

Regional Stratigraphy of the Southern Tethyan Margin, Lithofacies, Sequence Stratigraphy, Source, Seal, and Reservoir Rocks*

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Abstract

Paleozoic, Mesozoic through Cenozoic sedimentary fill of the Tethys southern margin is subdivided stratigraphically by the beat of second- and third-order changes in eustasy, tectonic movement, sediment supply, and Wilsonian cycles of plate movement. This northeastern flank of Gondwanaland extended from the Arabian Plate through Zagros and Taurus Mountains, Levant, and North Africa. Regional chronostratigraphic charts and cross-sections detail products of these processes and major petroleum production from carbonates and evaporites interbedded with clastic sequences; with flatter-lying horizons in Arabia, folded in the Zagros and Taurus Mountains of Iran and Turkey, wrenched margin through the Levant and disrupted block-faulted terrains in North Africa from Egypt through Libya.

In Arabia during Late Paleozoic and Mesozoic deposition was in tropical settings and on an extensional passive Tethyan margin, which by the Late Cretaceous to Tertiary was a foreland basin flanking the Zagros and Taurus uplift. Contrasting deposition on the North African plate also occurred in tropical settings, but followed an extensional passive margin through Late Paleozoic, to Mesozoic, and Tertiary.

A detailed and flexible sequence stratigraphic framework tracks and predicts distribution of evolving sedimentary facies on smaller spatial and temporal scales explaining regional spread of source-reservoir-seal, thermal maturation, modes of migration and accumulation and location of oil and gas fields and future plays of Middle East and North African basins. Tectonic mega-sequence events governed low-frequency accommodation of sedimentary fill interrupted by surfaces formed by periods of non-deposition, and/or unconformities. Maximum-flooding surfaces (MFS) express the maximum regional transgressions of fluctuations in eustasy. Both surfaces provide chronostratigraphic order to sedimentary fill dated by radiometric and biologic markers.

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Regional Stratigraphy of the Southern Tethyan Margin, Lithofacies, Sequence Stratigraphy, Source, Seal, and Reservoir Rocks.

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Presentation Organization

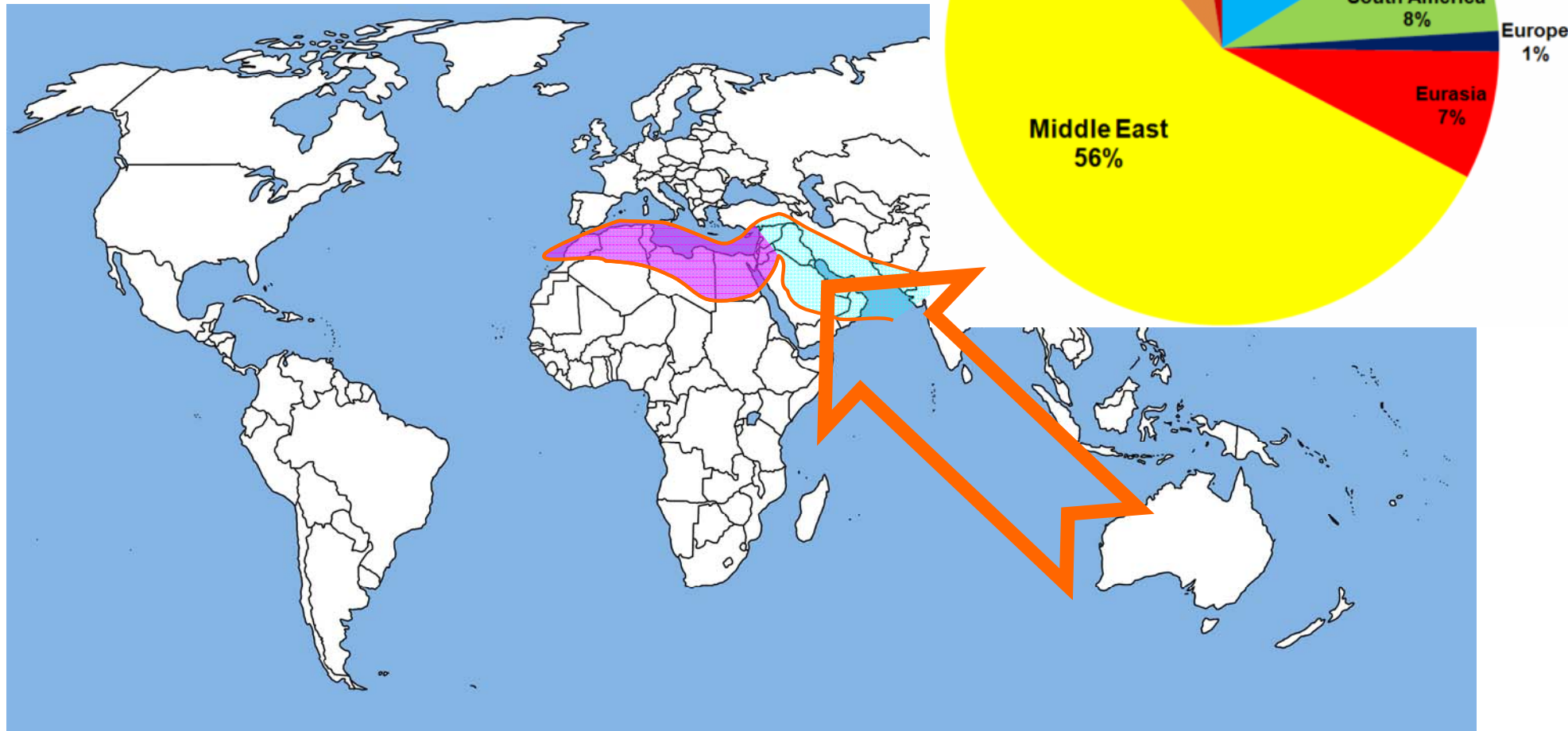
- Introduction to South Tethys stratigraphy, hydrocarbon fields, & future potential
- Wilsonian cycles & sequence stratigraphy
- Sedimentary section of N Africa & Arabia
- Plate tectonic control on sedimentary character, & hydrocarbons in the Precambrian-Tertiary
- Specific examples from Permian, Jurassic & Cretaceous
- Conclusions

South Tethyan Margin



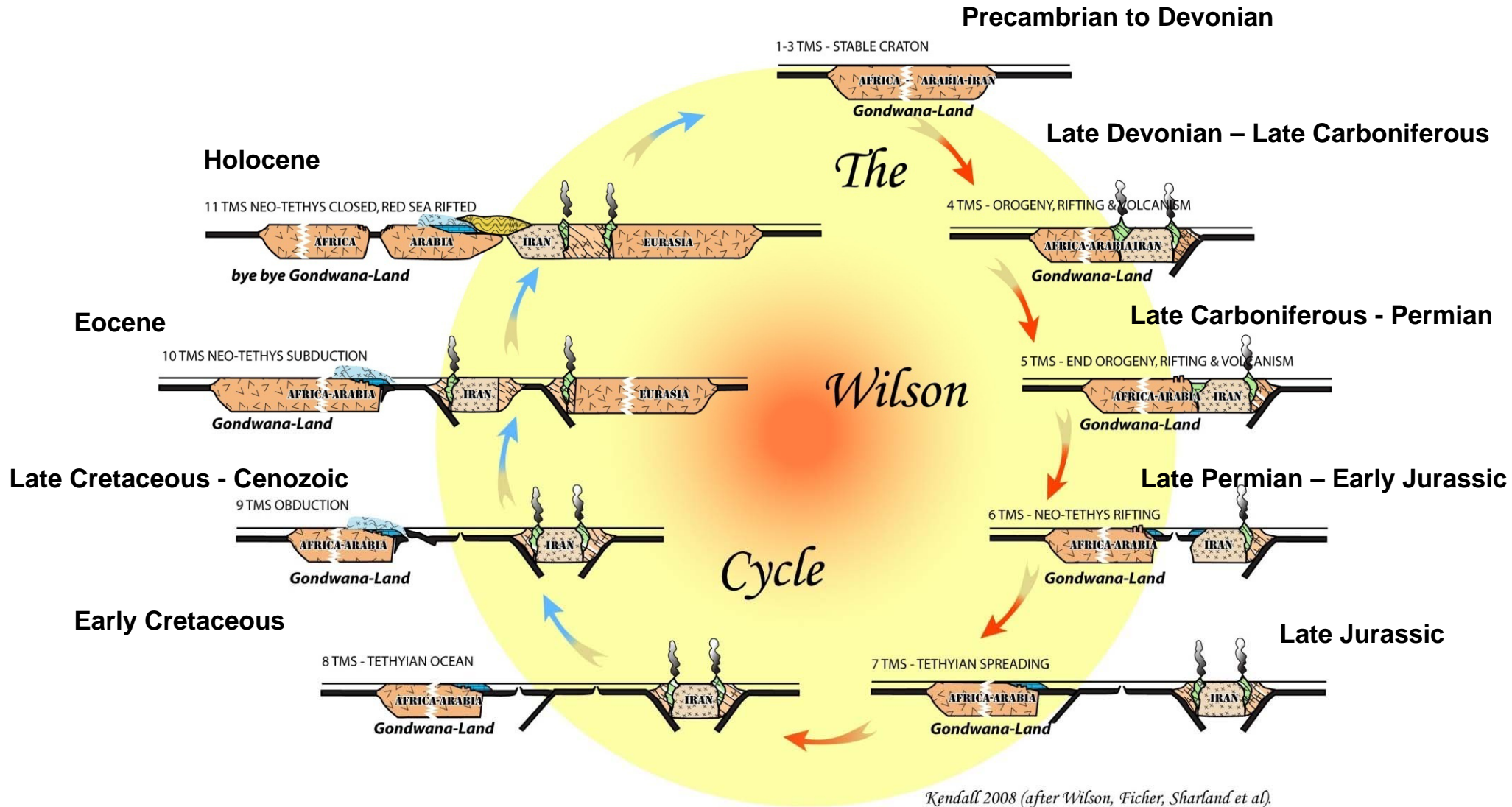
Northeastern flank of Gondwanaland from Arabian Plate
through Zagros & Taurus Mtns, Levant & N Africa

South Tethyan



Northeastern flank of Gondwanaland from Arabian Plate through Zagros & Taurus Mtns, Levant & N Africa

Wilson Cycle – South Tethys *Middle East & North Africa*



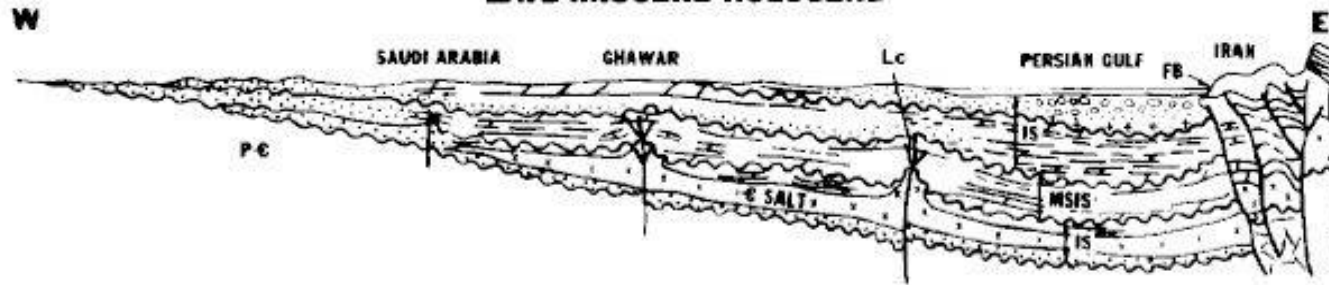
Sequence Stratigraphic Framework

Used to define hydrocarbon reservoirs, sources & seals & controlled by:

- Wilson cycle of S Tethyan Plate Tectonic history
- Sharland's 11 low frequency Tectono-Stratigraphic Mega-Sequences contain hydrocarbon plays within the tectonic accommodation & its sediment fill
- Mostly carbonate fields & architectures of their facies further subdivided by Sharland's 63 high frequency Maximum Flooding Surfaces (MFS) response to eustatic & structural change
- Organic rich MFS events sequester source rocks

Evolution of Arabian Shield - Tectonics

LATE MIOCENE-HOLOCENE

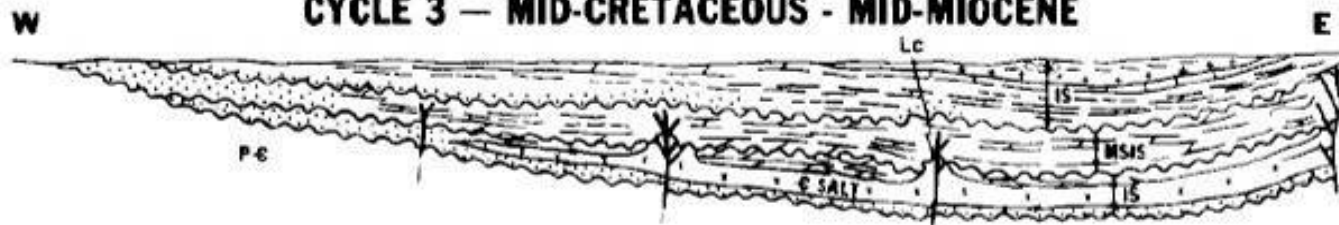


END CYCLE 3

Iranian foldbelt formed as India, Asia, and Afro-Arabian plates collided. Zagros Mountains form. Evaporites (Fars) and clastics deposited in front of the mountains. Wrench structures continue to be active. Final formula

FB/IS-3,2,1/Lc/MSIS-3,2,1/La/IS-3,2,1

CYCLE 3 — MID-CRETACEOUS - MID-MIOCENE

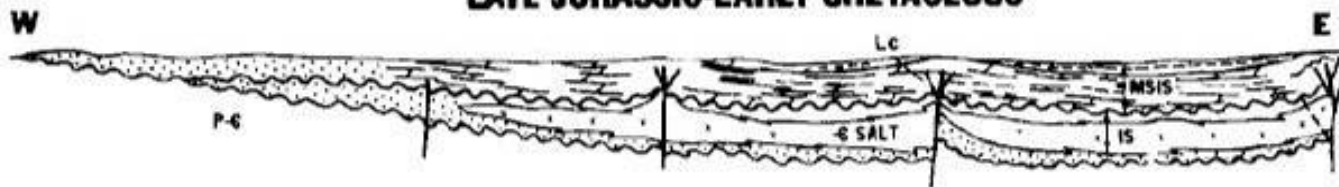


CYCLE 3

Interior sag—subsidence of basin with deposition of Cretaceous sandstone, shale, and carbonates, and lower Tertiary shale, limestone, and evaporite. Wrench fault structures periodically active.

