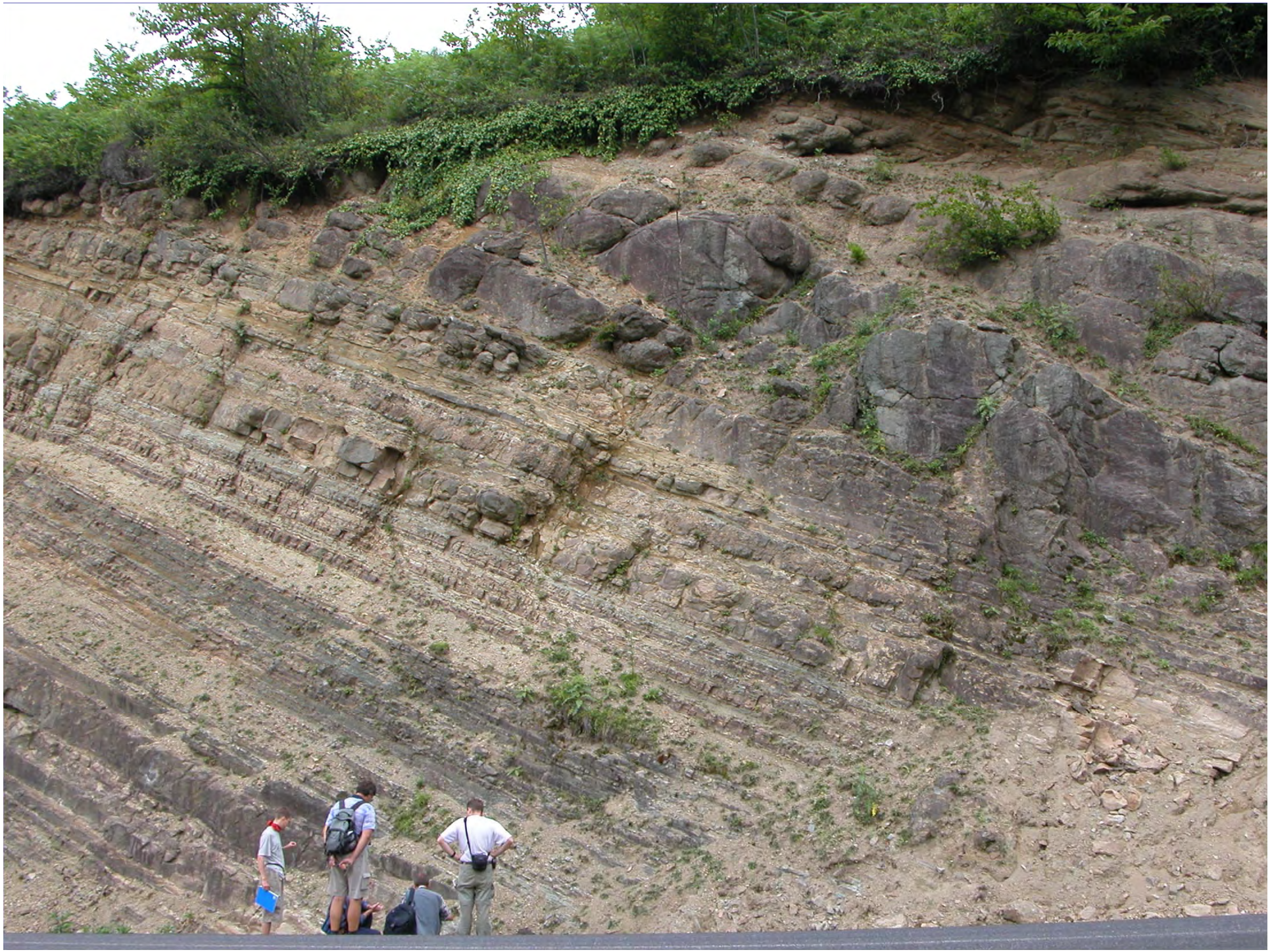
Volcanoclastic sandstone, basaltic, andesitic agglomerate, tuff

