Phosphogenesis in epicontinental and marginal sedimentary basins: problems with using the modern as an analog for the ancient rock record

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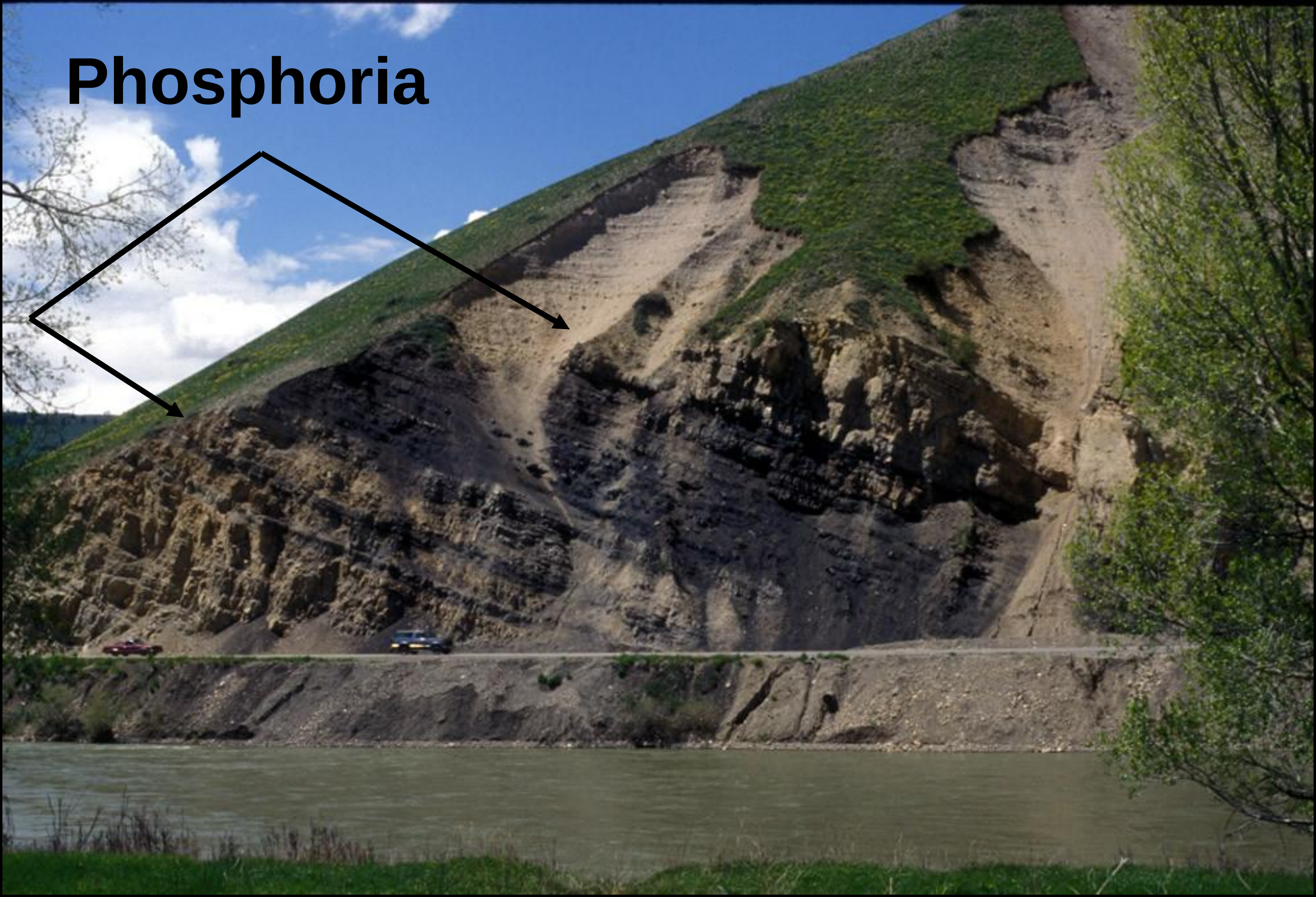