IS-3,2,1/Lc/MSIS-3,2,1/La/IS-3,2,1

LATE JURASSIC-EARLY CRETACEOUS



CYCLE 2

Margin sag—Permian-Triassic dolomite and shale, Jurassic carbonates, some evaporites, open sea to the east.

MSIS-3,2,1/La/IS-3,2,1

CYCLE 2 — PERMIAN - JURASSIC



END CYCLE 2

Cimmerian collision of Afro-Arabian block with Iranian and Asiatic plates, episodic wrench faults activated in Arabian plate, initiating structures.

Lc/MSIS-3,2,1/La/IS-3,2,1

CYCLE 1 — CAMBRIAN - CARBONIFEROUS

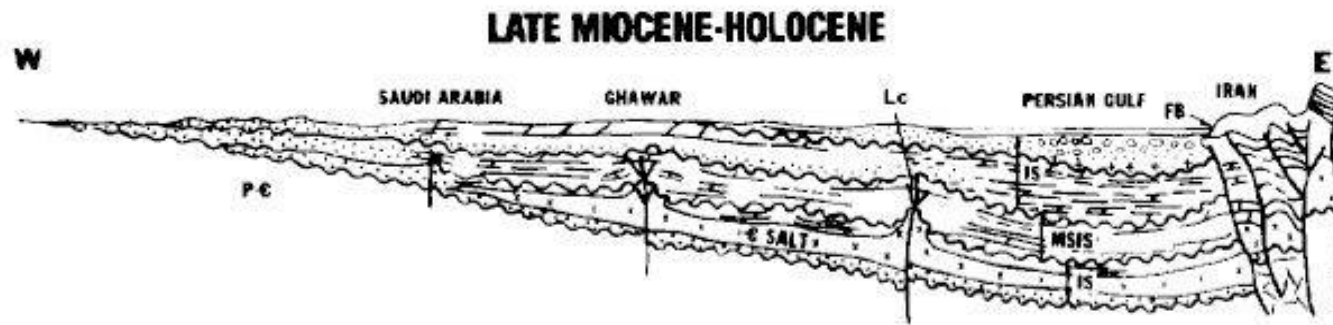


CYCLE 1

Interior sag—Basal sandstone, massive salt, dolomite, and shale.

La/IS-3,2,1

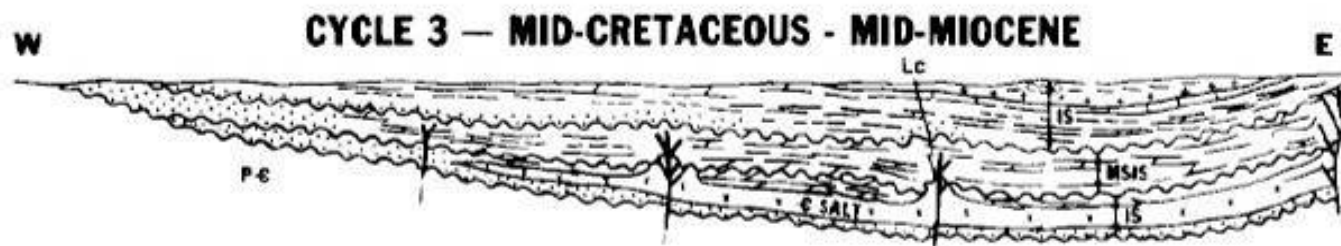
Evolution of Arabian Shield - Tectonics



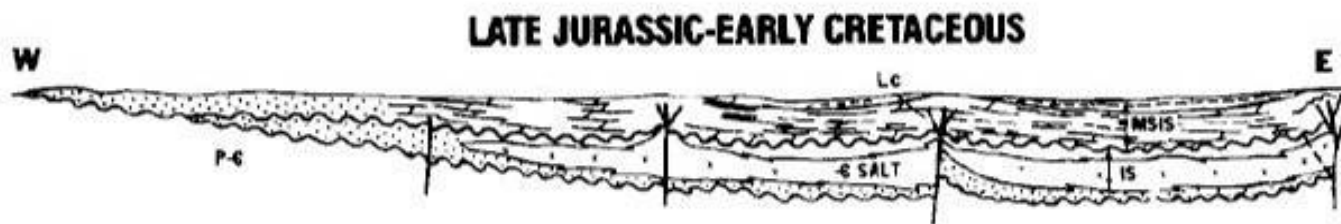
END OF CYCLE 3

Foreland Basin

be 1/Lc/MSIS-3,2,1/La/IS-3,2,1



Compression & Foreland Basin



Extensional margin

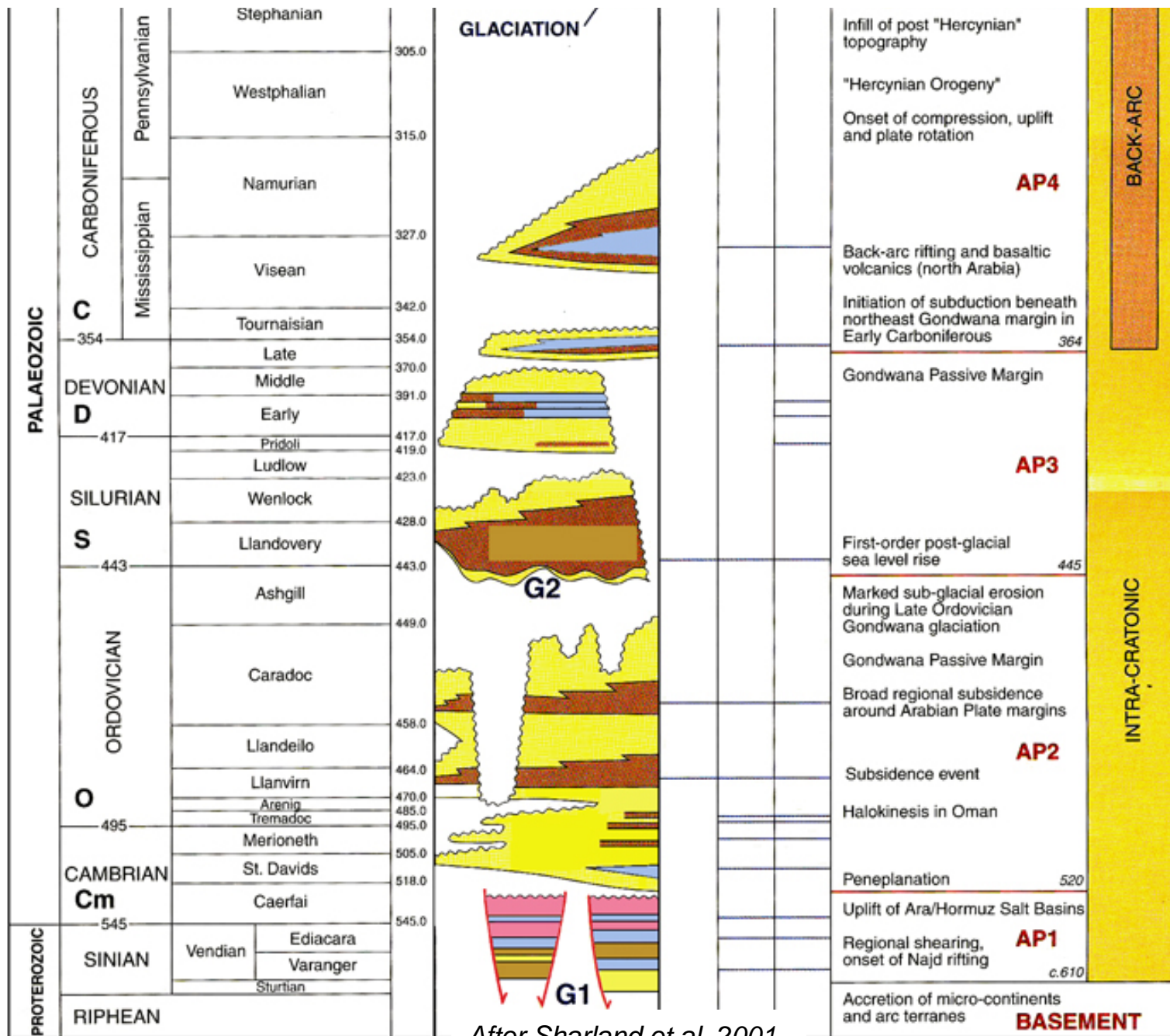


Extensional margin

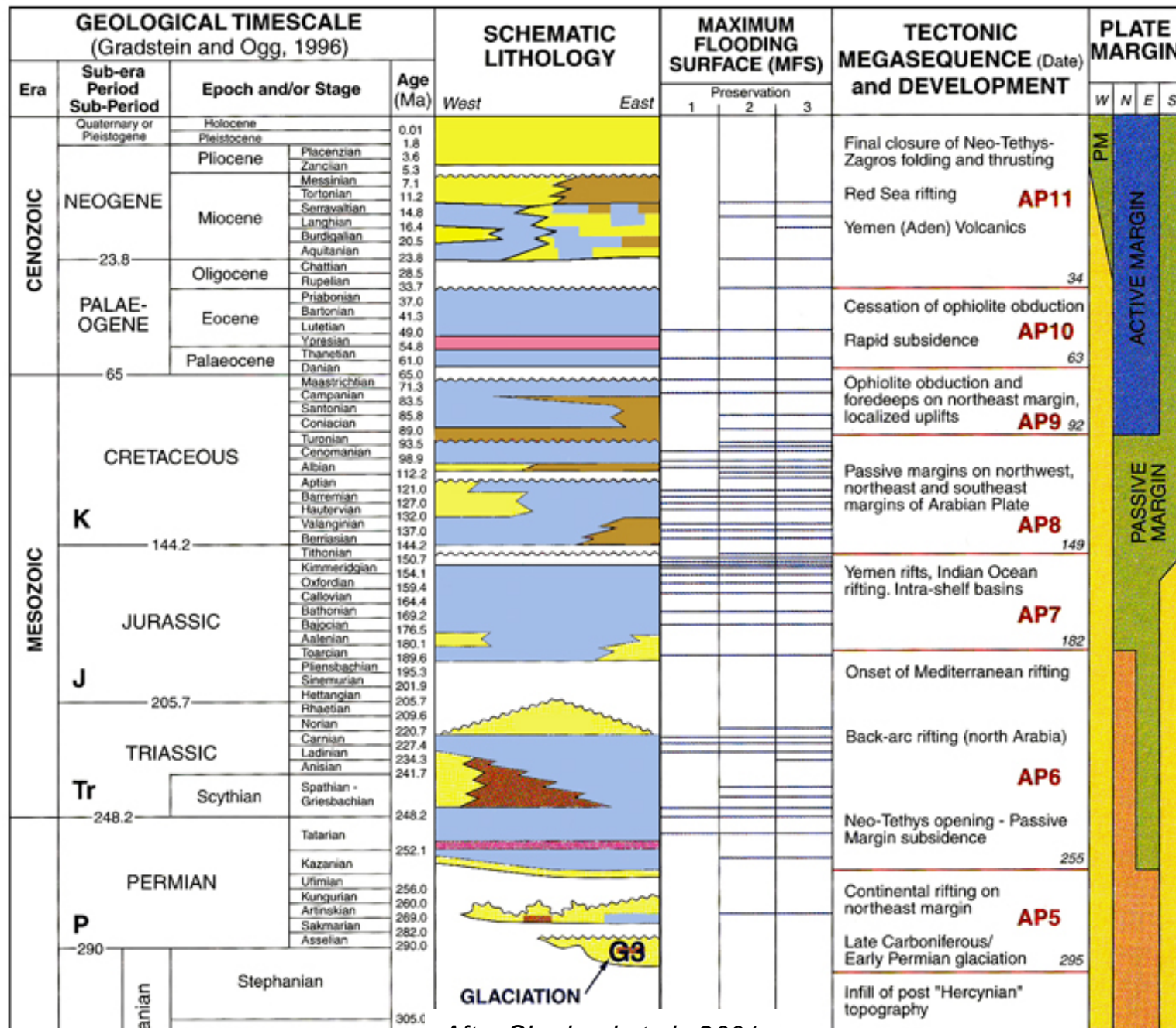


Interior Sag

Maximum Flooding Surfaces (MFS)

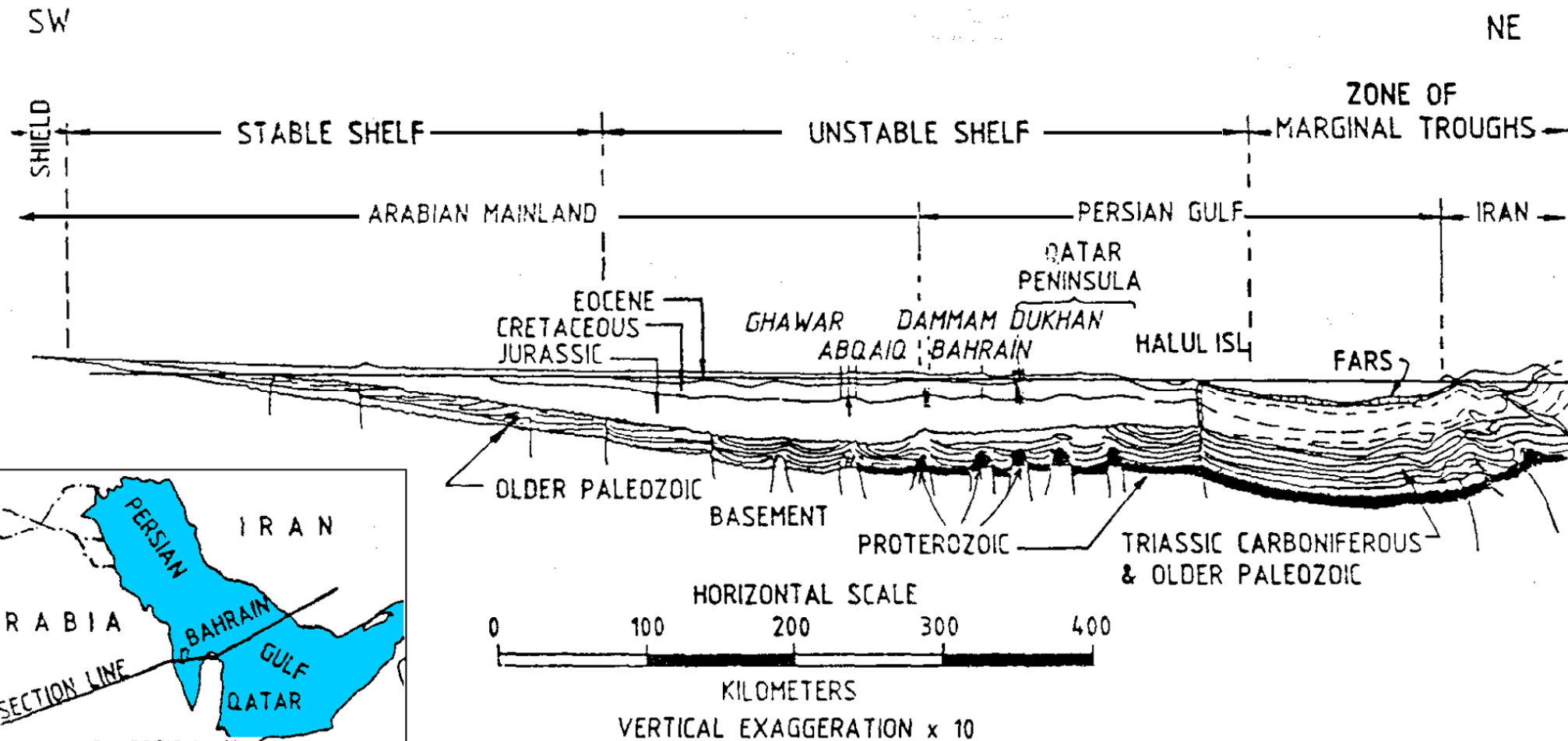


Maximum Flooding Surfaces (MFS)