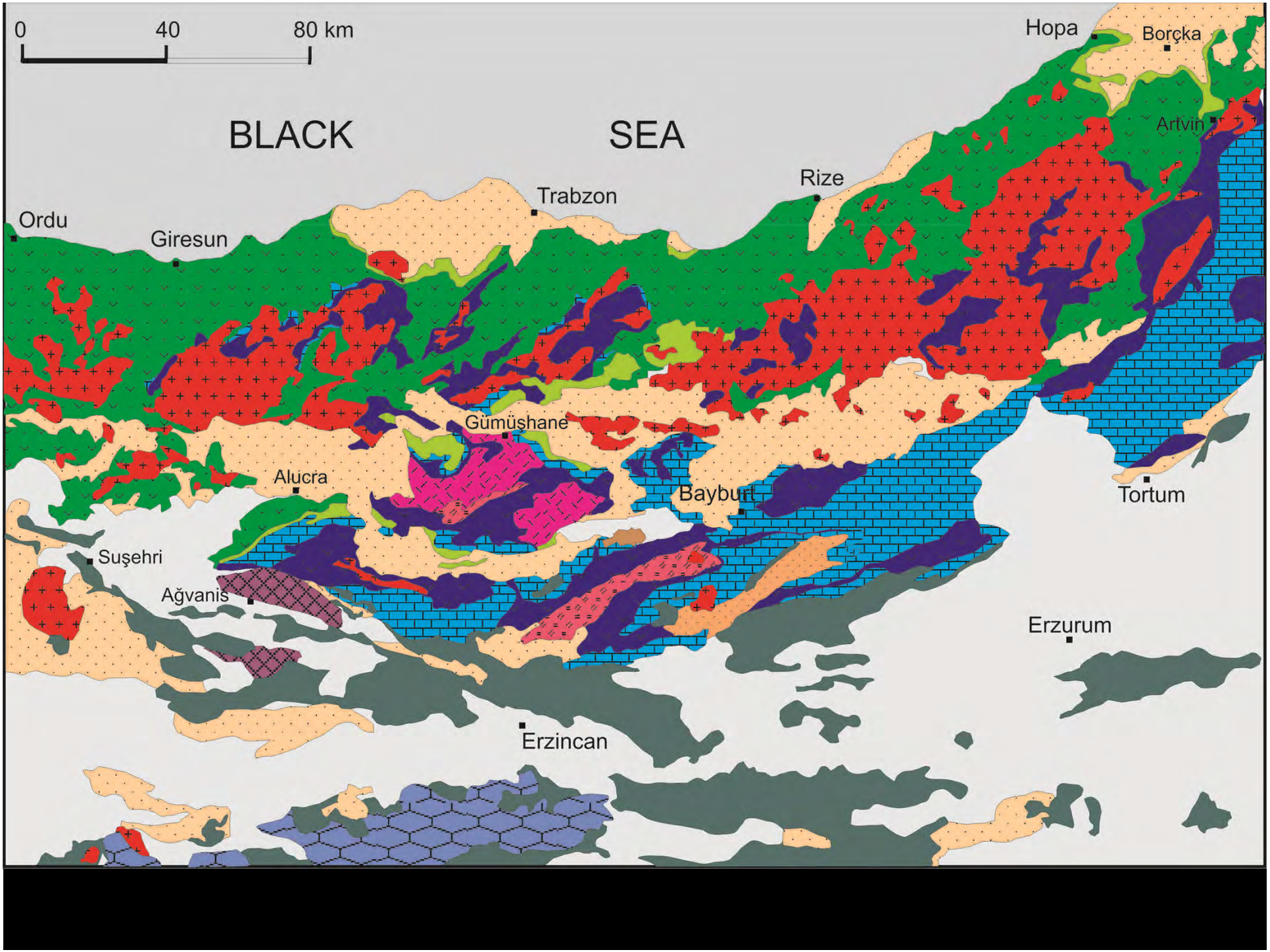
Pelagic limestone

Accretionary complex



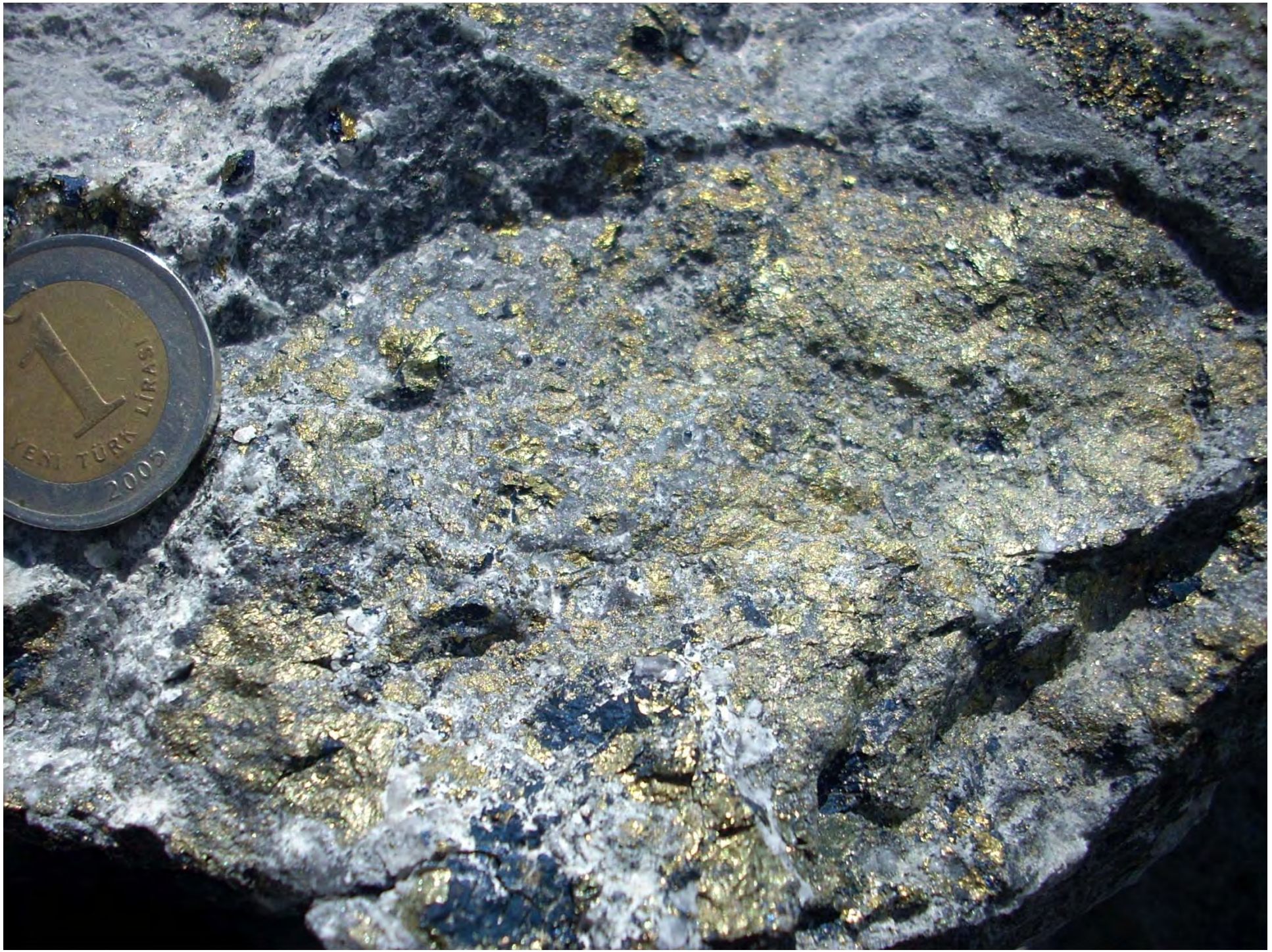
KURUKO TYPE VOLCANIC MASSIVE SULPHIDE DEPOSITS

MURGUL, ÇAYELİ etc.

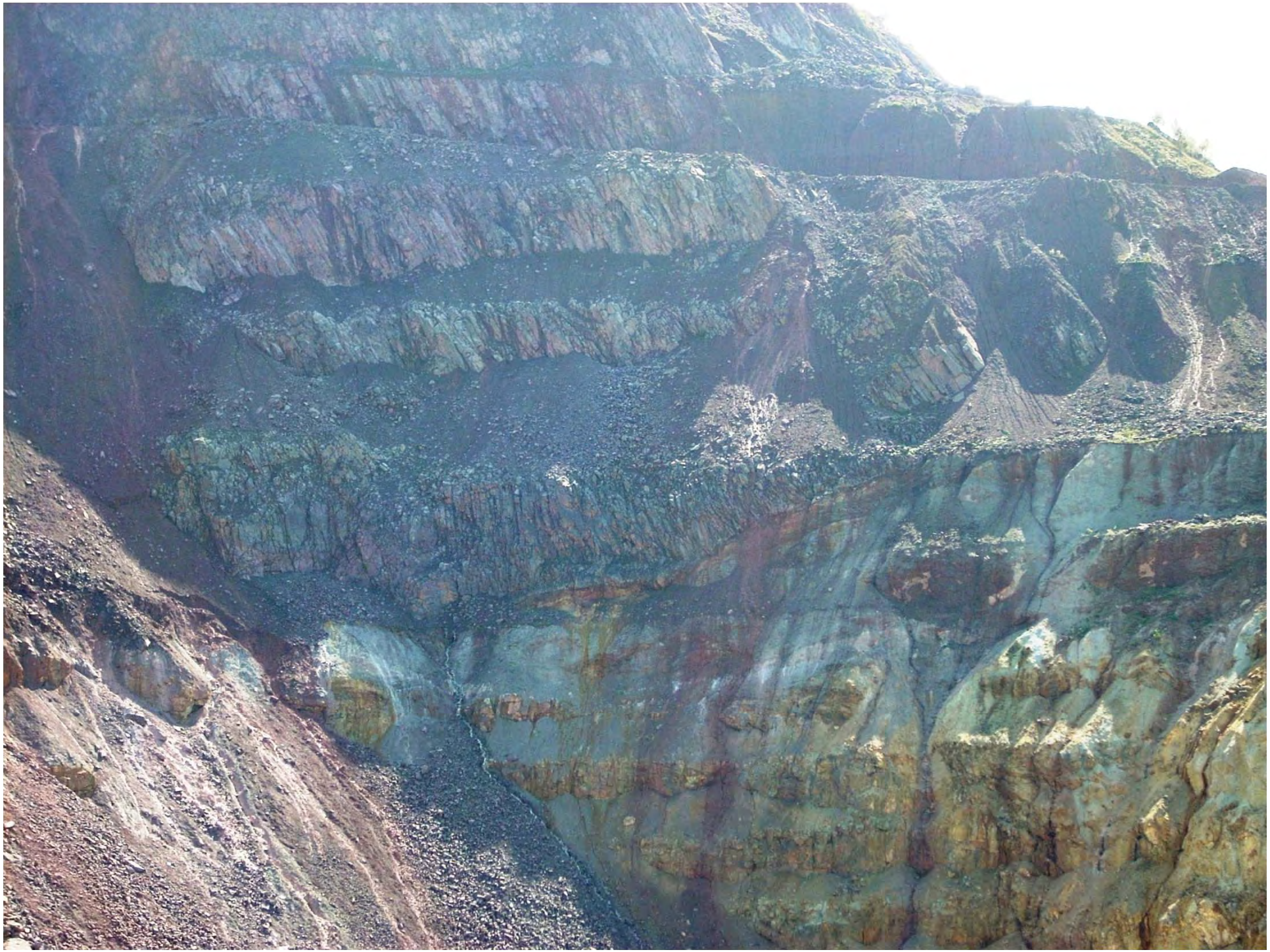

0
40
80 km
BLACK
SEA
Hopa
Borçka
Artvin
Rize
Trabzon
Ordu
Giresun
Gümüşhane
Alucra
Bayburt
Tortum
Suşehri
Ağvanis
Erzurum
Erzincan