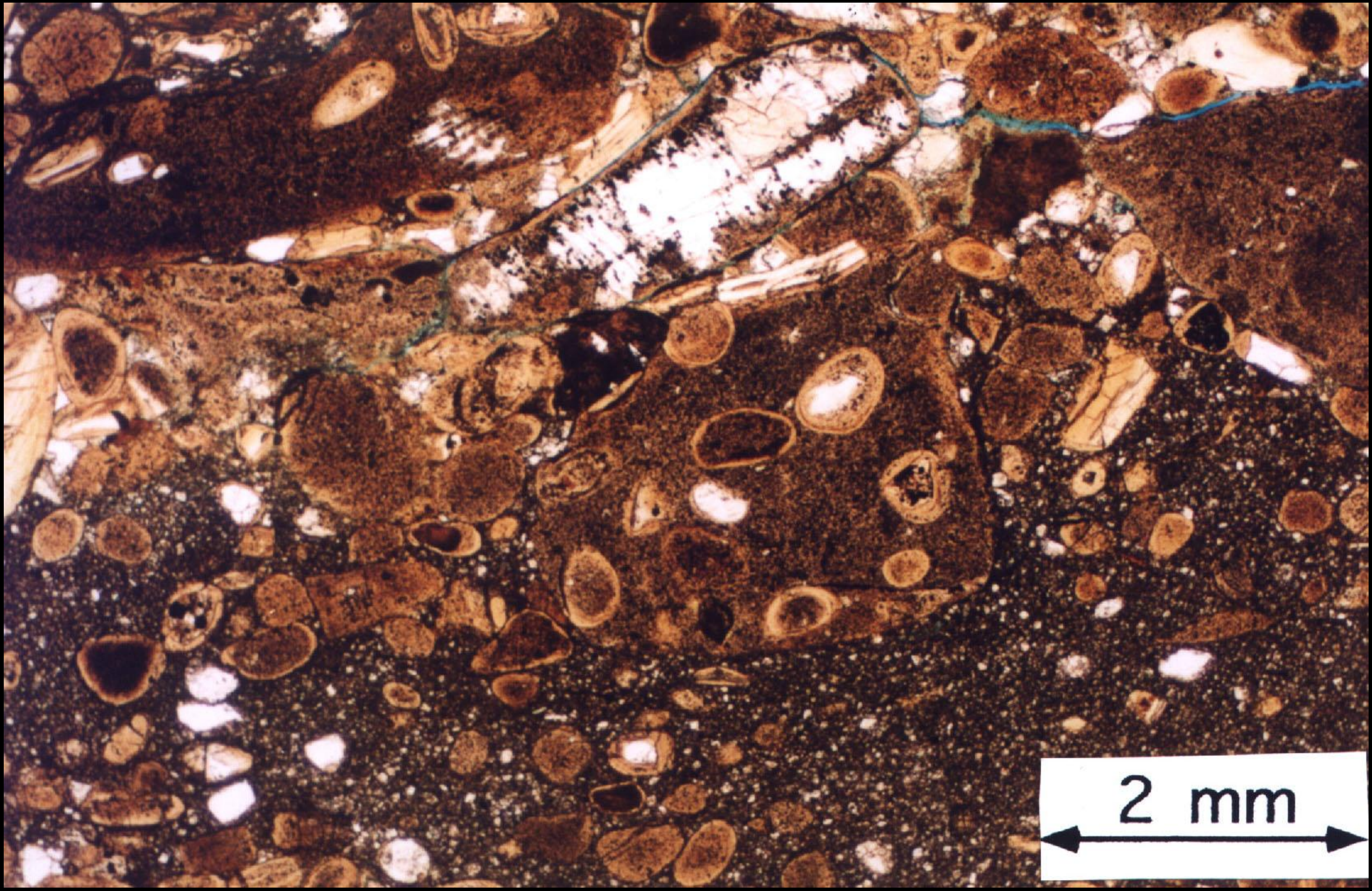
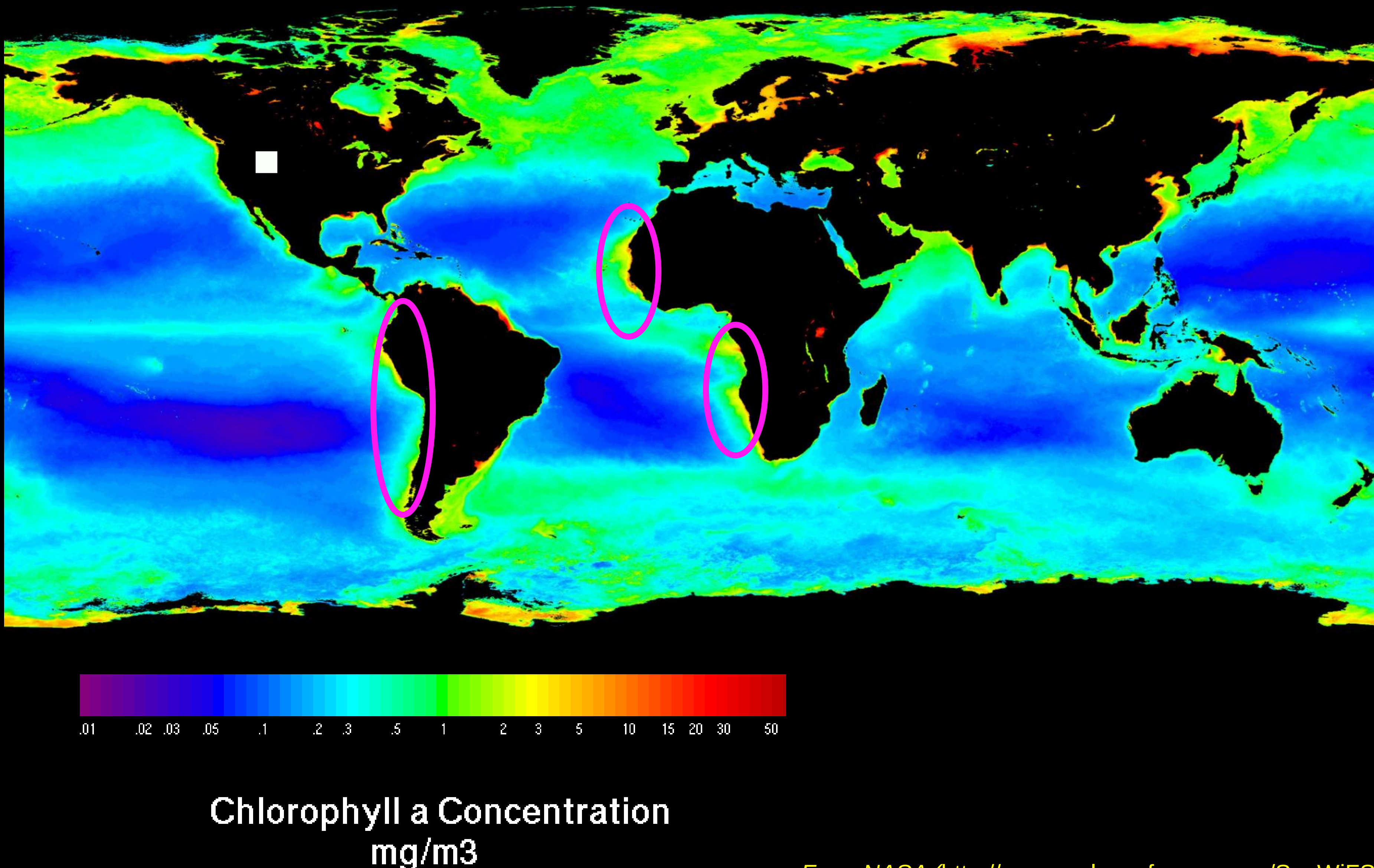

Phosphoria

Phosphorite:

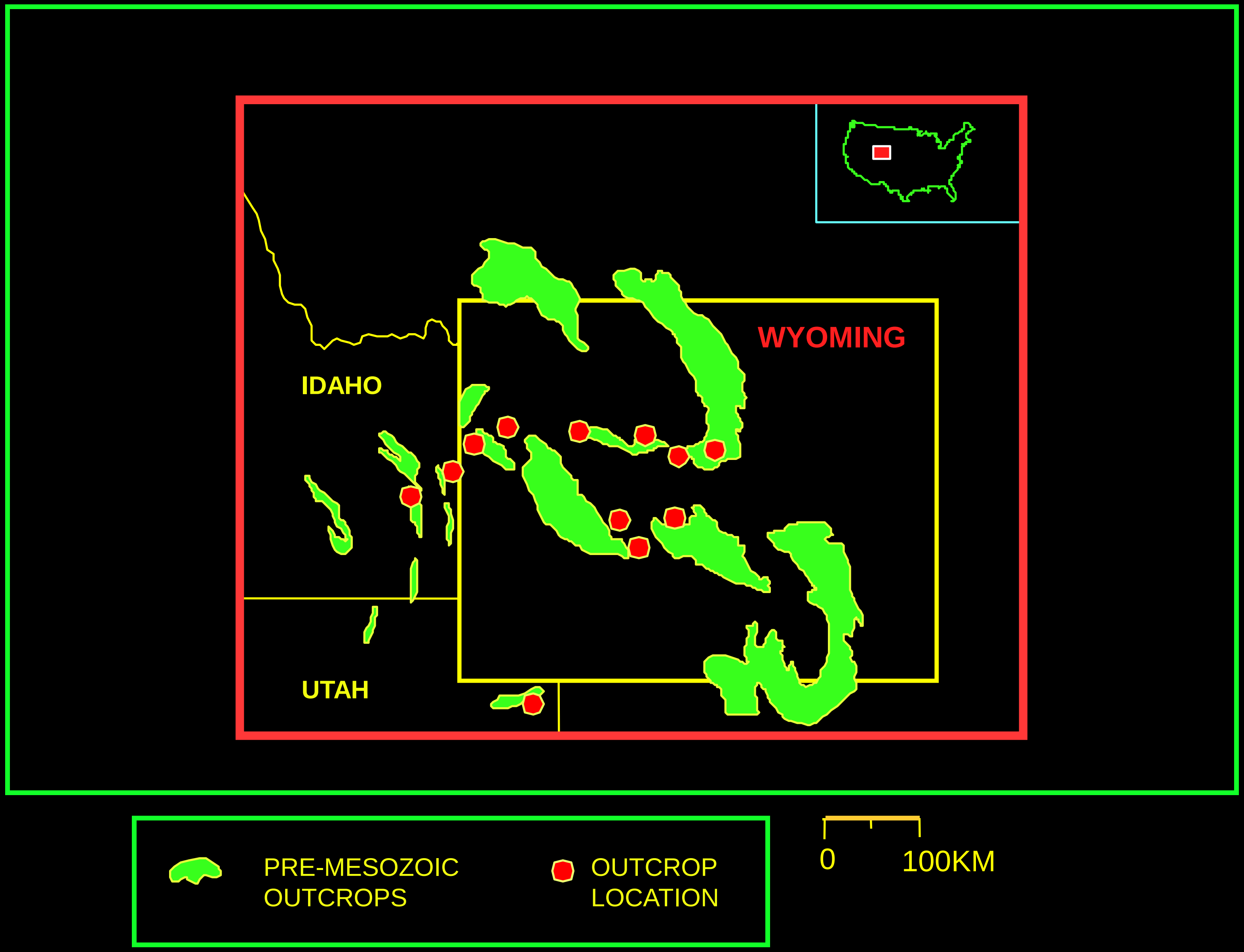
Francolite: $Ca_{10-a-b}Na_aMg_b(PO_4)6\text{-}x(CO_3)_{x-y-z}(CO_3,F)_y(SO_4)_zF_2$