After Sharland et al., 2001

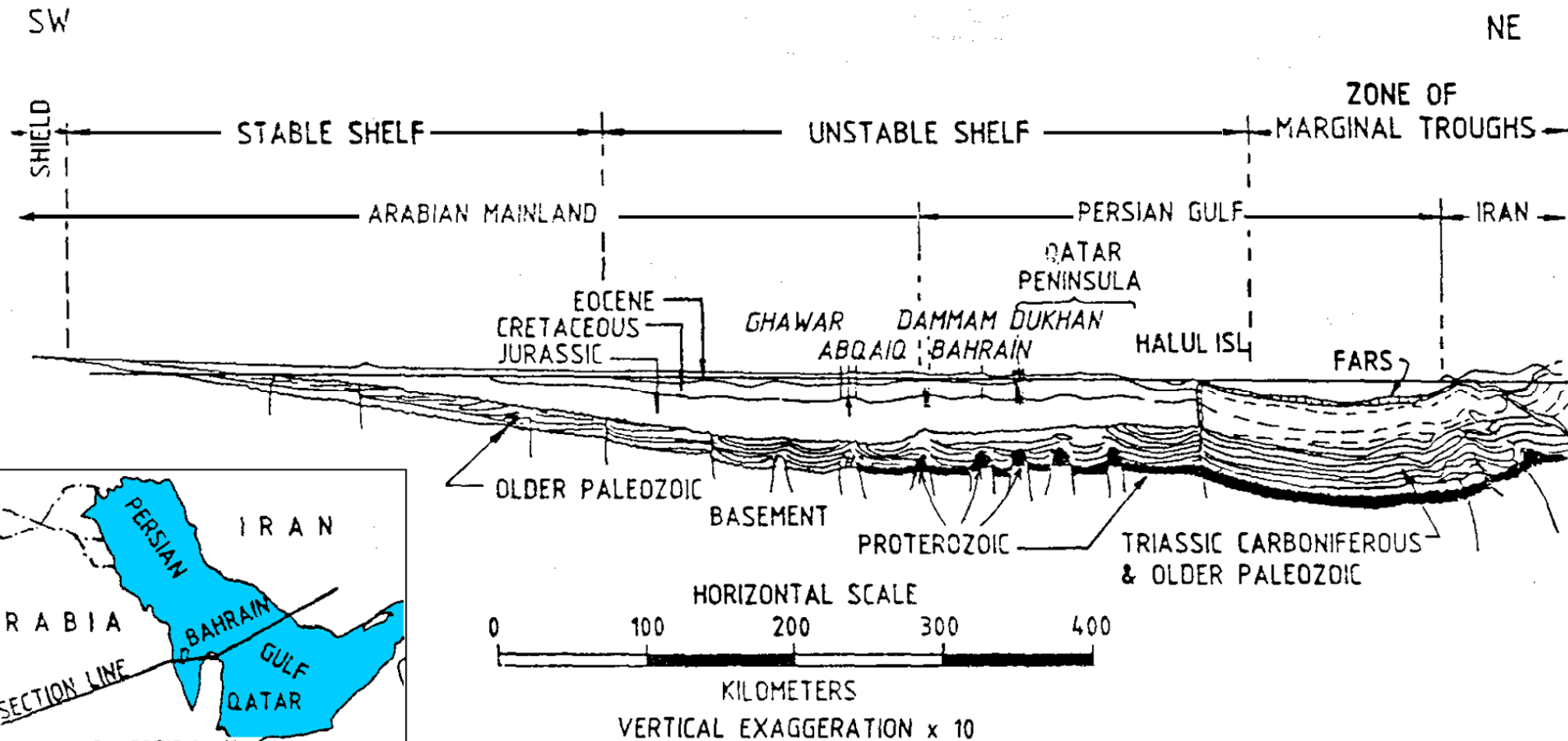
Geologic Cross-Section - Arabian Gulf



Edgell, 1992

Accommodation produced by low frequency tectonic subsidence modulated by higher frequency eustatic changes in sea level and varying rates of sediment accumulation

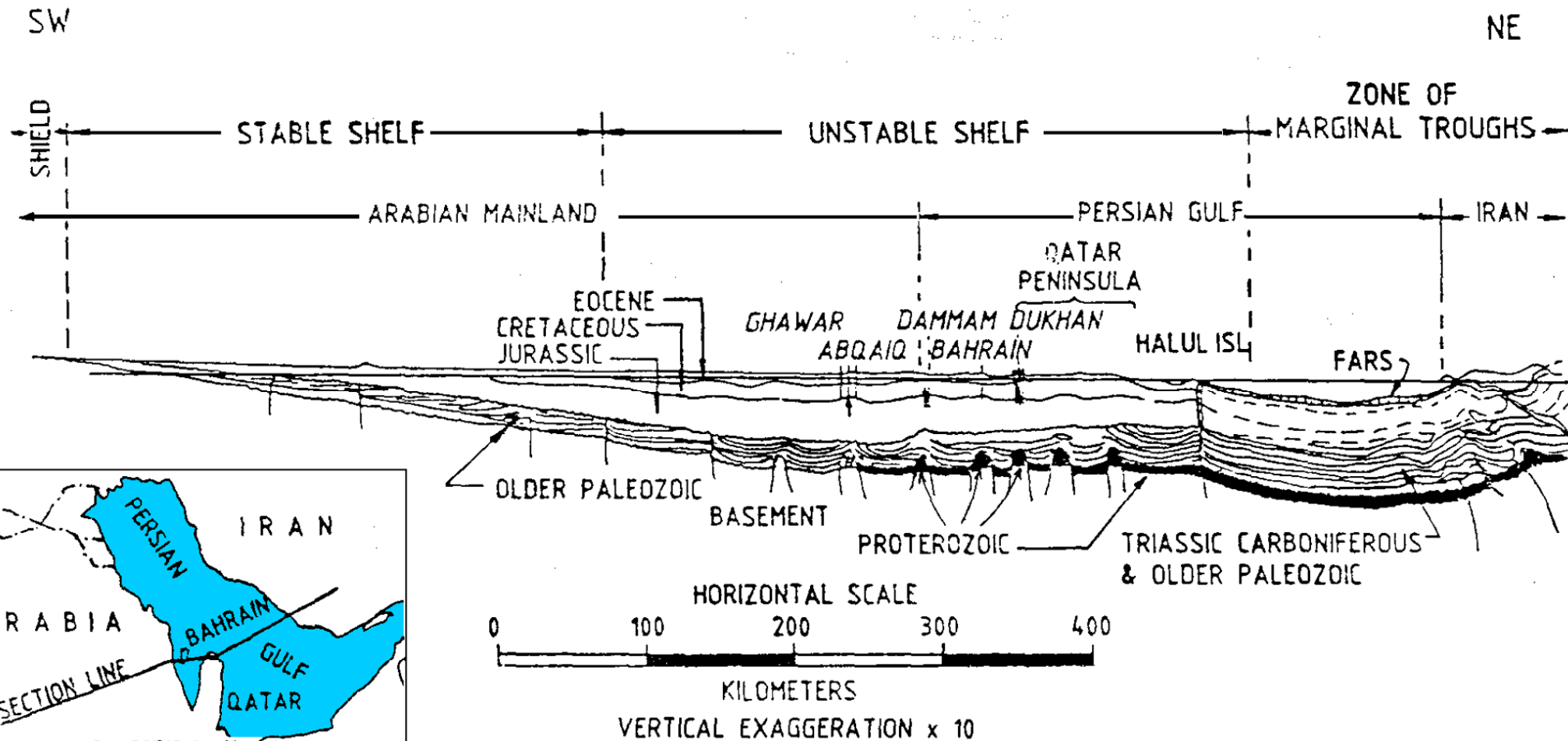
Geologic Cross-Section - Arabian Gulf



Edgell, 1992

Relatively flat-lying assemblages of Paleozoic, Mesozoic through Cenozoic interbedded carbonates, evaporites and clastic horizons

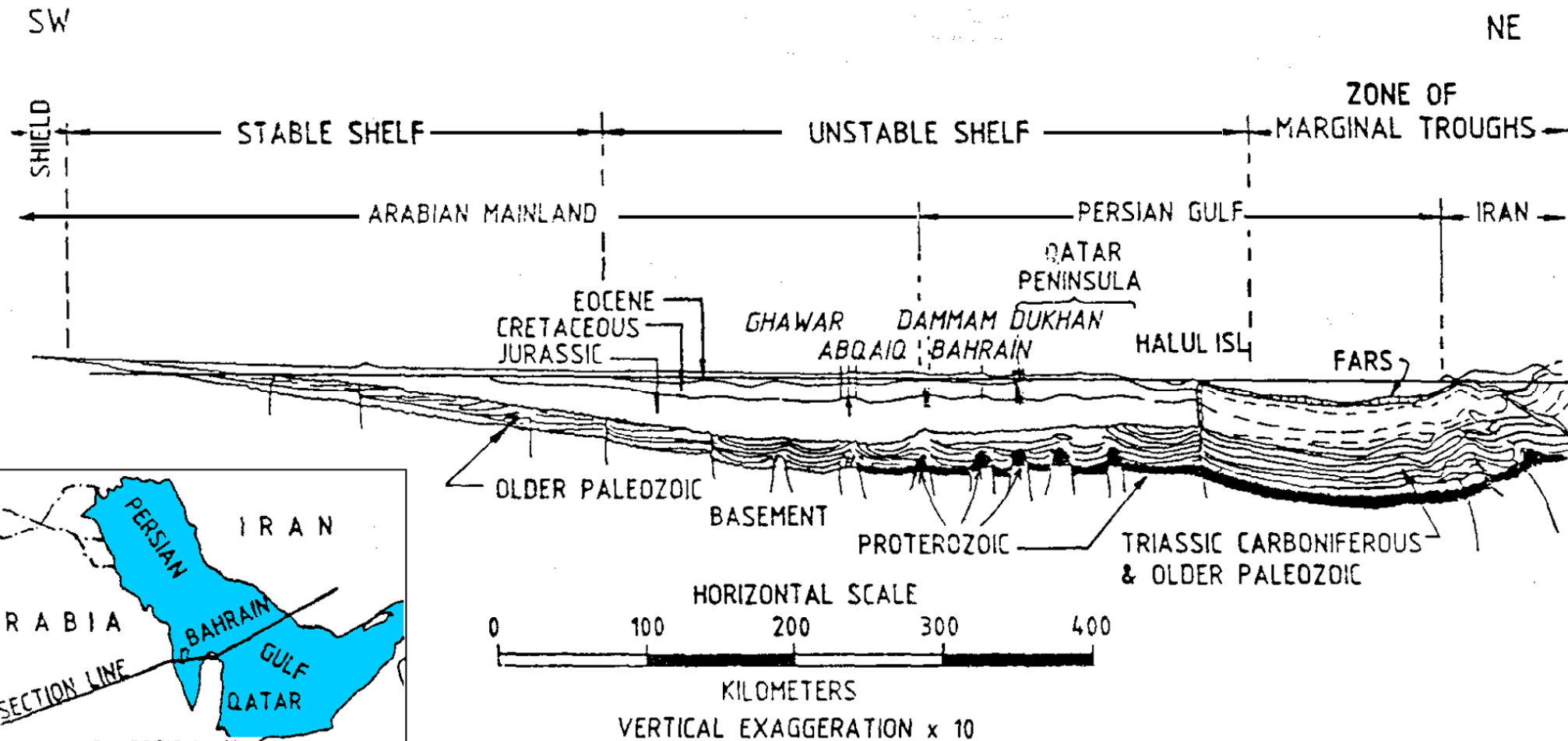
Geologic Cross-Section - Arabian Gulf



Edgell, 1992

Paleozoic landward dominantly siliciclastic-continental to fluvio-deltaic & glacial, seaward shales & carbonates

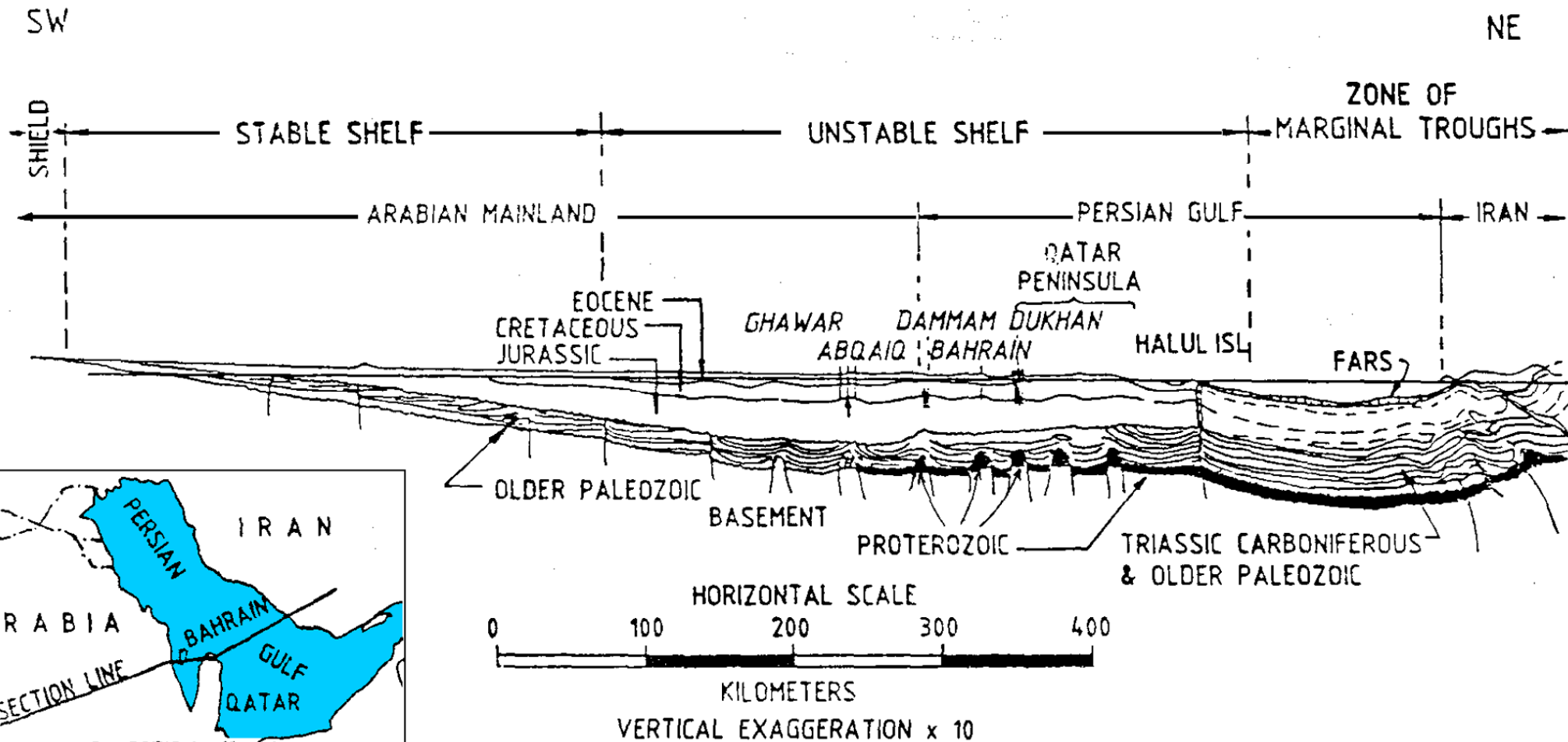
Geologic Cross-Section - Arabian Gulf



Edgell, 1992

Mesozoic exposed areas updip while dominantly carbonate on shelf and intraplate basins