TAHANOS 625
1980
normet

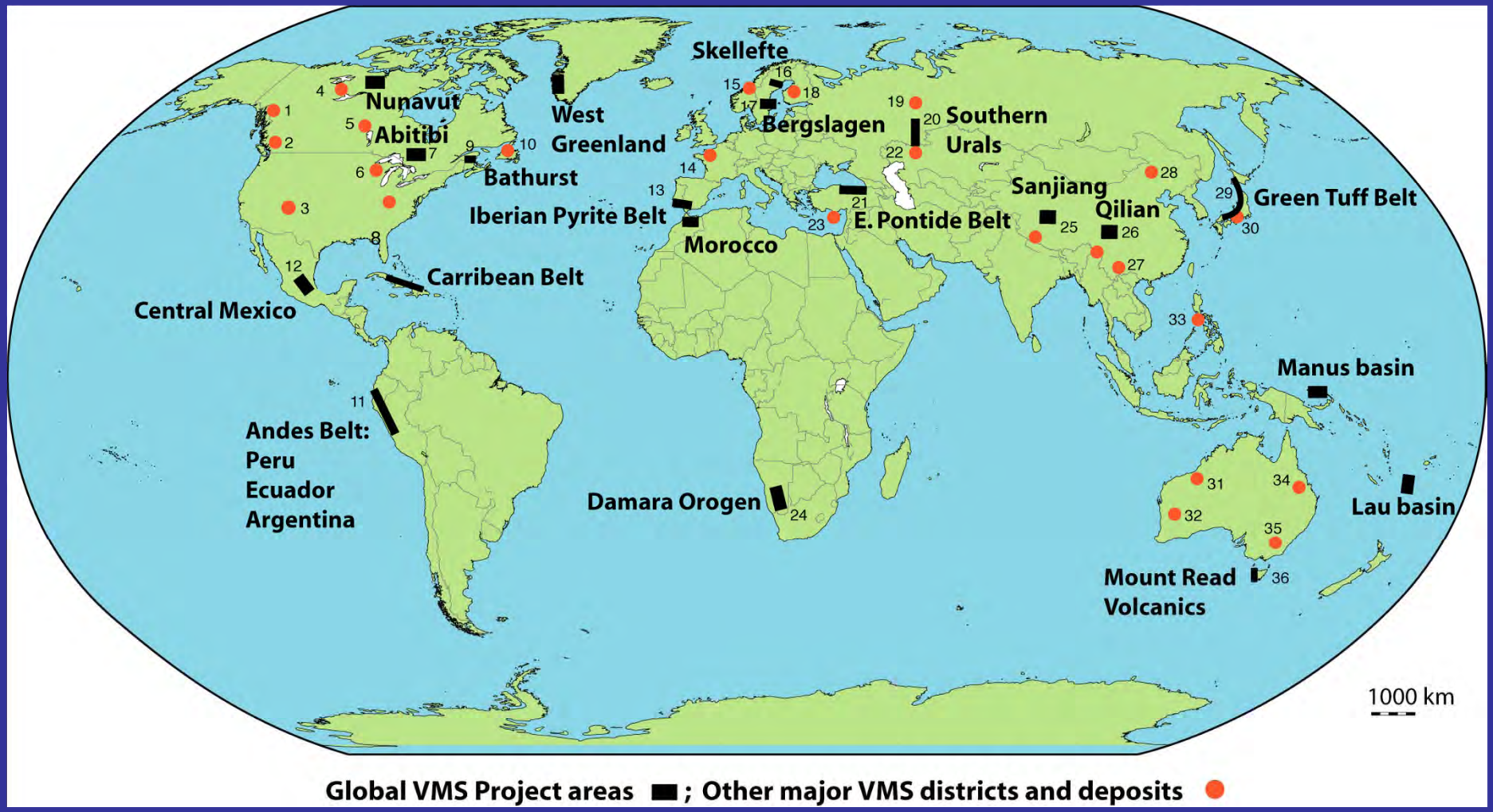
ÇAYELİ

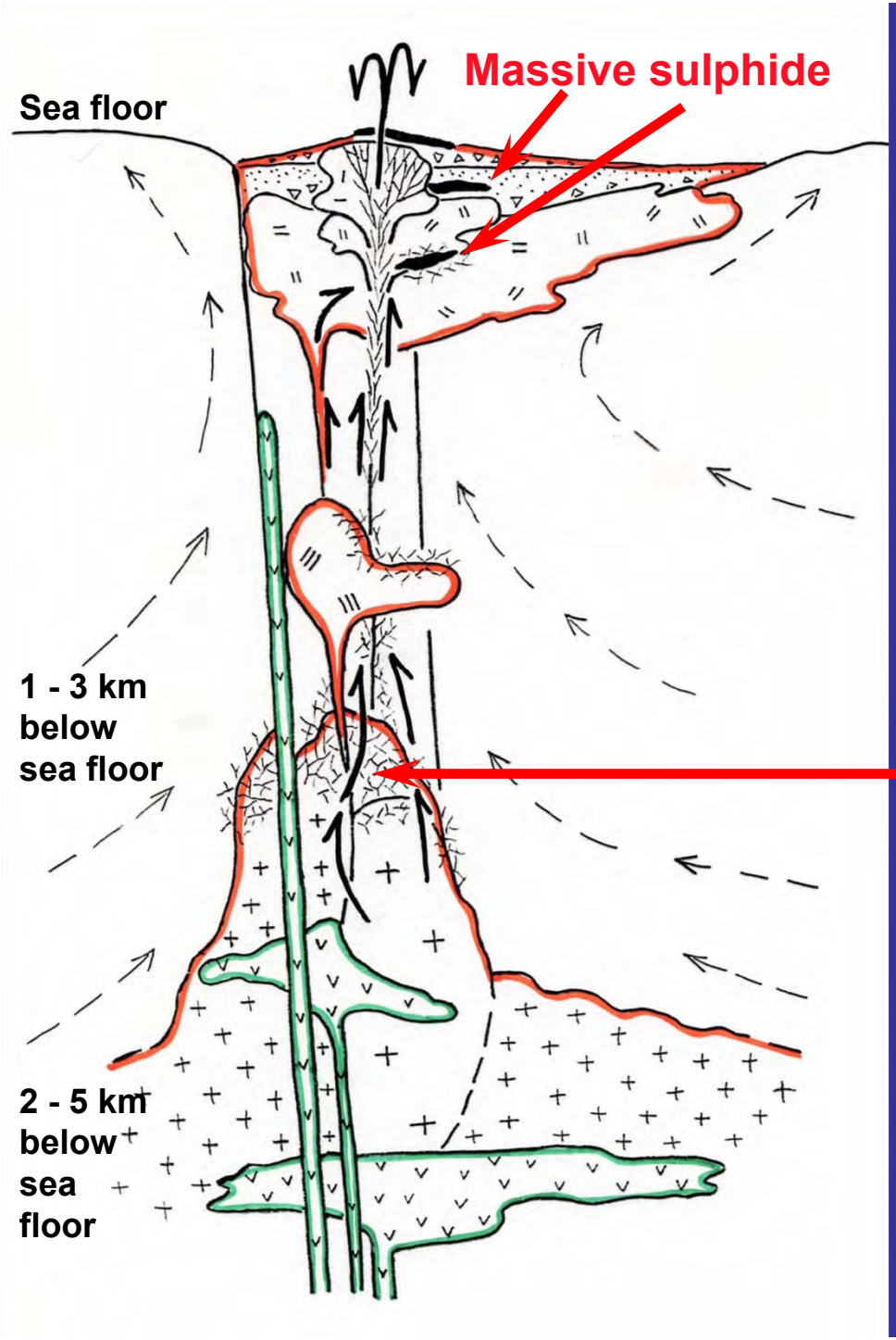

1
YENİ TÜRK LİRASI
2005

MURGUL



Global Comparison of VMS Districts: Project Study Areas





Model for rhyolite-hosted massive sulphide ores

Submarine rhyolite volcano

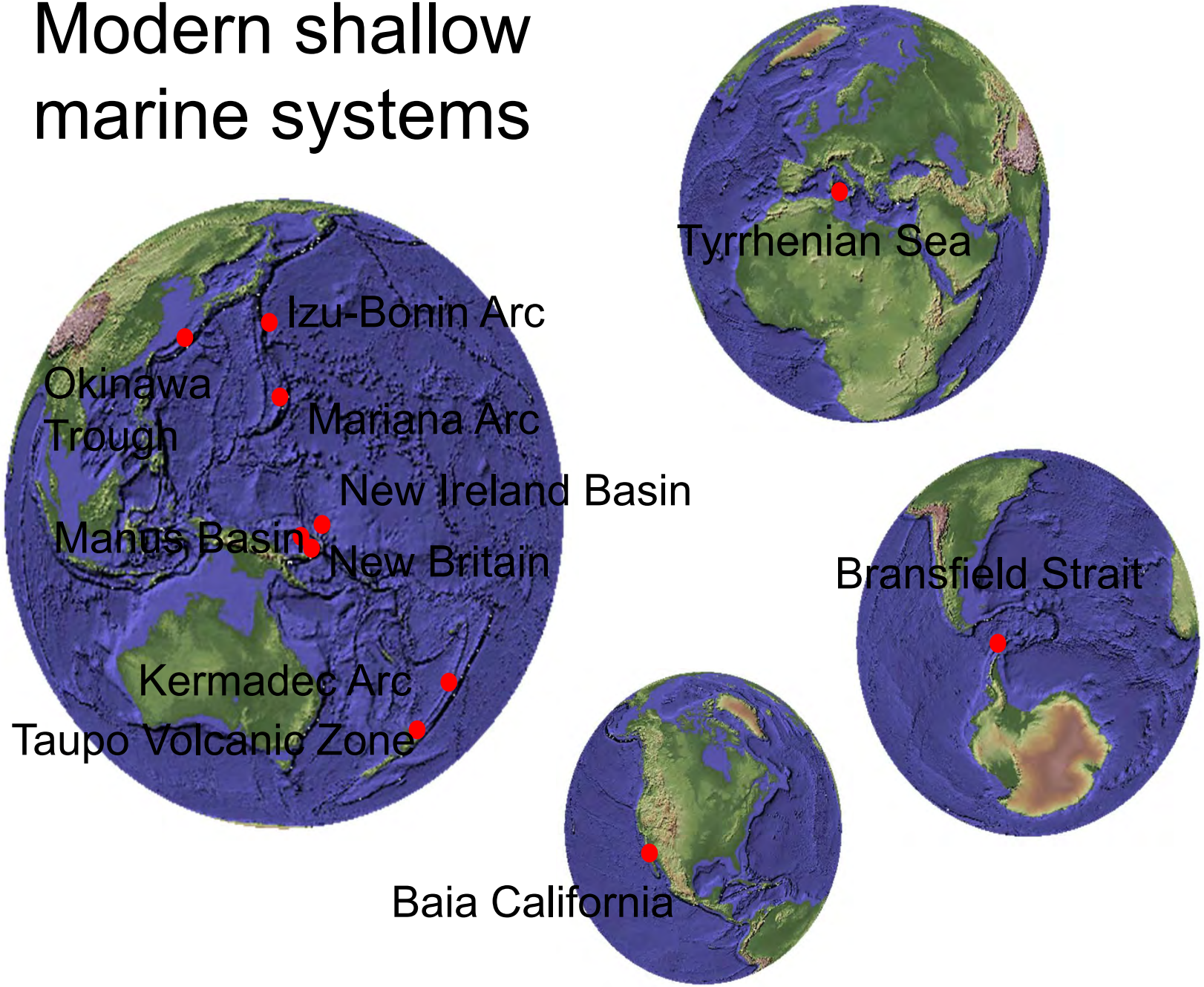
Regional convective sea water hydrothermal system (carries metals, causes alteration)