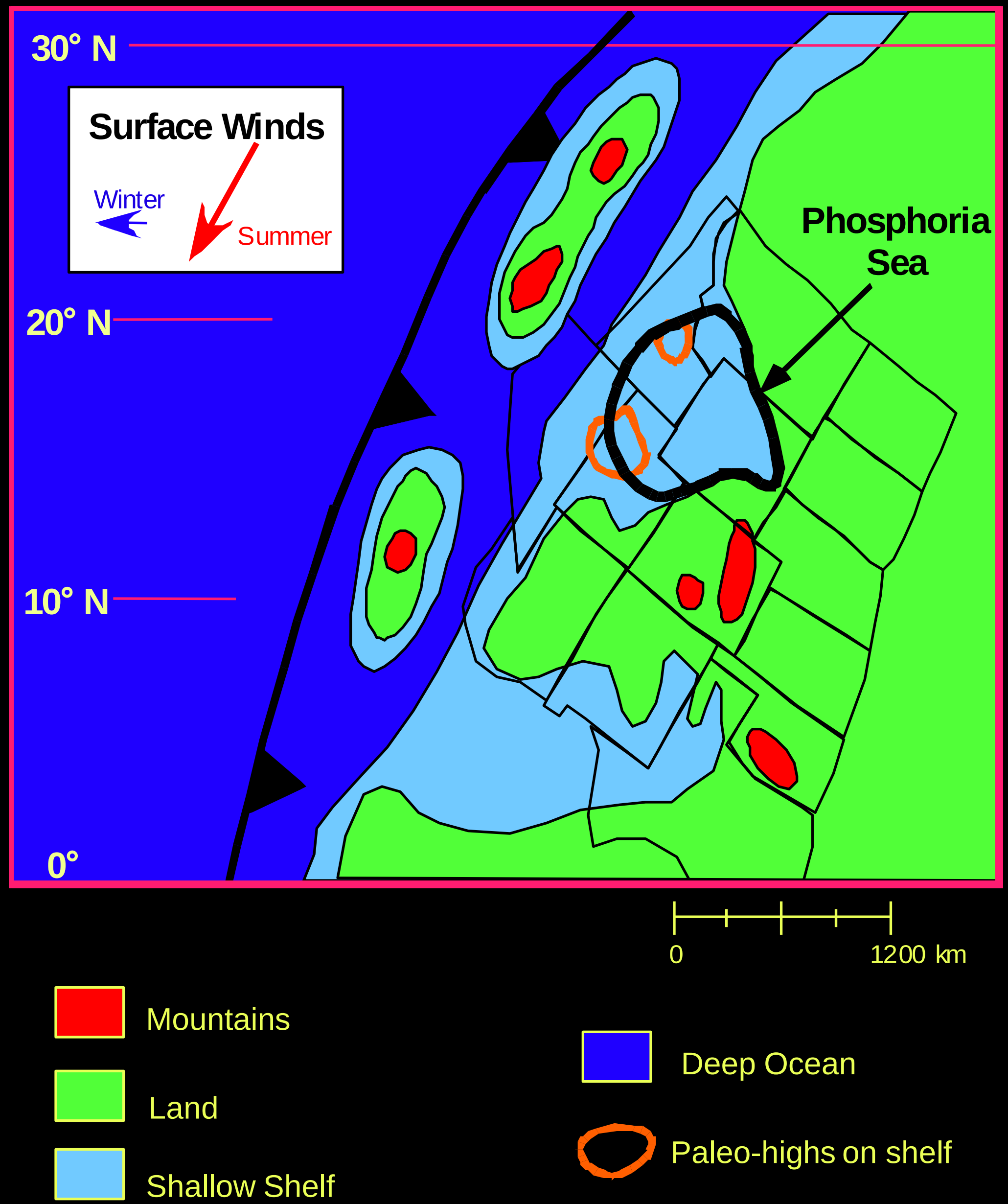
Modern Phosphogenic Environments:



*From NASA (*http://oceancolor.gsfc.nasa.gov/SeaWiFS/)