Geologic Cross-Section - Arabian Gulf



Edgell, 1992

Oil fields are younger from west to east; Paleozoic stratigraphy caps Precambrian in almost all Southern Tethys with exceptions that include the Burgan Arch (Kuwait), or Sirte Basin (Libya)

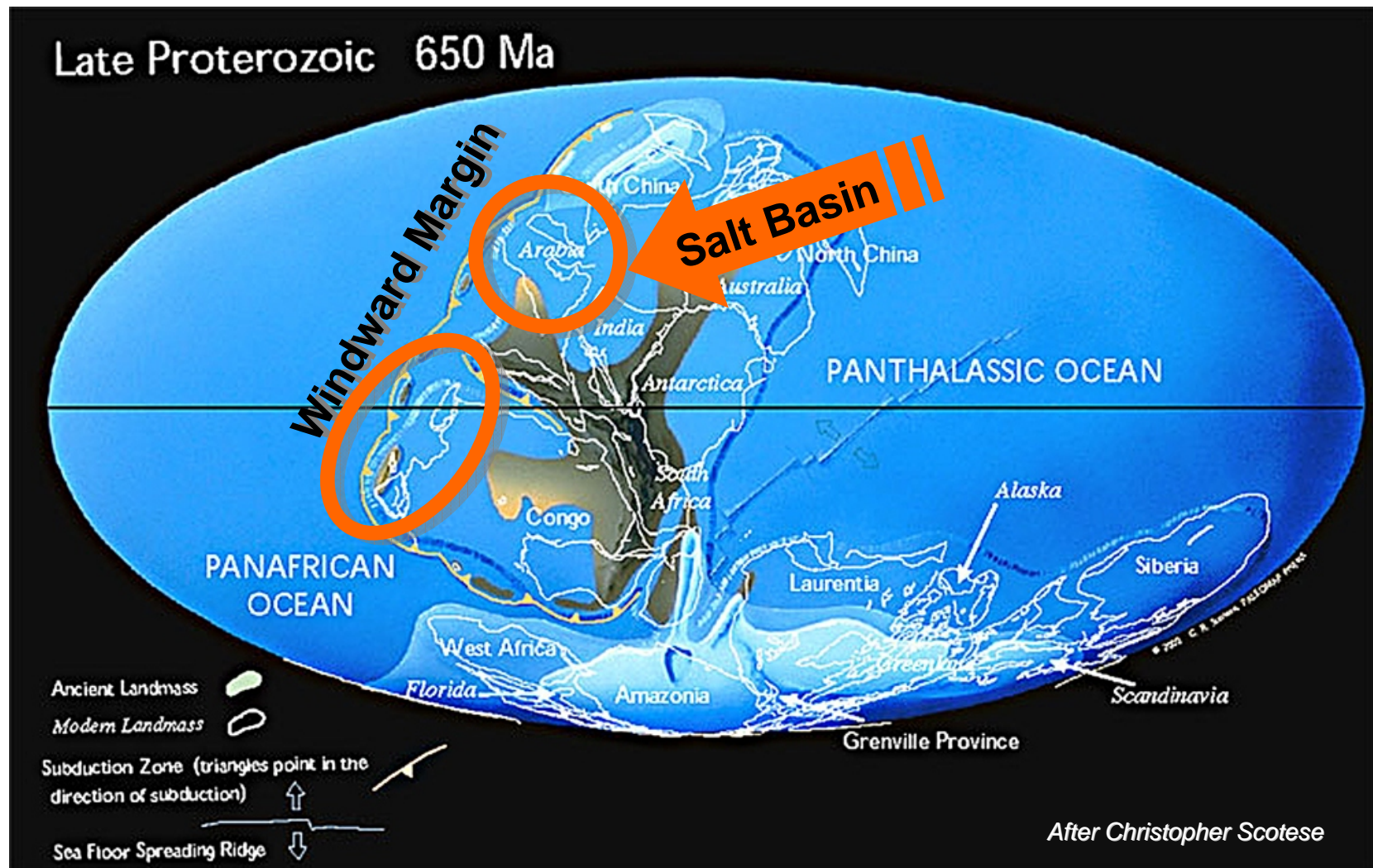
Controls on the Petroleum Systems of the Southern Tethys

Petroleum Systems function of:-

- Plate position
- Climate and oceanography
- Organic productivity
- Sediment character
- Structural and thermal history

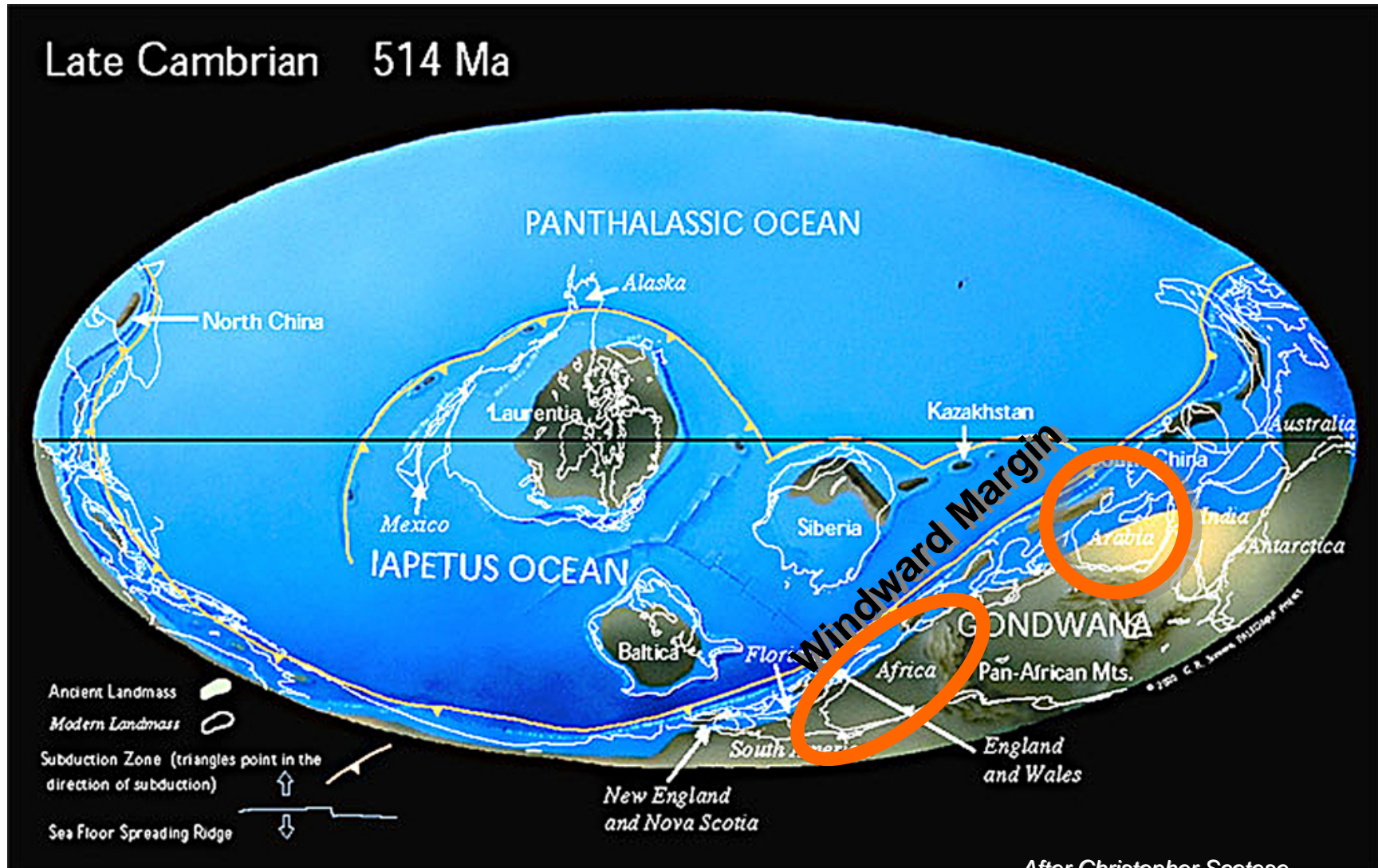
Many of these factors dependent on others