Magmatic hydrothermal system (carries metals, causes alteration

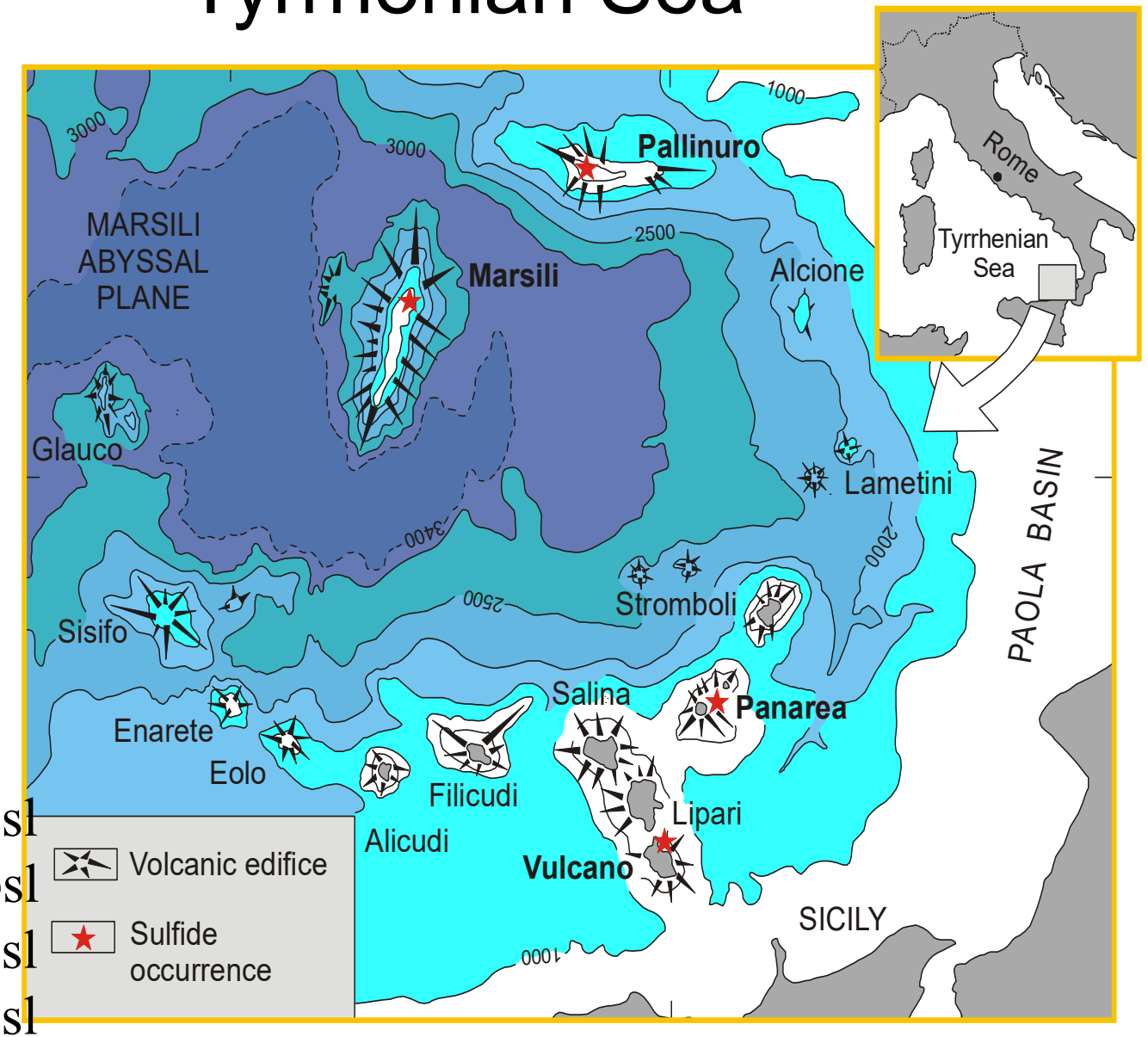
Felsic subvolcanic intrusion

Mafic intrusions

Modern shallow marine systems

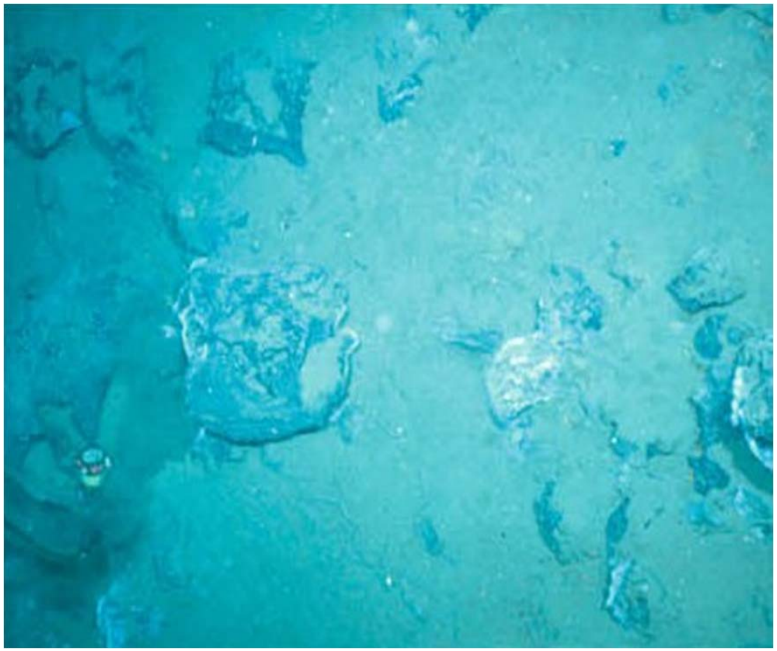


Tyrrhenian Sea

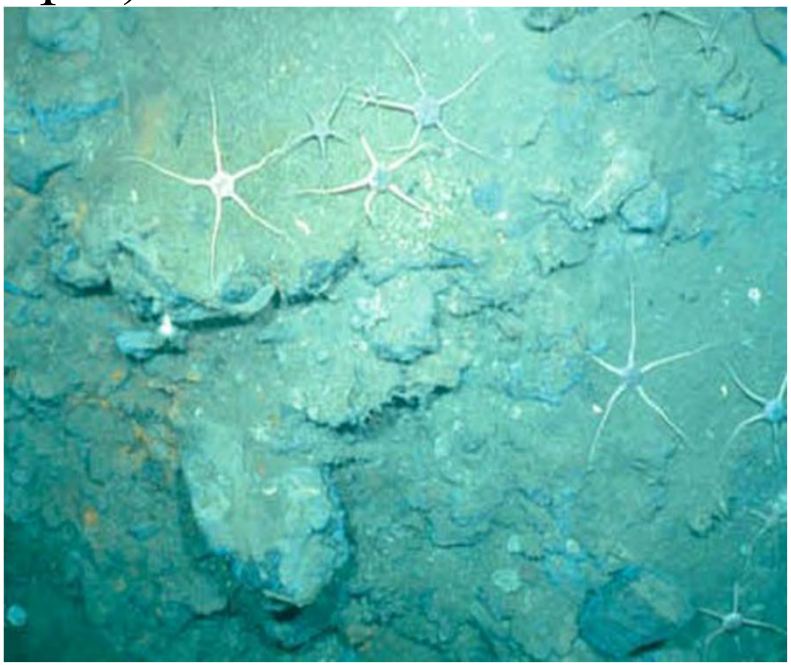


Vulcano: <15 mbsl
Panarea: 80 mbsl
Marsili: 500 mbsl
Palinuro: 600 mbsl

Beccaluva et al. (1985)



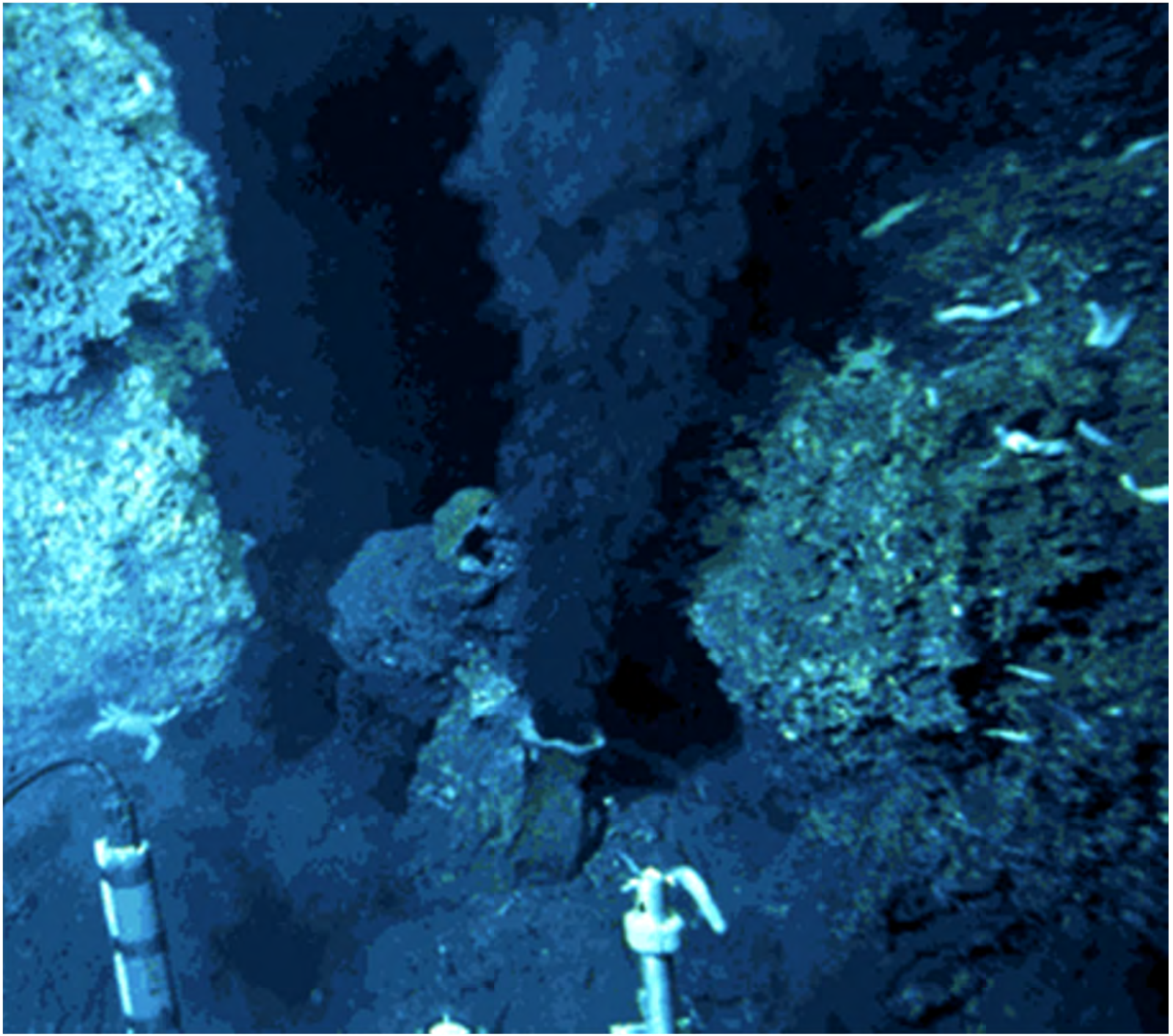
Sulfide talus at Hook Ridge (1070 m water depth)