Precambrian

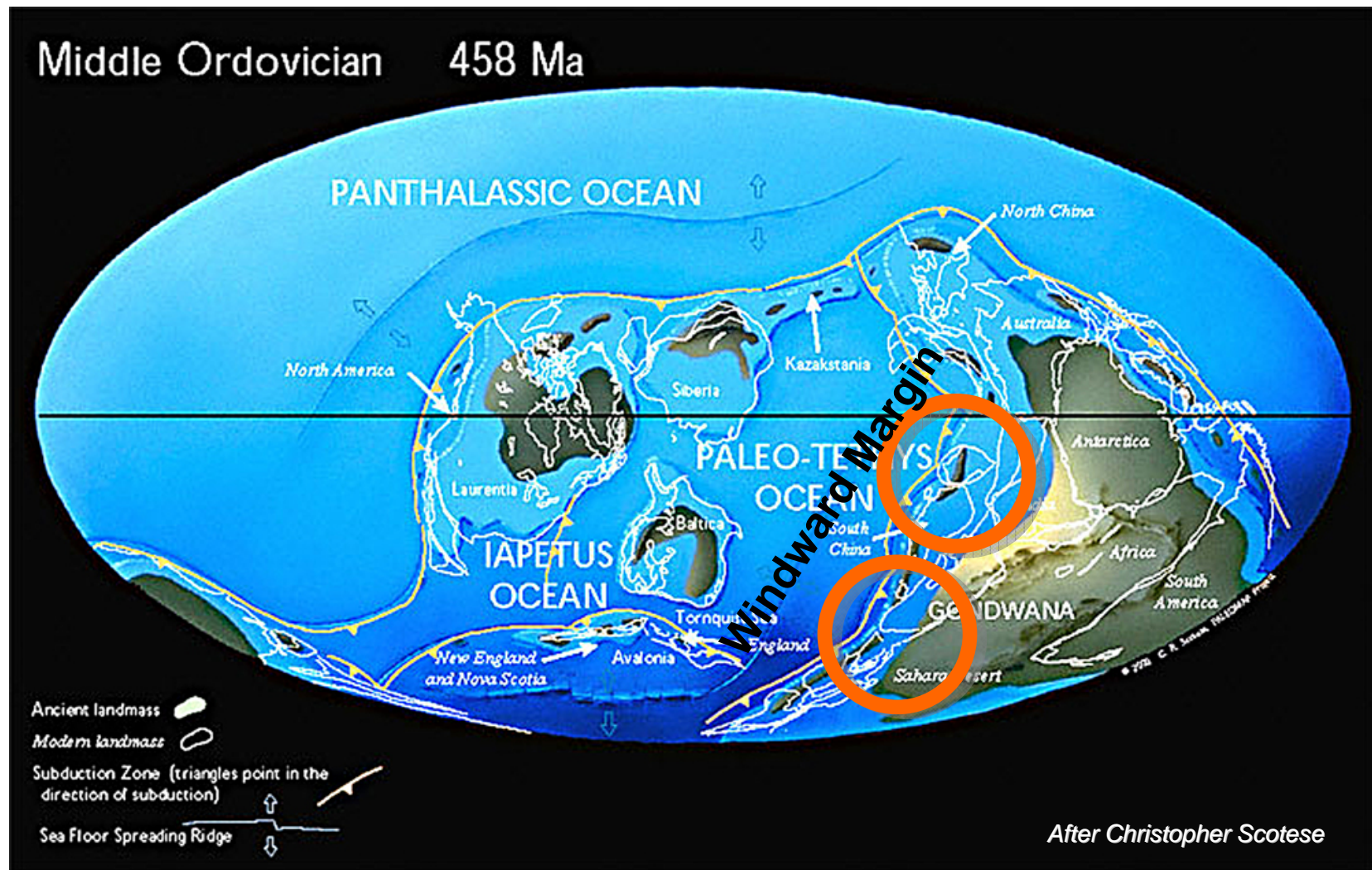


Cambrian

Late Cambrian 514 Ma

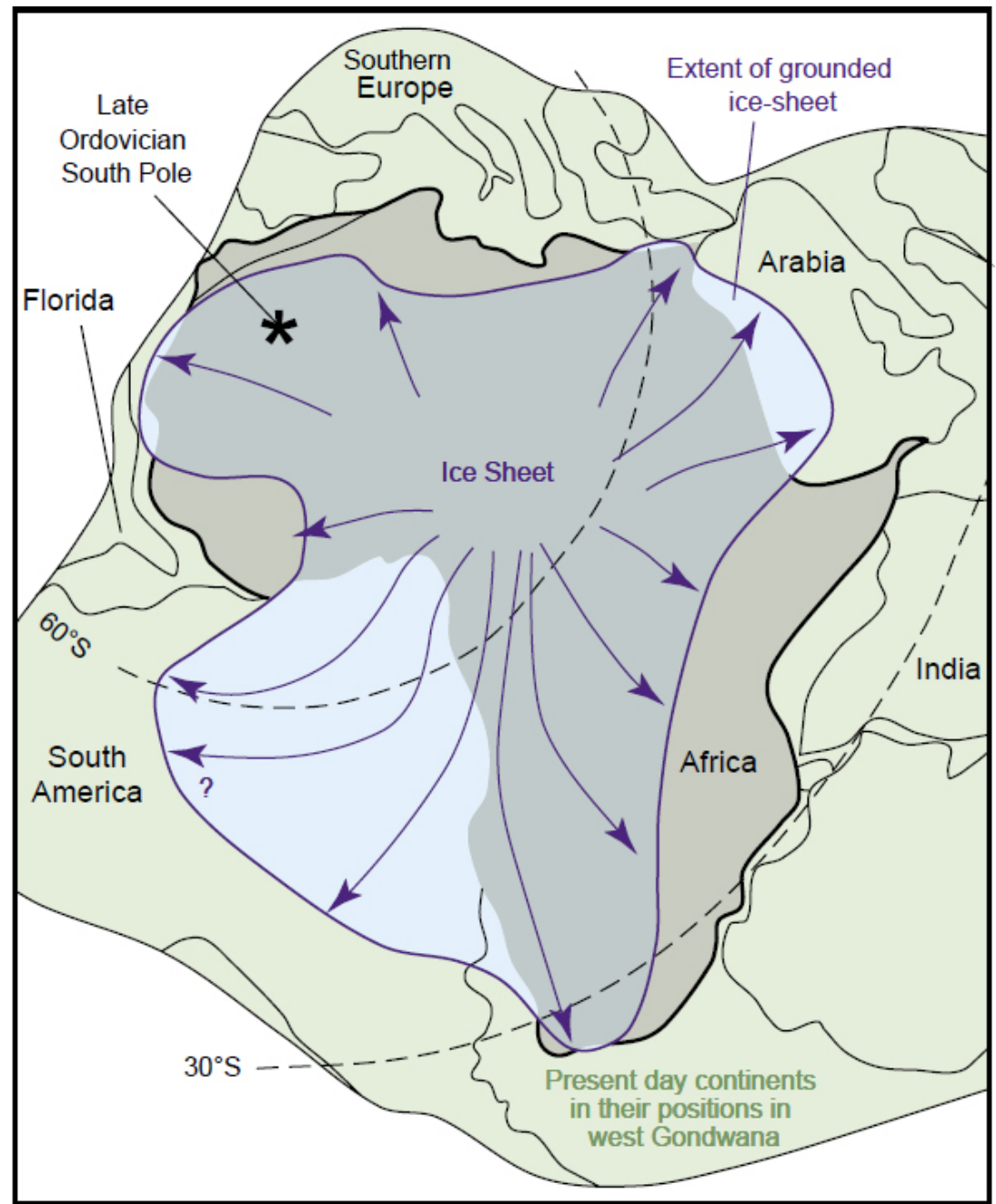


Ordovician



Ordovician Glaciation

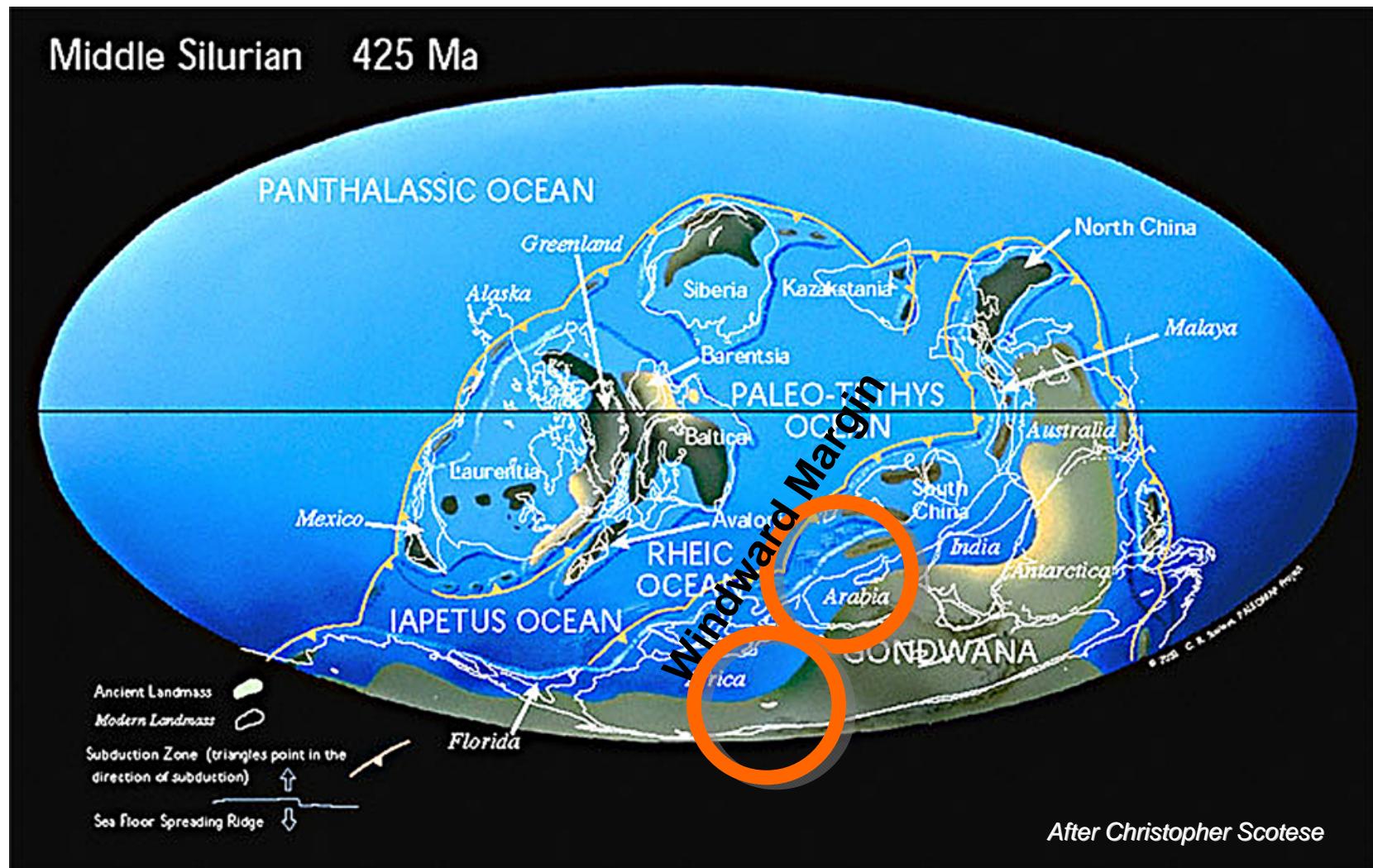
**Blue arrows
indicate
direction of ice
sheet advance**



(after Scotese et al., 1999; Sutcliffe et al., 2000; Le Heron, et al., 2004)