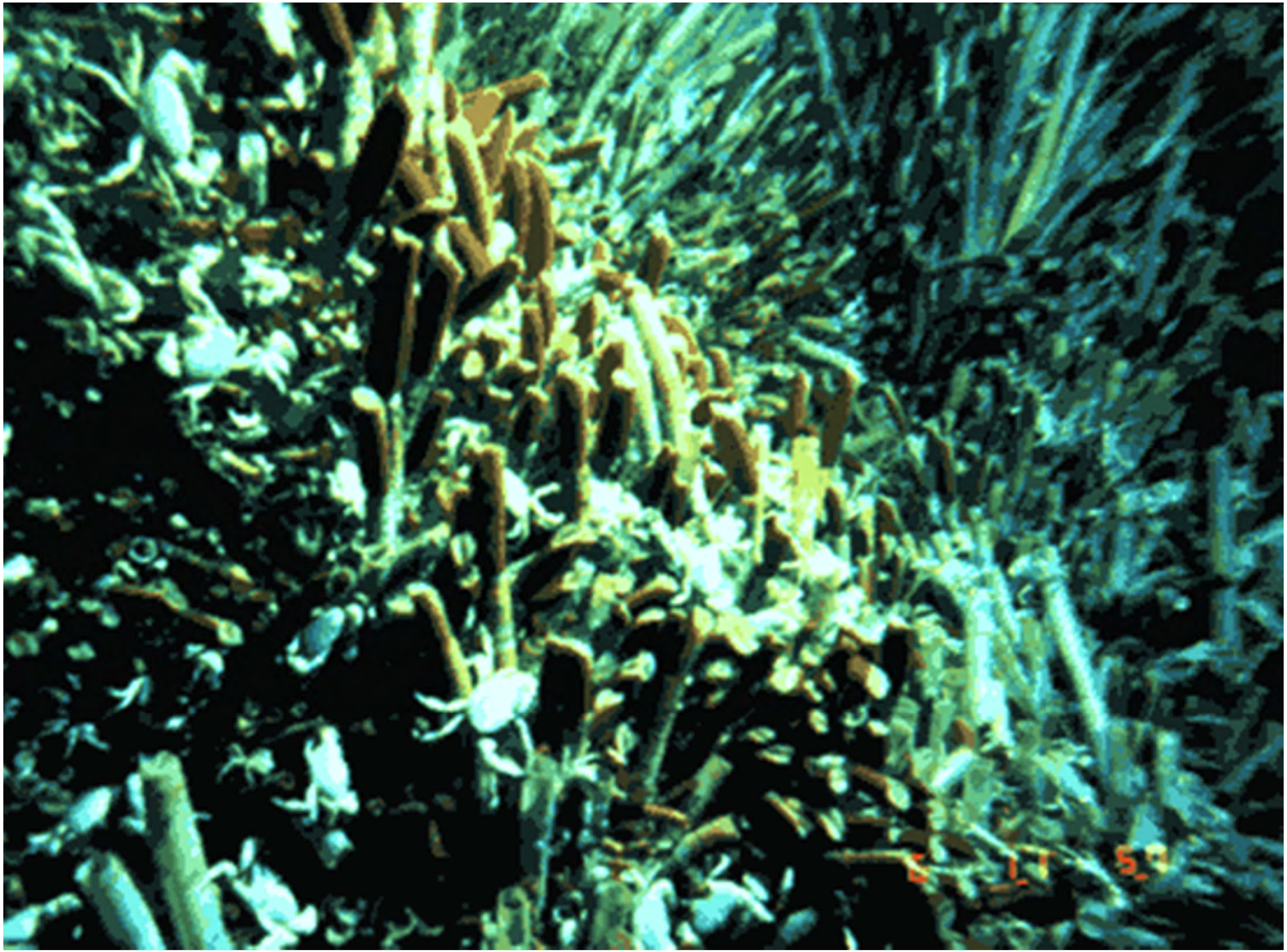


Polymetallic mineralization in a sedimented marginal basin ➔ broadly similar to the Iberian Pyrite Belt, the largest massive sulfide accumulation in the world

Sulfide talus at Hook Ridge (1060 m water depth)

Petersen et al. (2004)

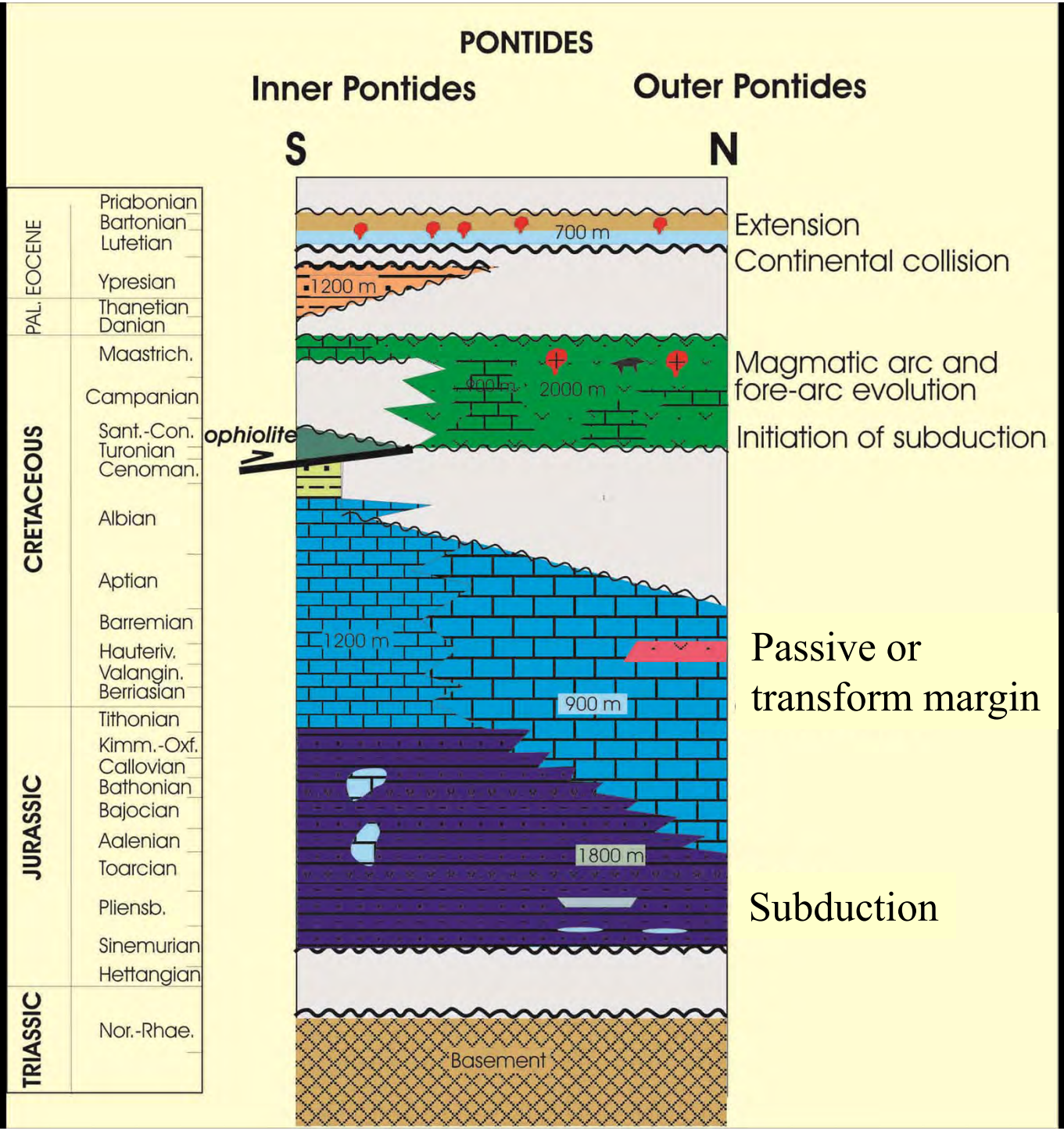





100
BİN LİRA
2004

MAASTRICHTIAN – PALEOCENE

END OF MAGMATISM – LIMESTONE DEPOSITION


PONTIDES
Inner Pontides
Outer Pontides
S
N
PAL. EOCENE
Priabonian
Bartonian
Lutetian
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Pliensb.
Sinemurian
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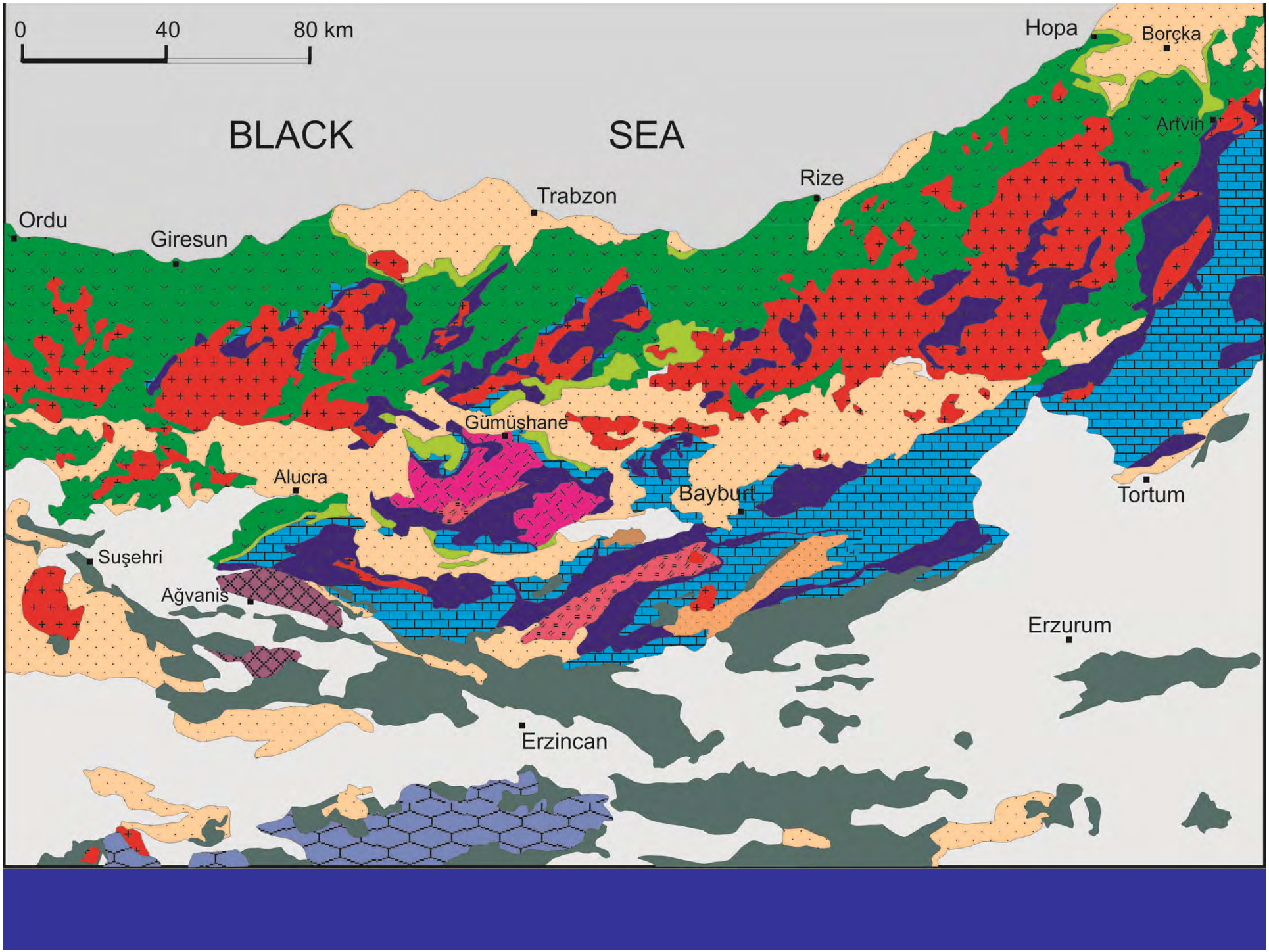
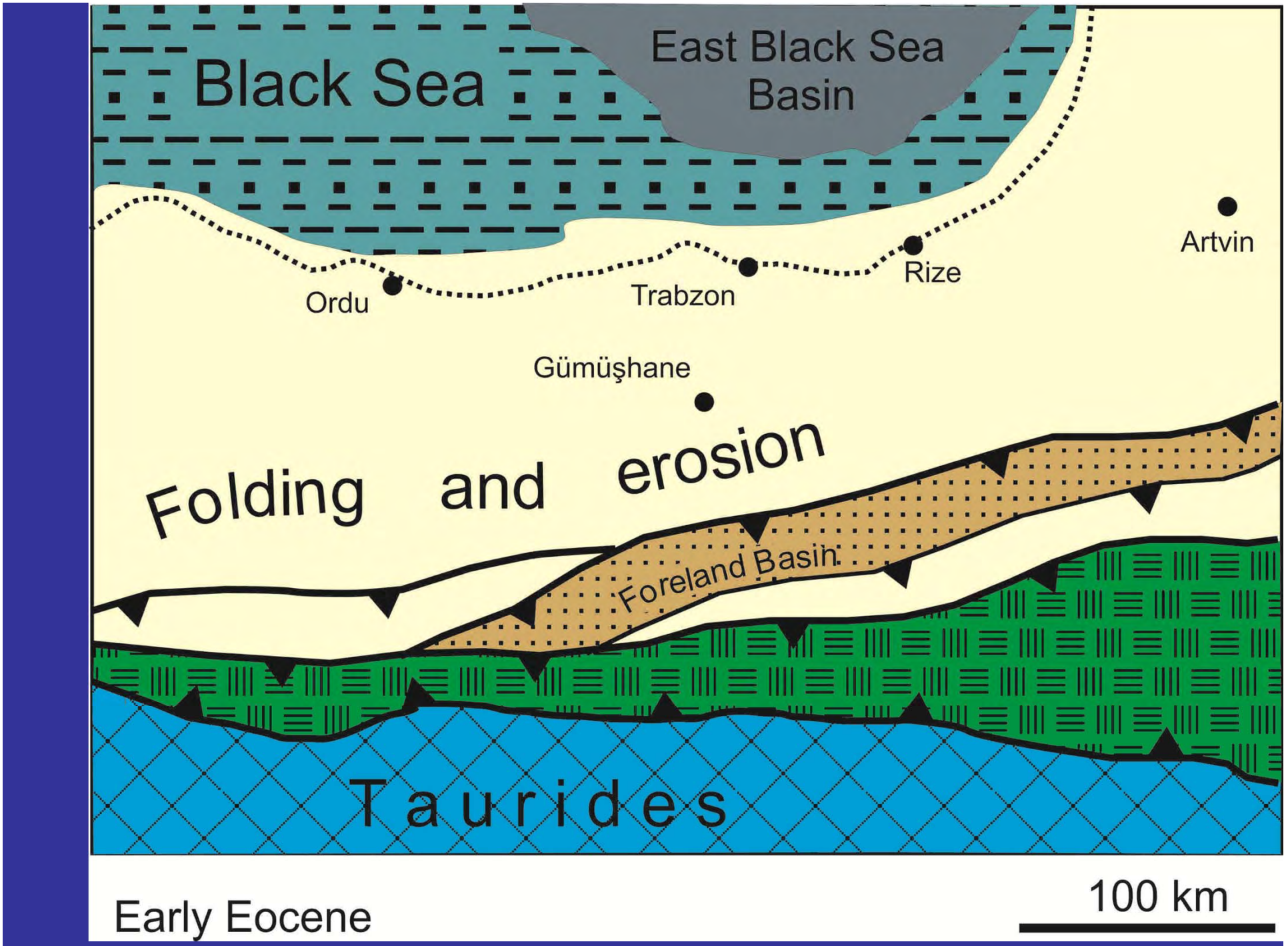
TRIASSIC
Nor.-Rhae.
ophiolite
700 m
1200 m
2000 m
1200 m
900 m
1800 m
Basement
Extension
Continental collision
Magmatic arc and
fore-arc evolution
Initiation of subduction
Passive or
transform margin
Subduction

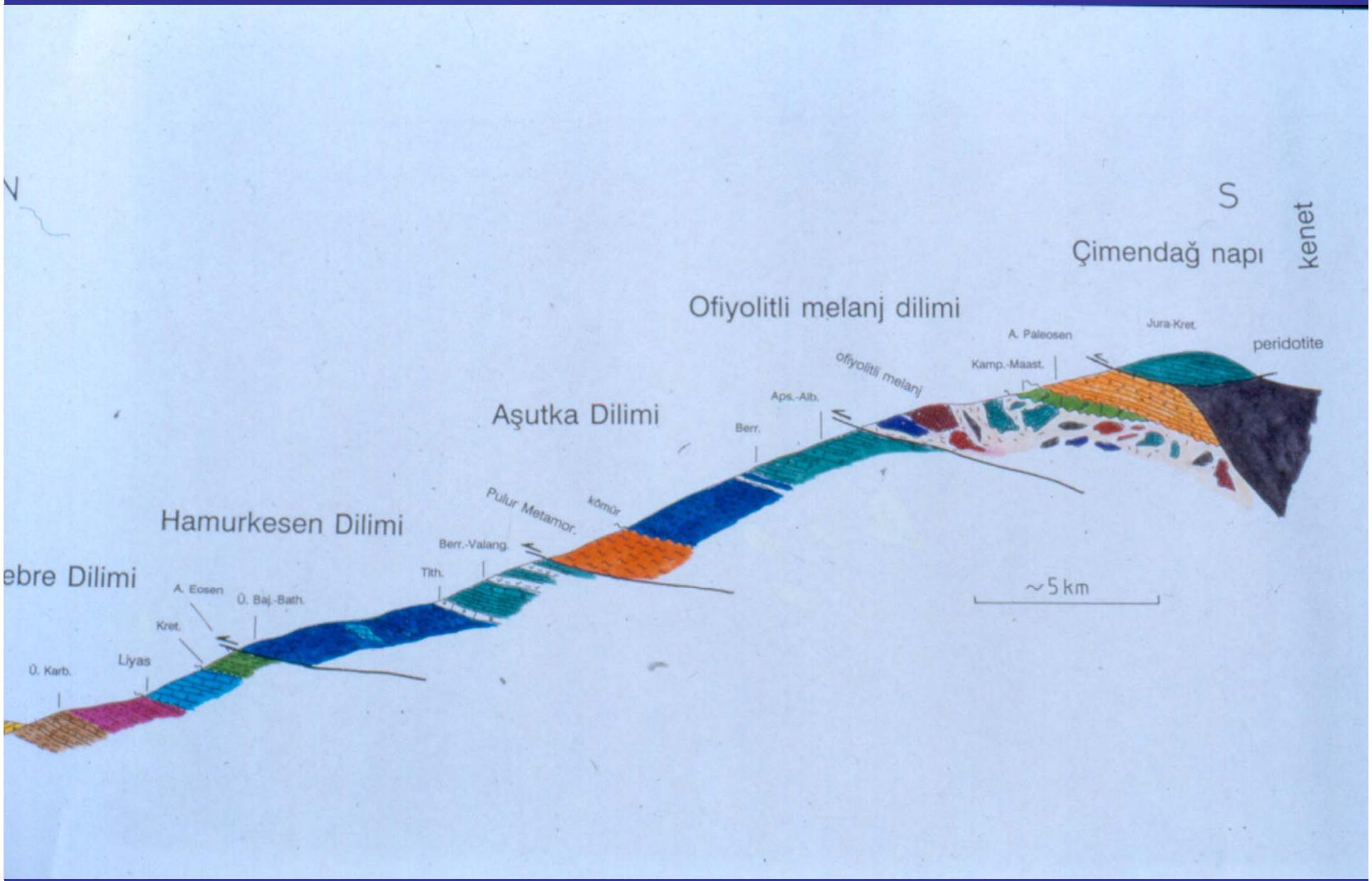

100
BİN LİRA
2001

LATE PALEOCENE – EARLY EOCENE

COLLISION BETWEEN THE PONTIDES AND THE ANATOLIDE-TAURIDE BLOCK


0
40
80 km
BLACK
SEA
Hopa
Borçka
Artvin
Rize
Trabzon
Ordu
Giresun
Gümüşhane
Alucra
Bayburt
Tortum
Suşehri
Ağvanis
Erzurum
Erzincan