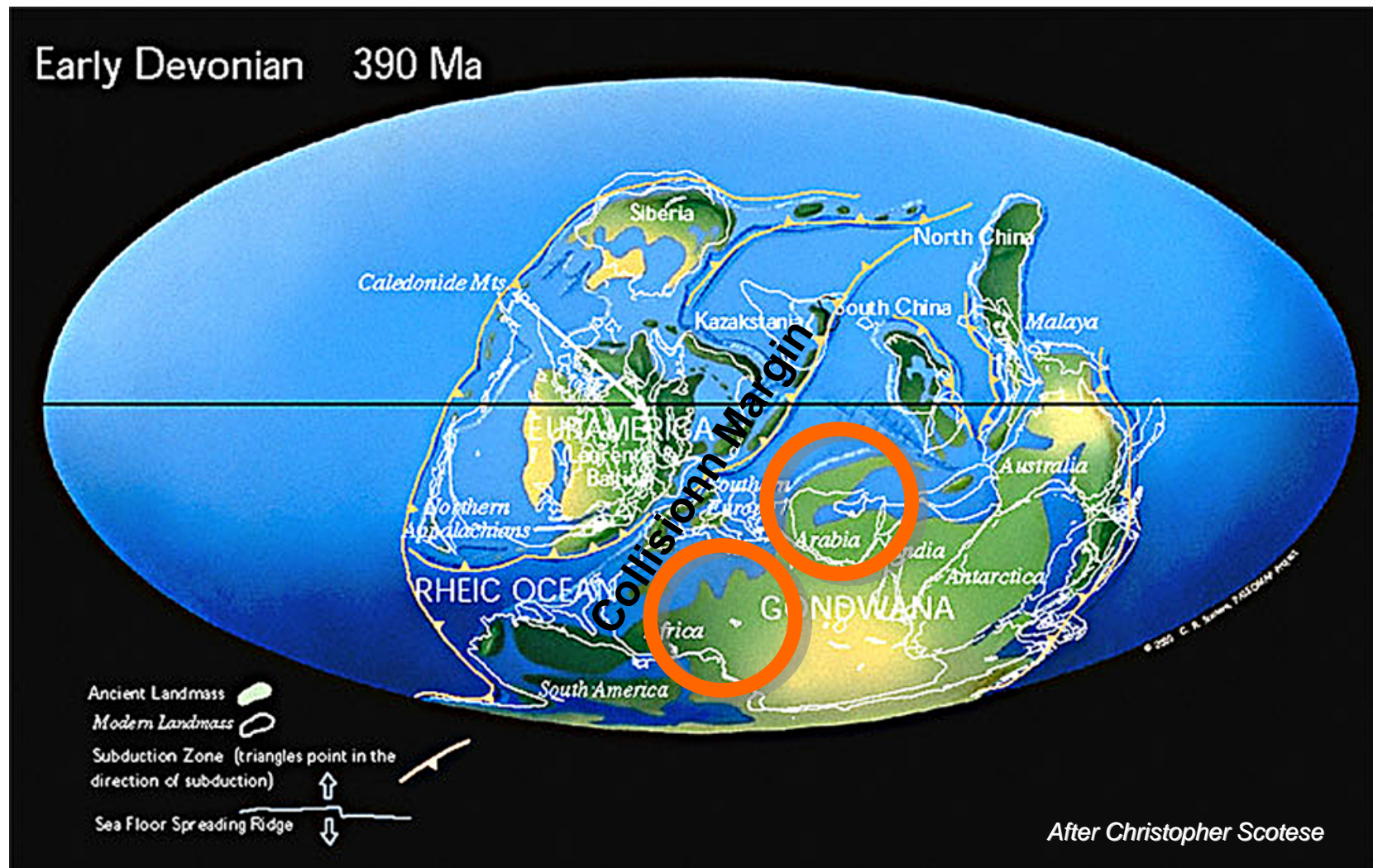
Silurian

Middle Silurian 425 Ma

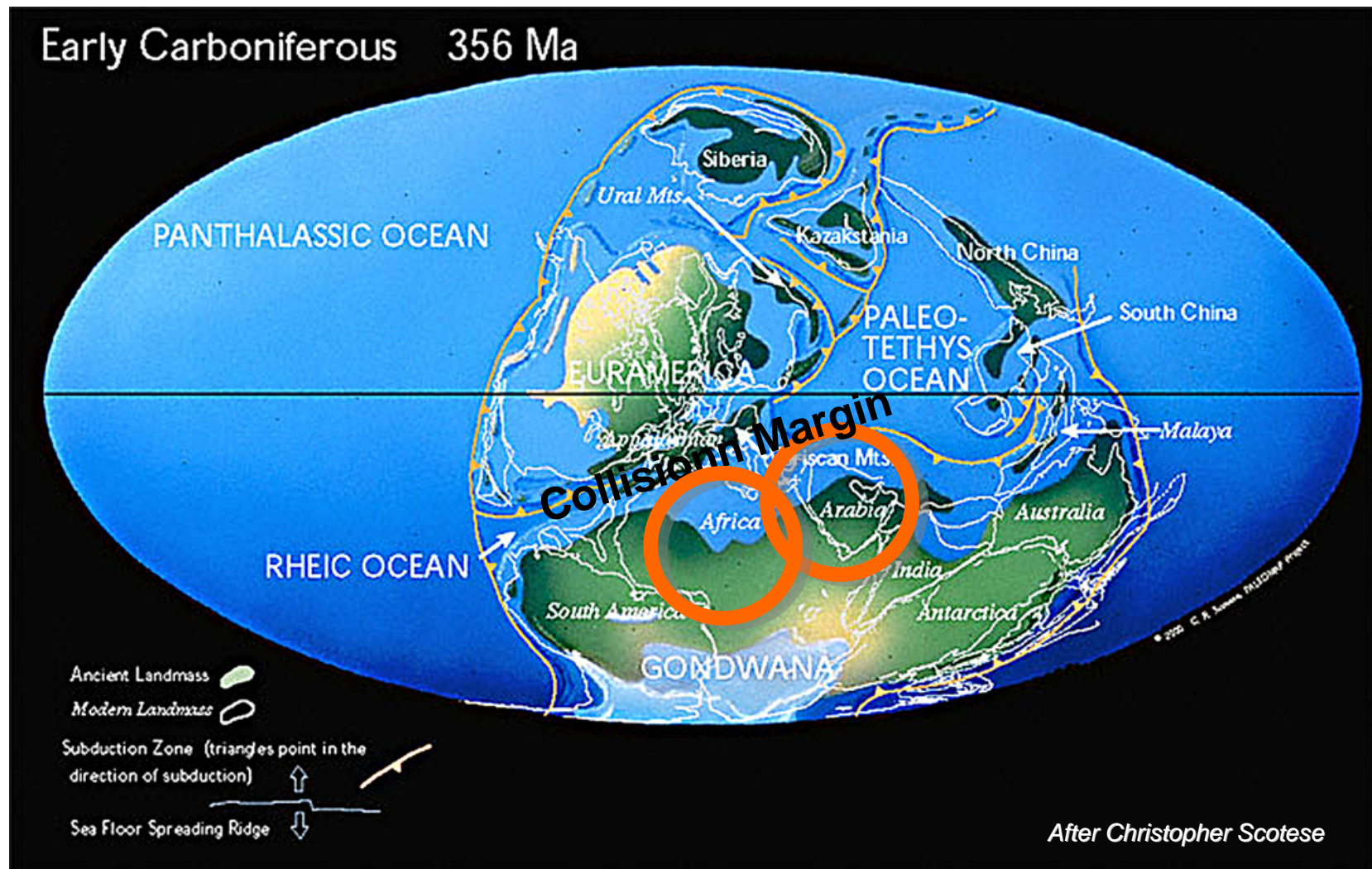


Devonian

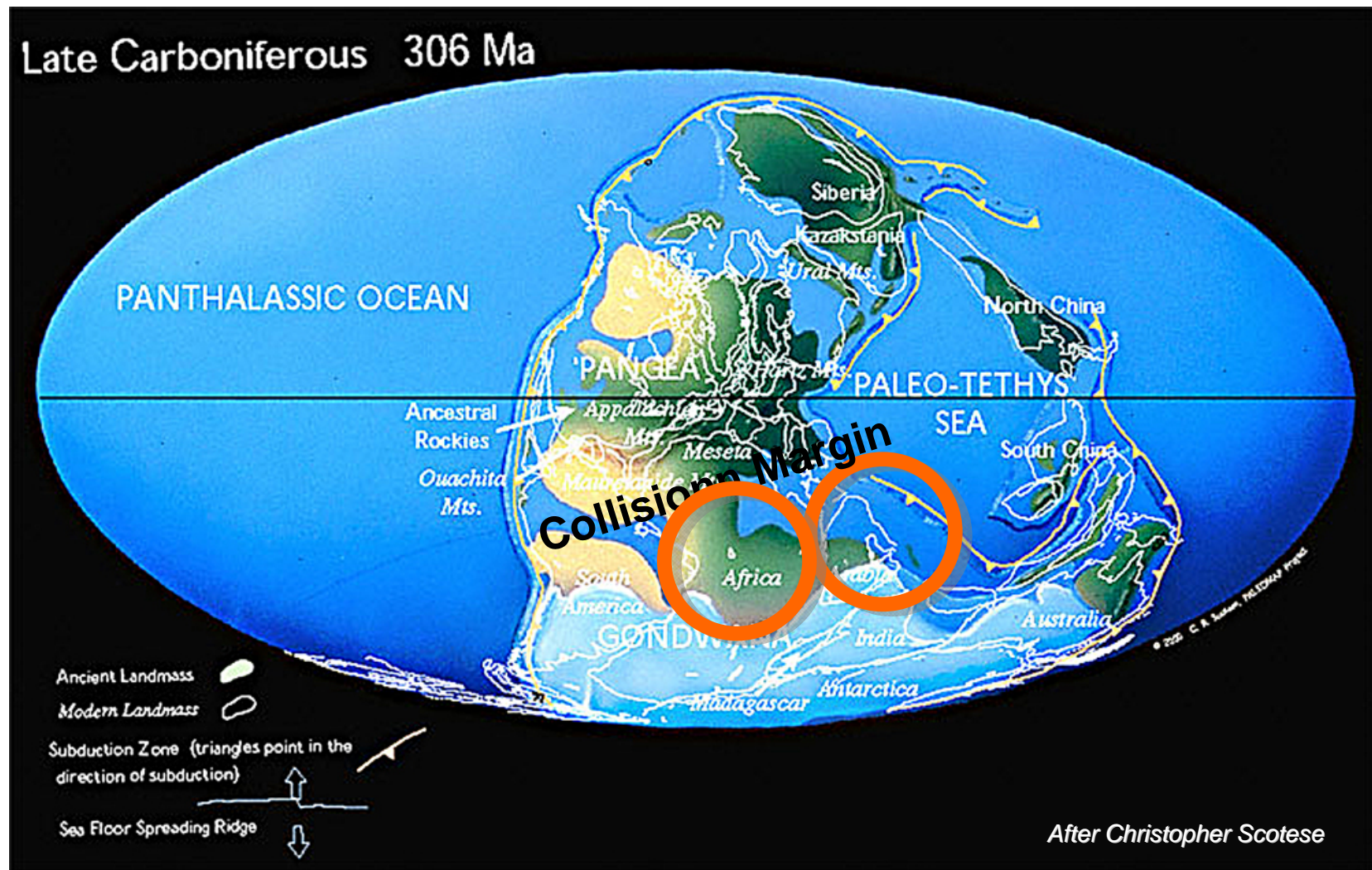
Early Devonian 390 Ma



Early Carboniferous



Late Carboniferous



Paleozoic Sediments

- Paleozoic landward dominantly siliciclastic continental to fluvio-deltaic & glacial sediments while seaward shales & carbonates more common
- Oil fields probably sourced from organic rich mfs events
- These same organic rich sediments associated with reservoir quality rocks high grade the hydrocarbon potential of these rocks

Plate tectonics & Hydrocarbons: Permian, Jurassic & Cretaceous examples

- Mesozoic deposition in tropical settings on an extensional passive Tethyan margin favored organic sequestration
- Late Cretaceous to Tertiary was a foreland basin flanking the Zagros and Taurus uplift.
- Deposition on North African plate occurred in tropical settings and followed an extensional passive margin
- Late Cretaceous--it changed to a dominantly compressional margin with localized wrench margins.

Permian Khuff Saudi Arabia Kuwait, Iran & UAE

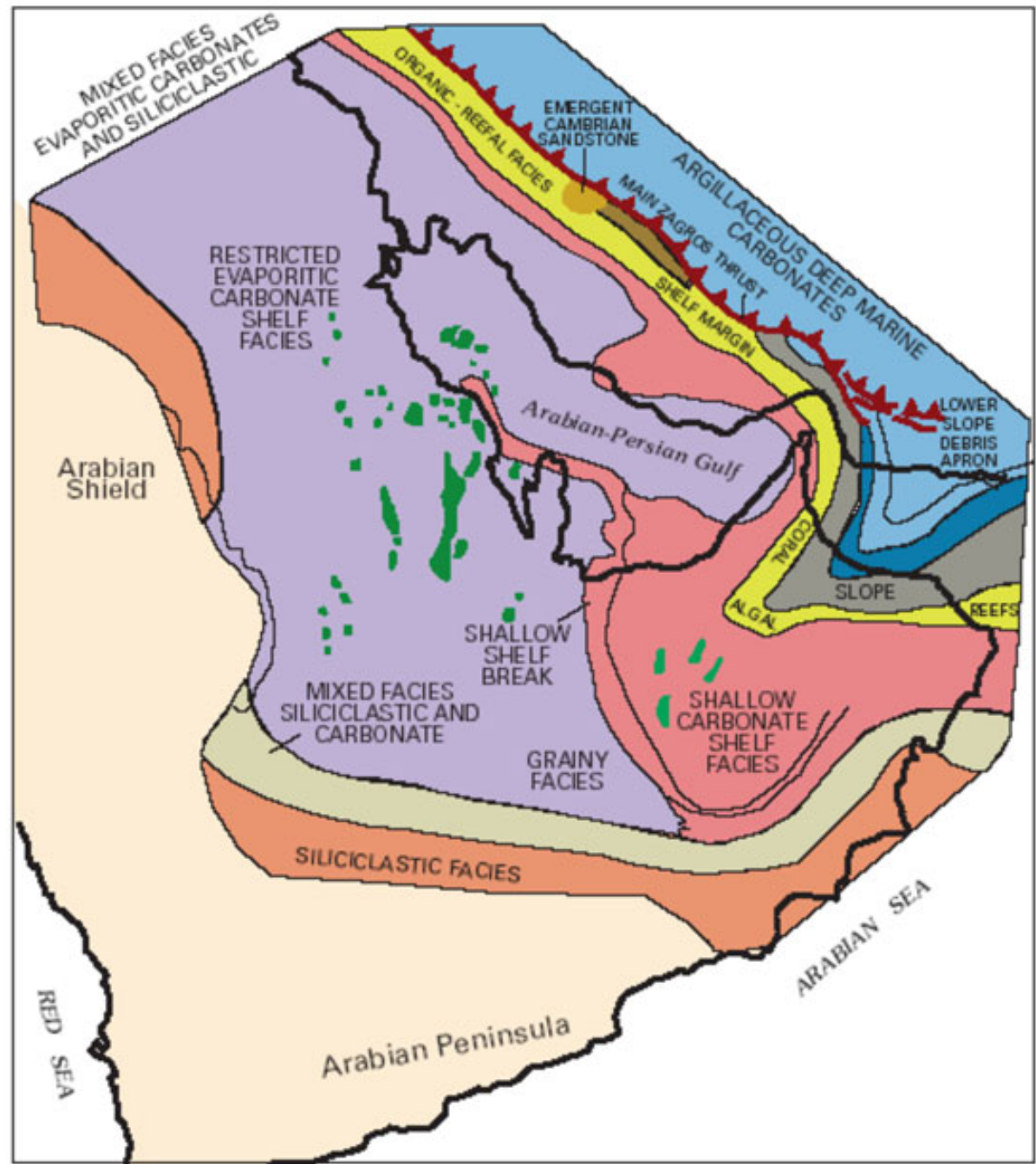
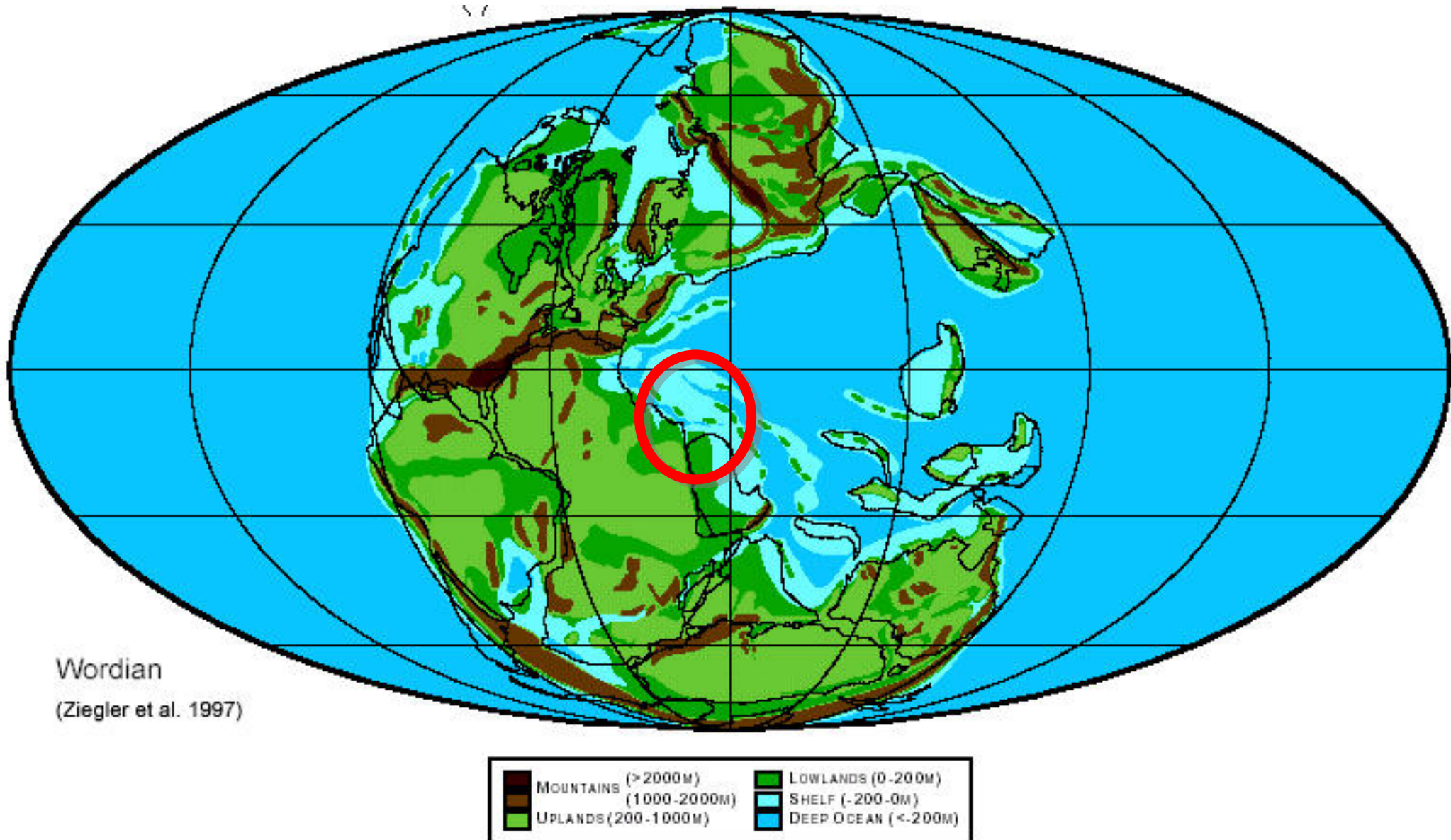


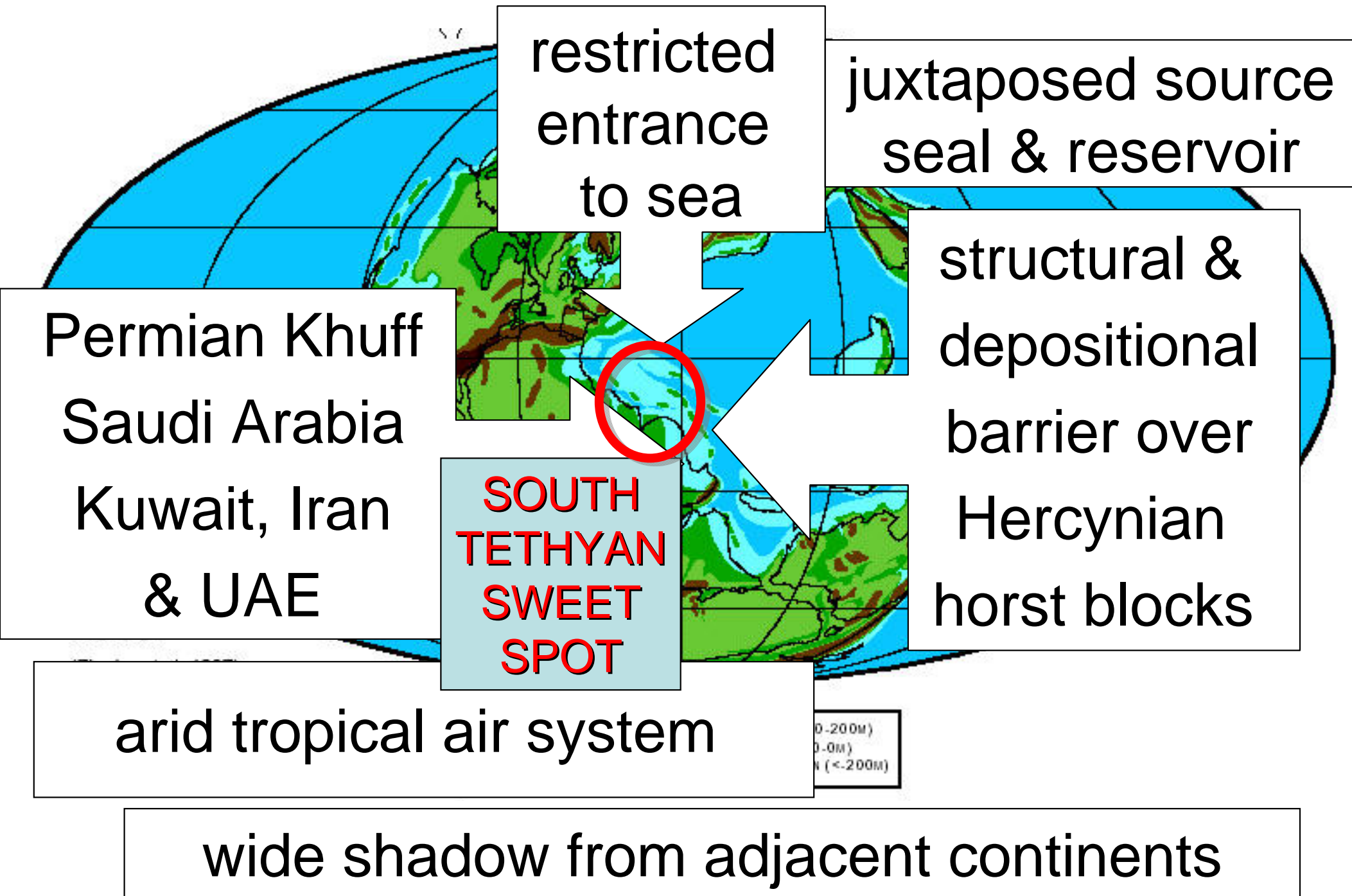
Figure 29. Major environments of deposition and regional facies of the Khuff Formation over the eastern Arabian Peninsula and Zagros Fold Belt. Modified from Al-Jallal (1995).

Permian - Structural Barred Basin - Arabian Gulf



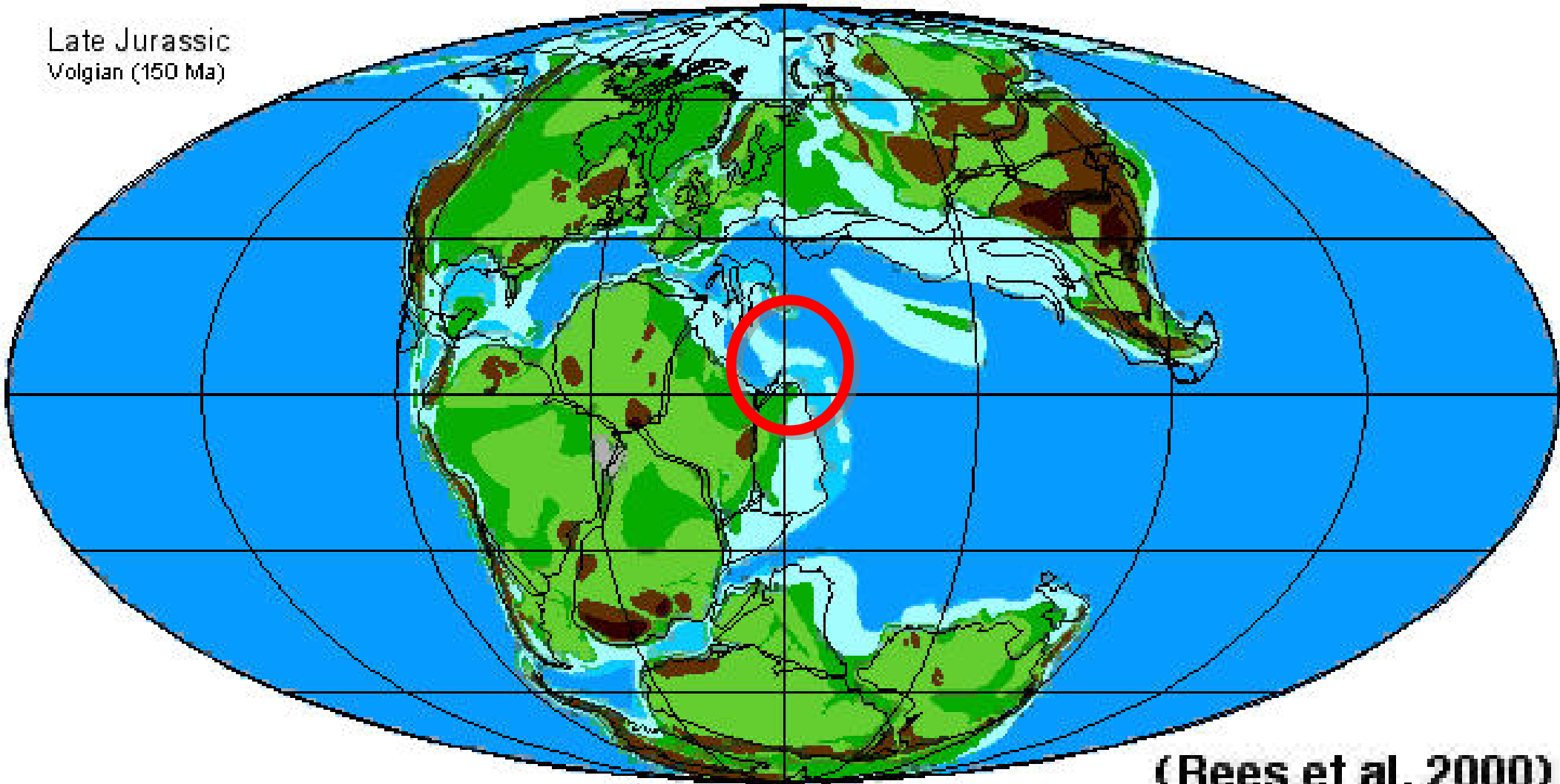
wide shadow from adjacent continents

Permian - Structural Barred Basin - Arabian Gulf



Example of Barred Basin Mesozoic - Arabian Gulf

Late Jurassic
Volgian (150 Ma)

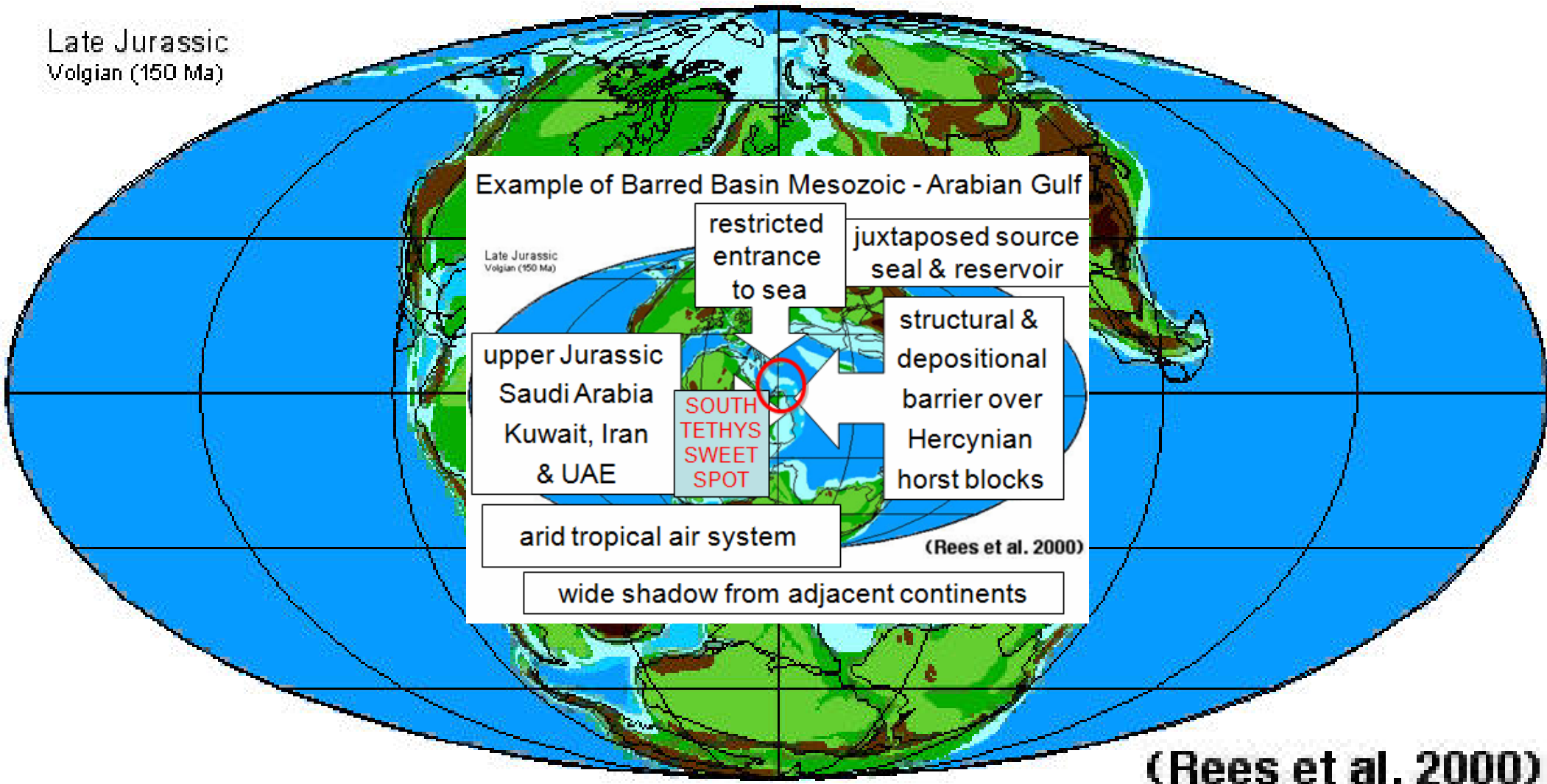


(Rees et al. 2000)

wide shadow from adjacent continents

Example of Barred Basin Mesozoic - Arabian Gulf

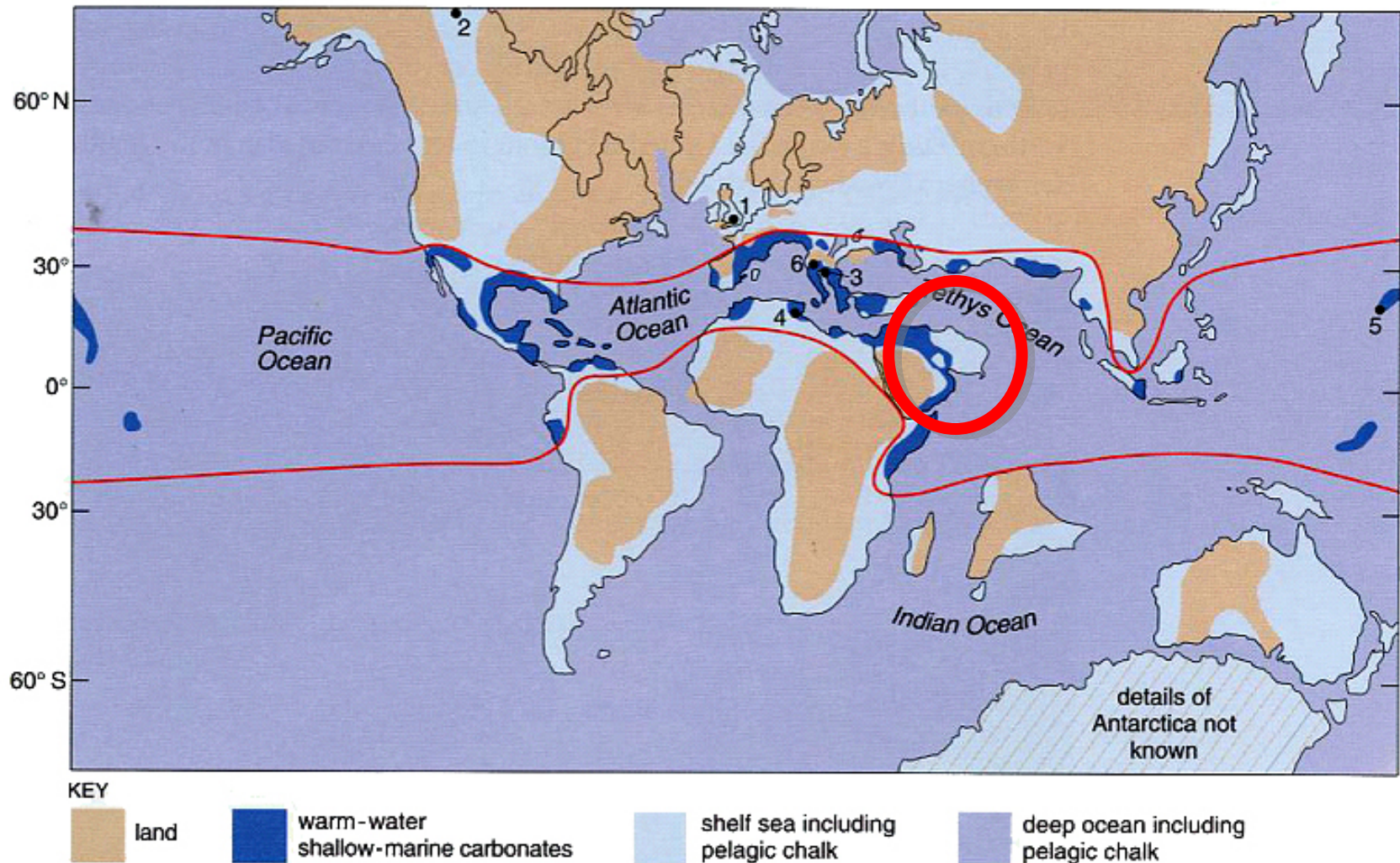
Late Jurassic
Volgian (150 Ma)



(Rees et al. 2000)