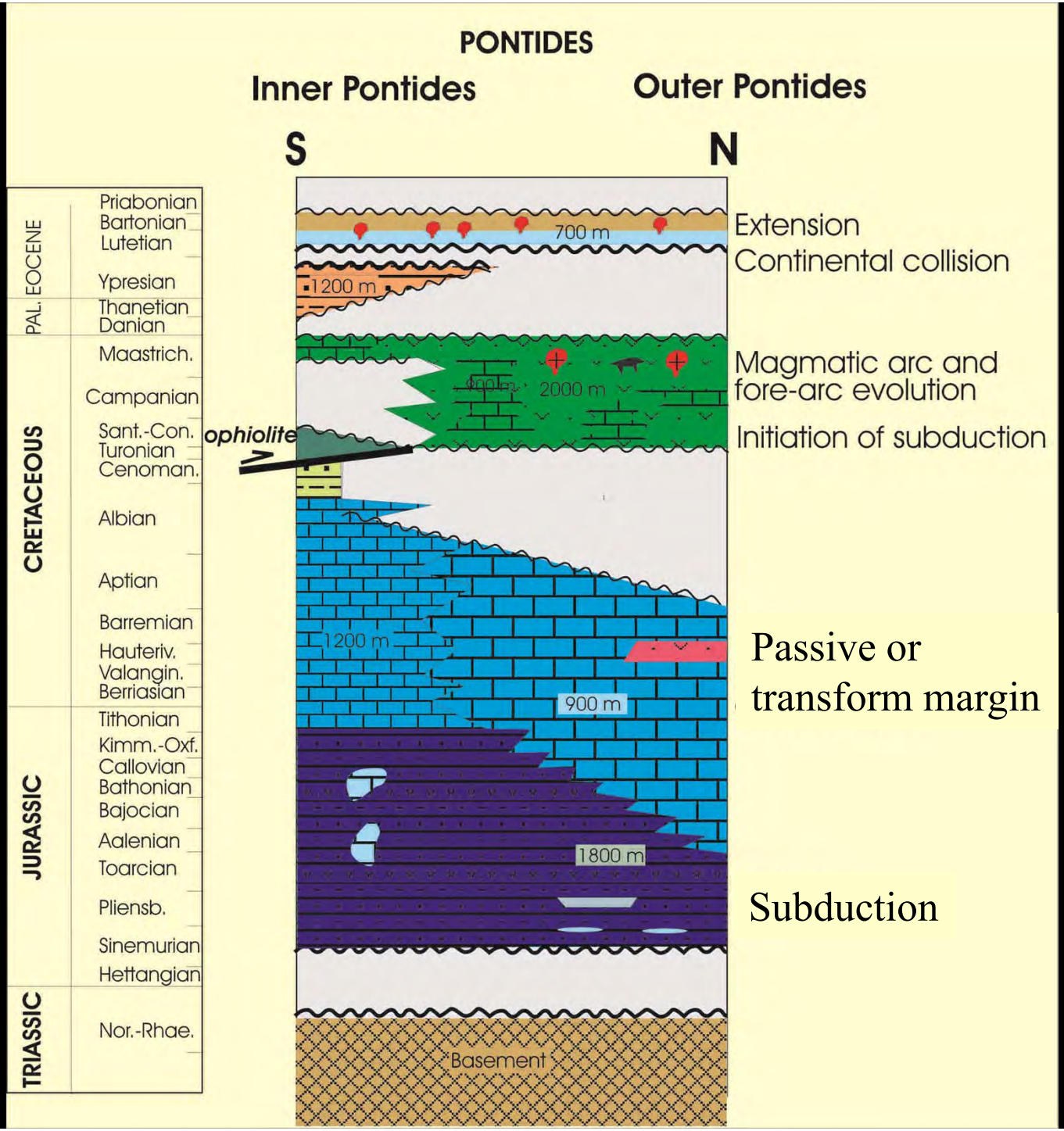

Black Sea
East Black Sea Basin
Artvin
Rize
Trabzon
Ordu
Gümüşhane
Folding and erosion
Foreland Basin
Taurides
Early Eocene
100 km


N
S
Çimendağ napı
kenet
Ofiyolitli melanj dilimi
A. Paleosen
Jura-Kret.
peridotite
Kamp.-Maast.
ofiyolitli melanj
Aps.-Alb.
Aşutka Dilimi
Berr.
Pulur Metamor.
kömür
Hamurkesen Dilimi
Berr.-Valang.
ebre Dilimi
Tith.
A. Eosen
Ü. Baj.-Bath.
Kret.
Liyas
Ü. Karb.
~5 km

MIDDLE – LATE EOCENE

POST-COLLISIONAL EXTENSION AND MAGMATISM

A NEW PHASE OF DEPOSITION


PONTIDES
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Outer Pontides
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PAL. EOCENE
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Lutetian
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Albian
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Barremian
Hauteriv.
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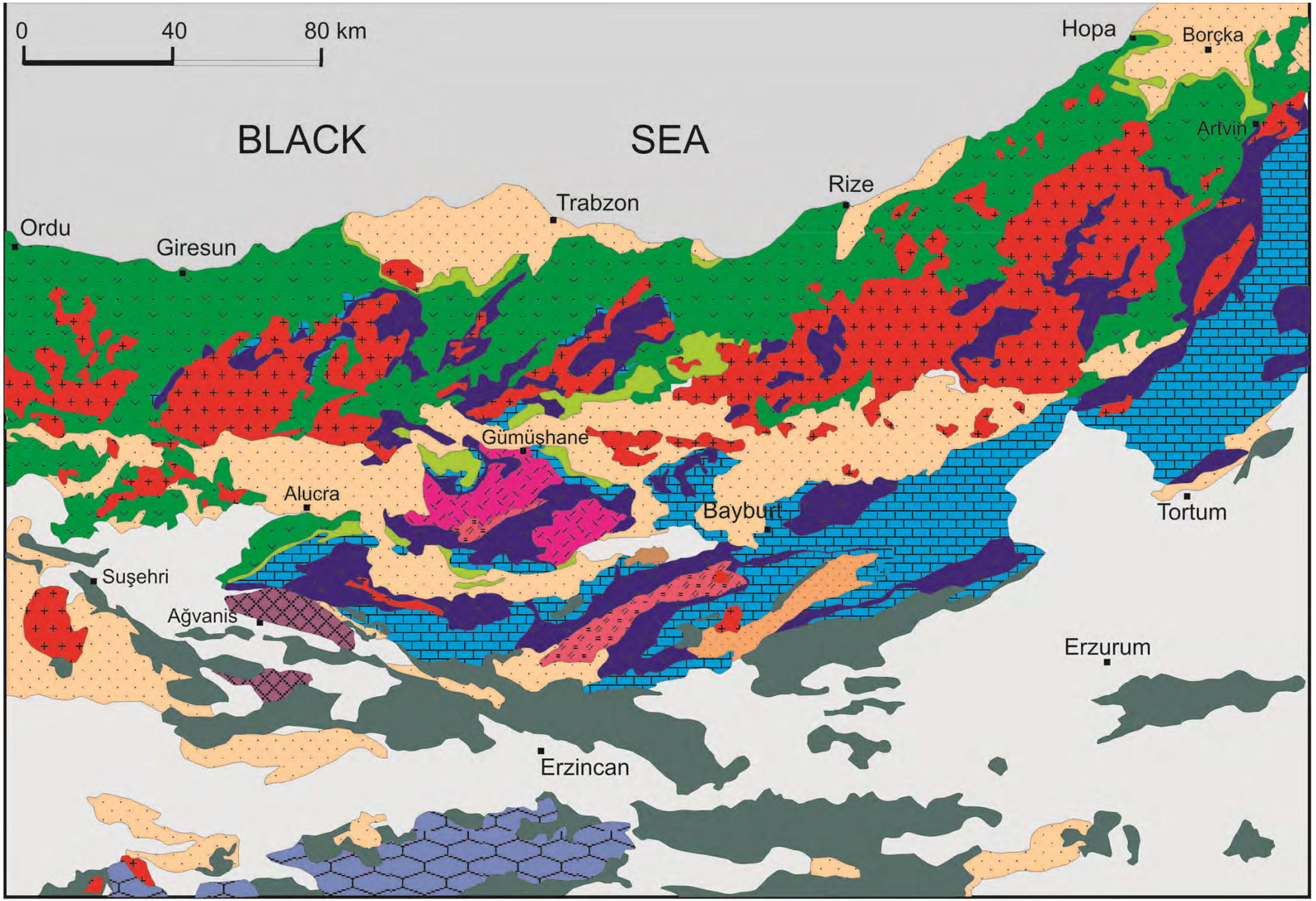
fore-arc evolution
Initiation of subduction
Passive or
transform margin
Subduction


0
40
80 km
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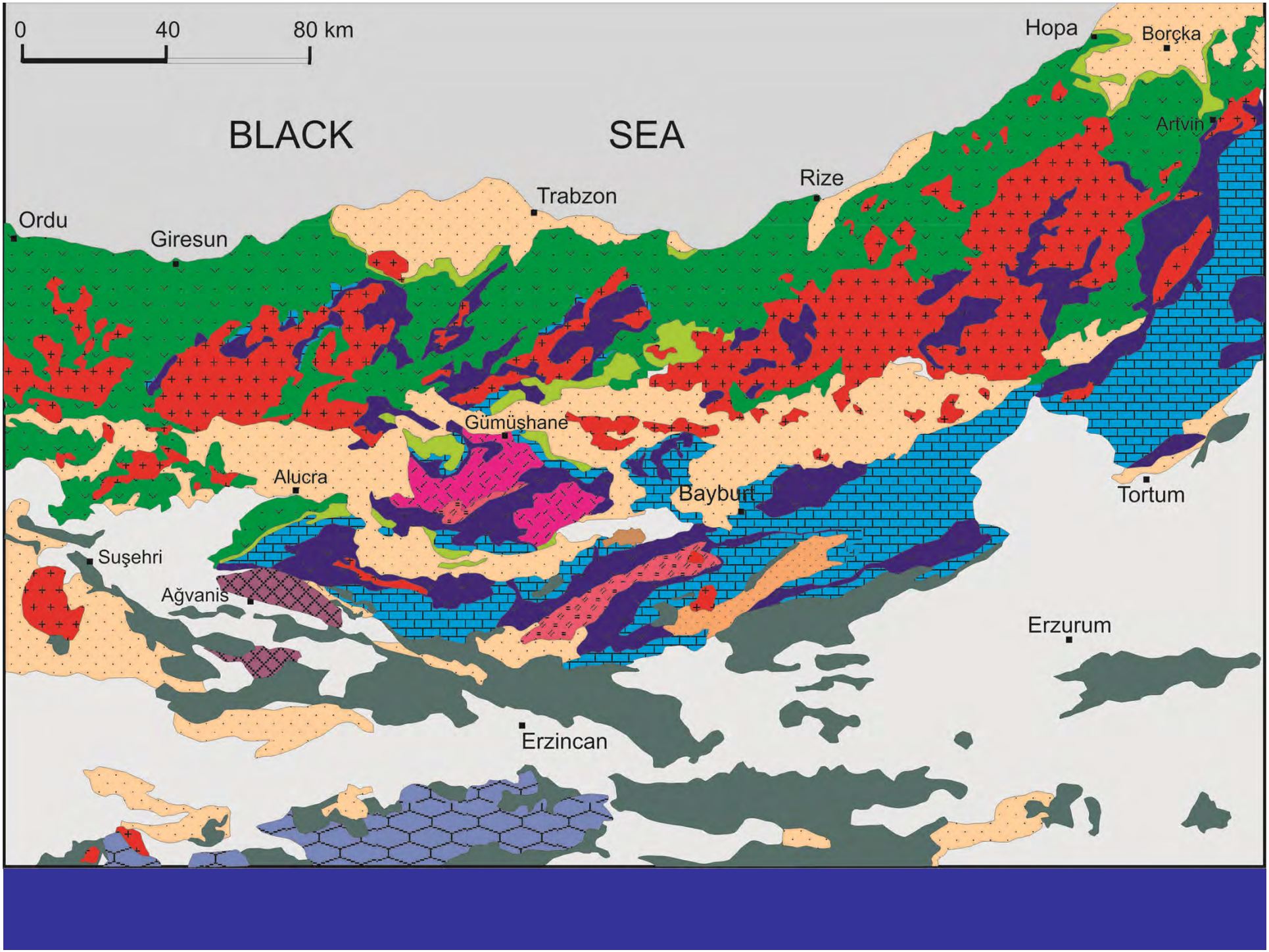
Rize
Trabzon
Ordu
Giresun
Gümüşhane
Alucra
Bayburt
Tortum
Suşehri
Ağvanis
Erzurum
Erzincan