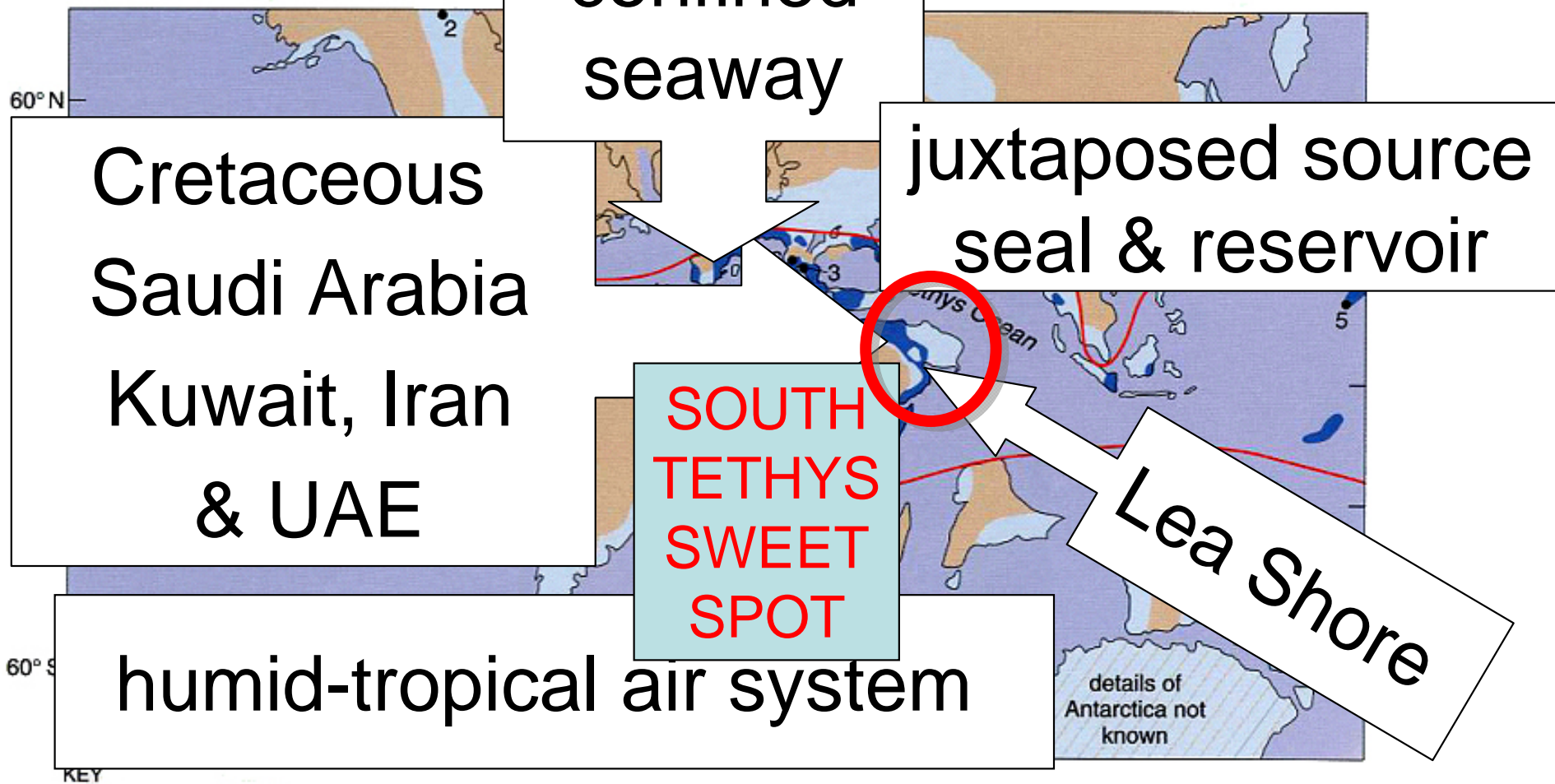
wide shadow from adjacent continents

Cretaceous Paleogeography



After Peter Skelton

Cretaceous Paleogeography



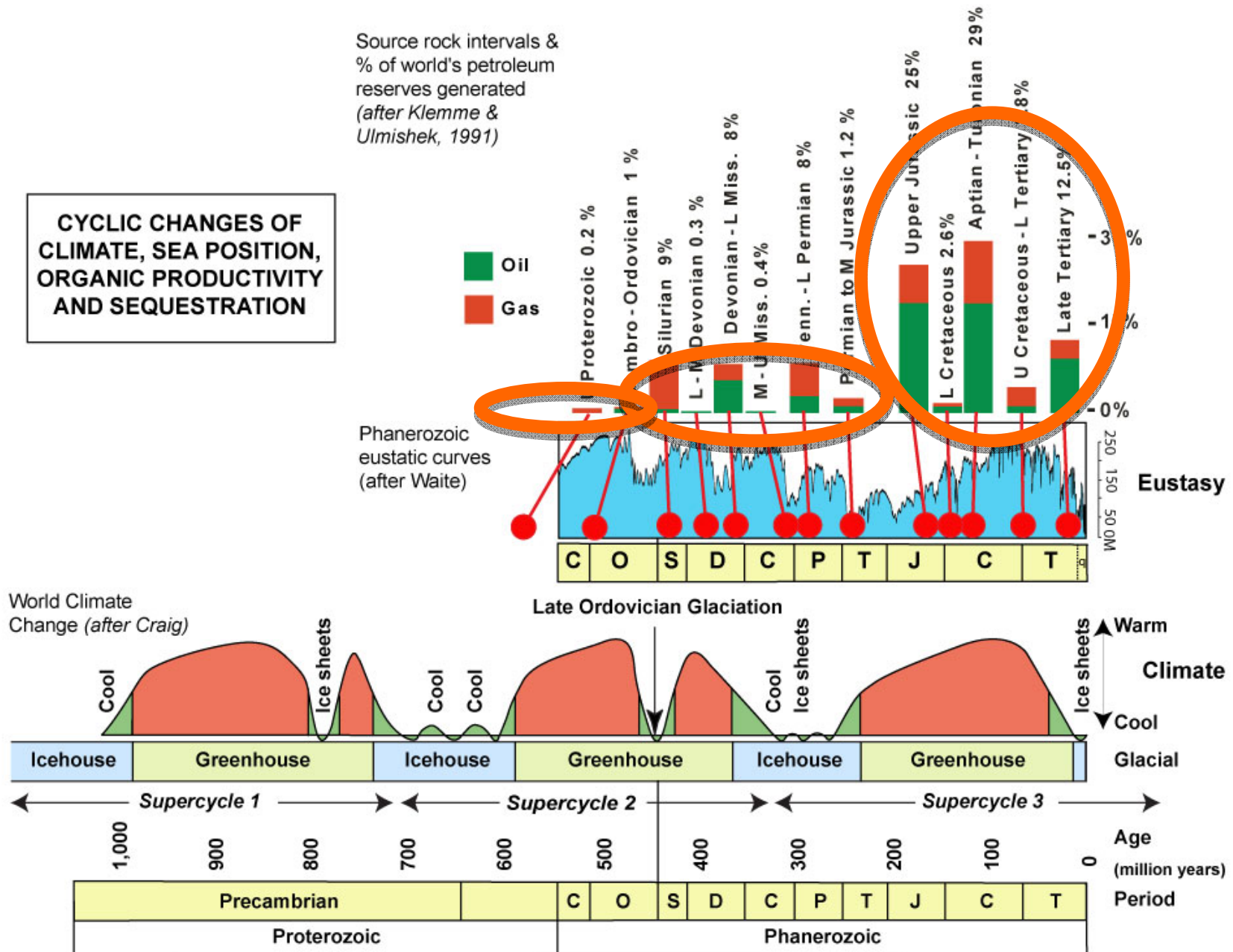
some shadow from adjacent continents

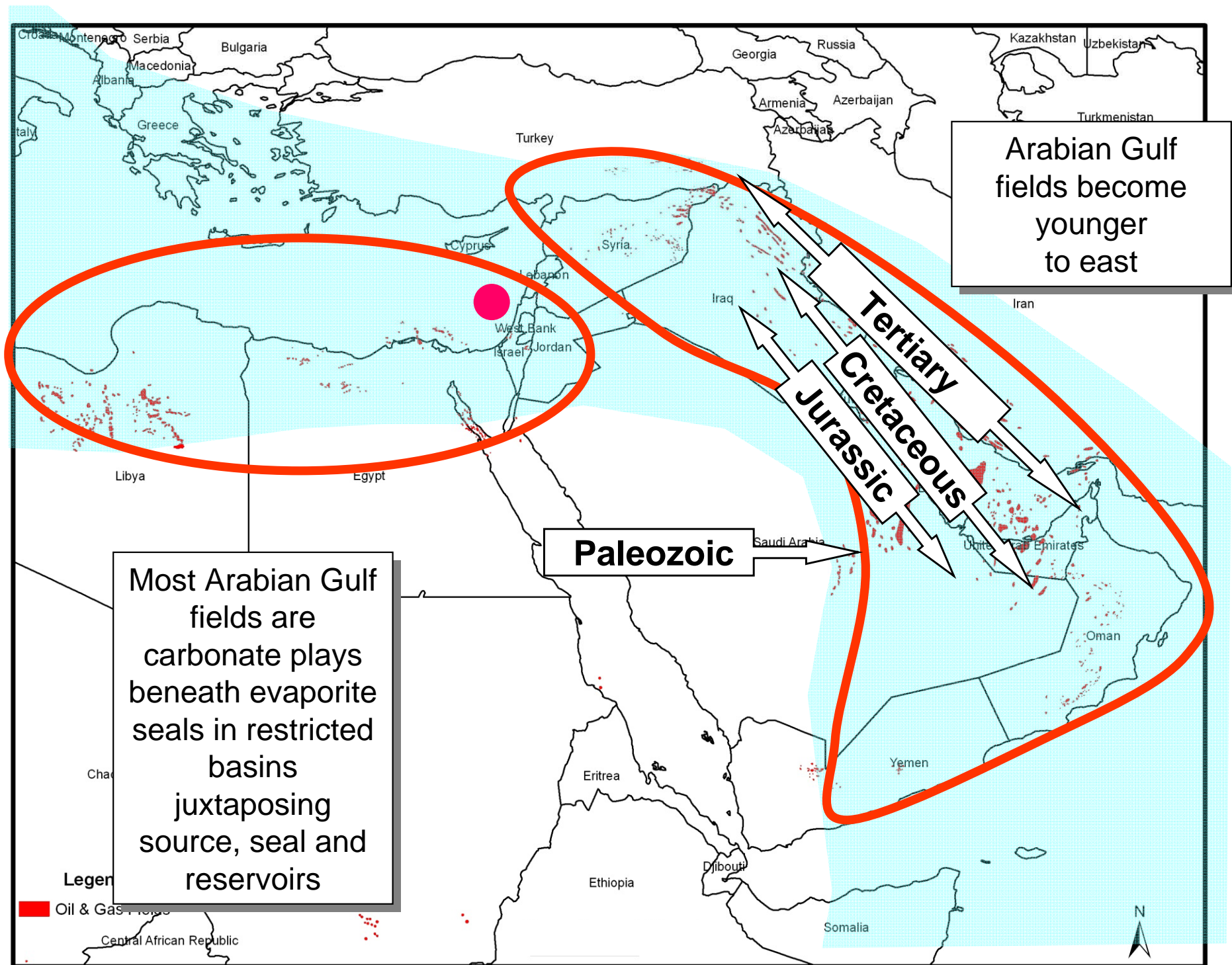
After Peter Skelton

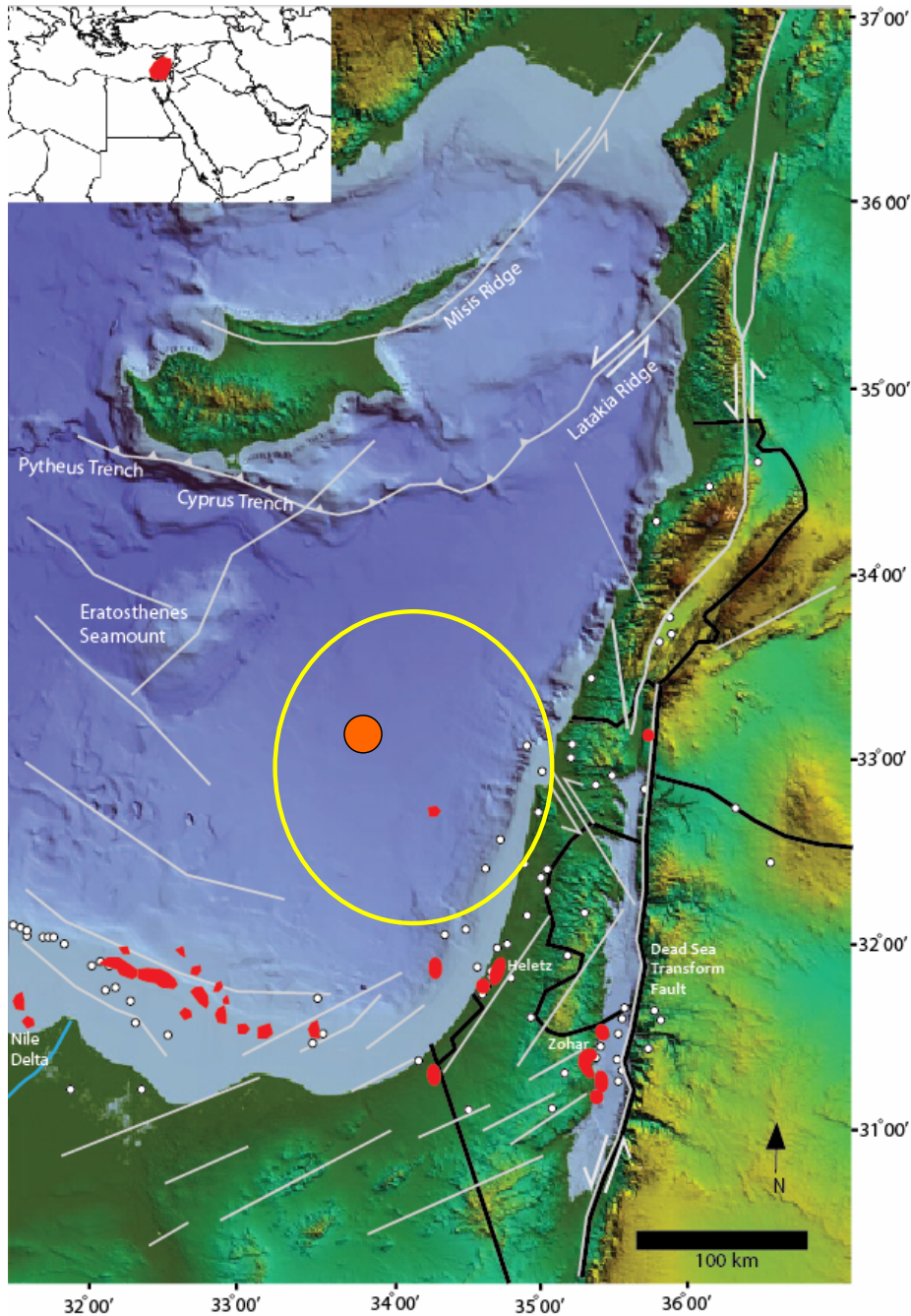
Conclusions

- Hydrocarbons trapped in fields in relatively horizontal Paleozoic, Mesozoic through Cenozoic sediments of Tethys southern margin
- These fields can be analyzed and characterized in terms of Wilsonian cycles of plate drift that control:
 - Low frequency Tectonic movement
 - 2nd and 3rd order eustatic changes
 - Sediment supply and organic matter sequestration
- Analysis of South Tethys margin suggests similar hydrocarbon plays with great potential are abundant

Climate, Eustasy, & Source Rock Potential







- Previous discoveries in Levantine Basin - zero
- Undiscovered reserves – recent & exciting discovery in lower Miocene subsalt at Tamar of 5 tcfs gas in the Levantine basin
- Great implications for offshore all of North Africa

Conclusions

- South Tethys margin is the world's premier hydrocarbon producing area, best in the Middle East, good in Africa and promising in the Levant, Syria and Turkey
- Analysis of South Tethys margin suggests hydrocarbon plays have great potential and are abundant and similar to current fields