0
40
80 km
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SEA
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Borçka
Artvin
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Trabzon
Ordu
Giresun
Gümüşhane
Alucra
Bayburt
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Suşehri
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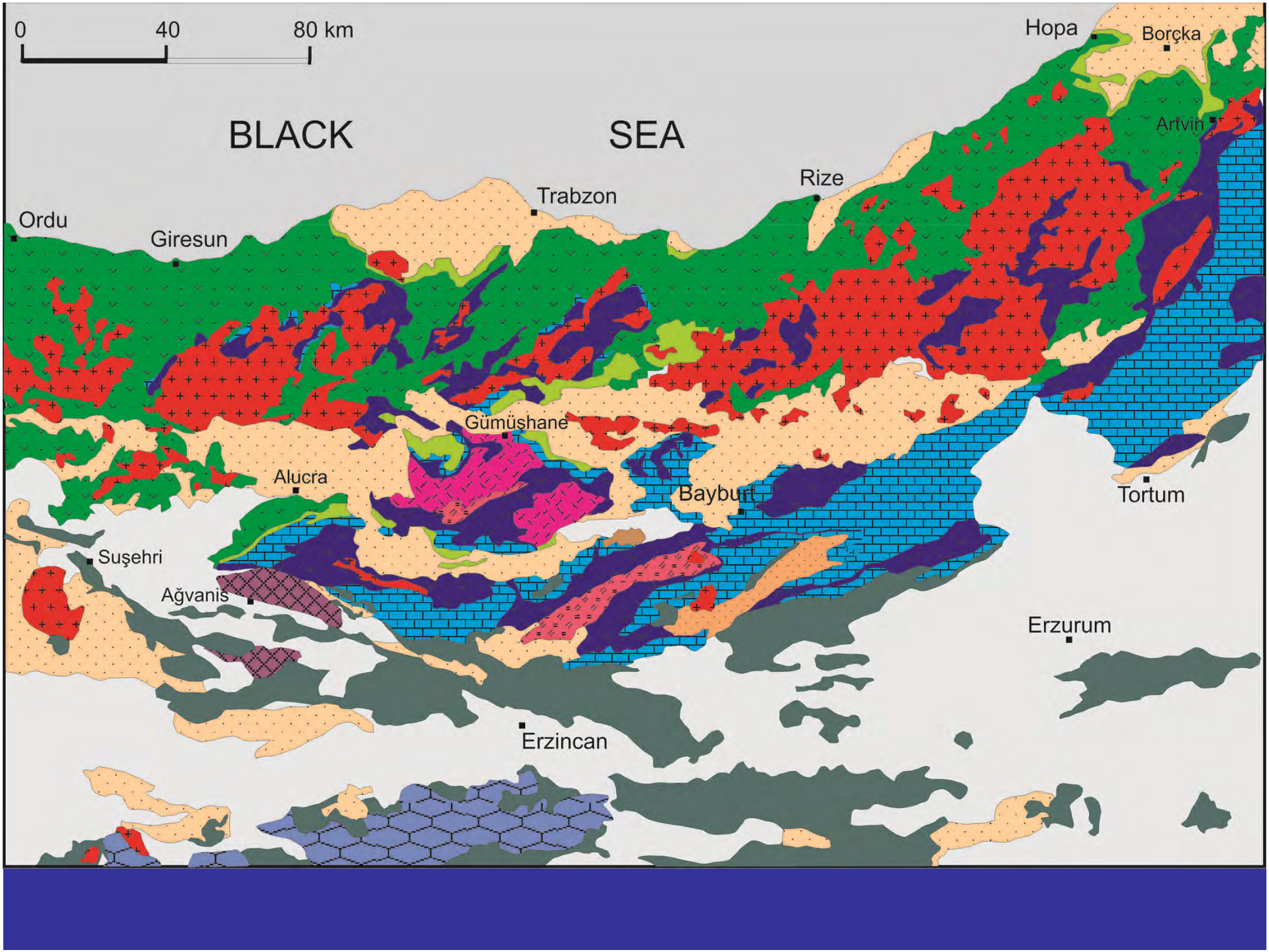
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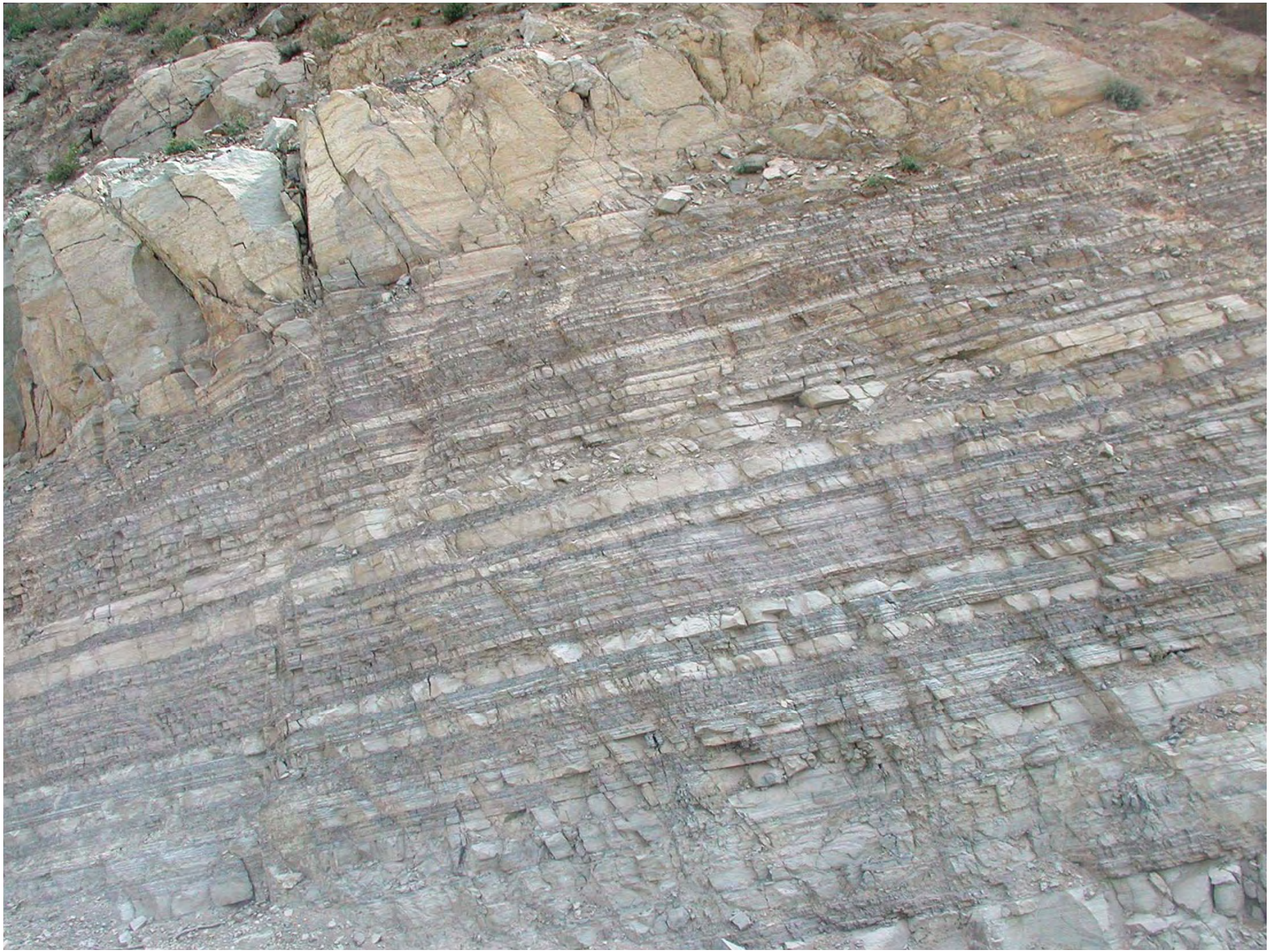

AFTER THE EOCENE

CONTINENTAL DEPOSITION AND VOLCANISM

Main Tectonic Features of the Eastern Pontides

- - A complex and heterogeneous pre-Jurassic basement.
- - Volcanoclastic Early to Middle Jurassic – arc volcanism
- - Upper Jurassic – Lower Cretaceous carbonates – south-facing passive continental margin.
- - North-vergent emplacement of ophiolitic melange in Mid-Cretaceous.
- - Build-up of a magmatic arc in the Senonian. Formation of the Kuruko-type sulfide deposits.
- - Continent-arc collision in the Late Paleocene - Early Eocene.
- - Widespread post-collisional magmatism and sedimentation in the Mid-Eocene.