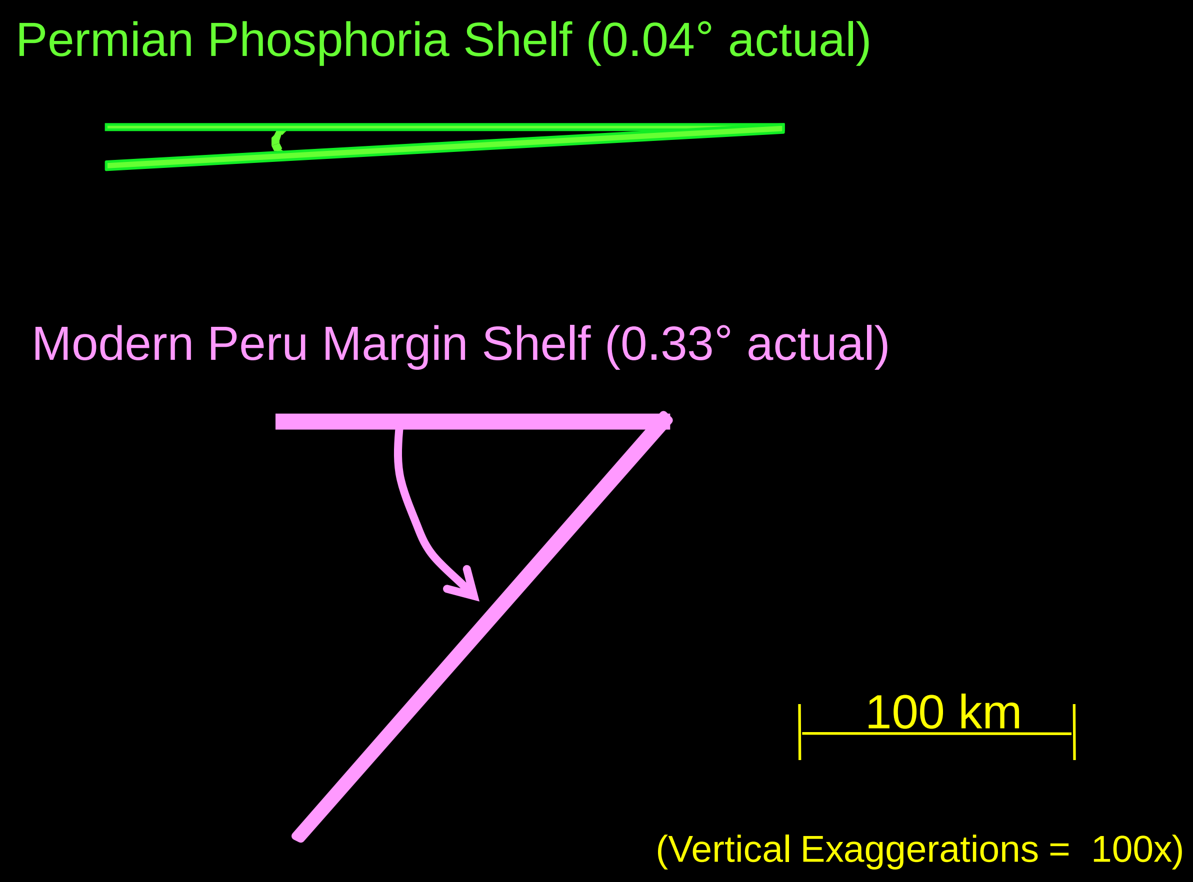


WYOMING
IDAHO
UTAH
PRE-MESOZOIC
OUTCROPS
OUTCROP
LOCATION
0
100KM

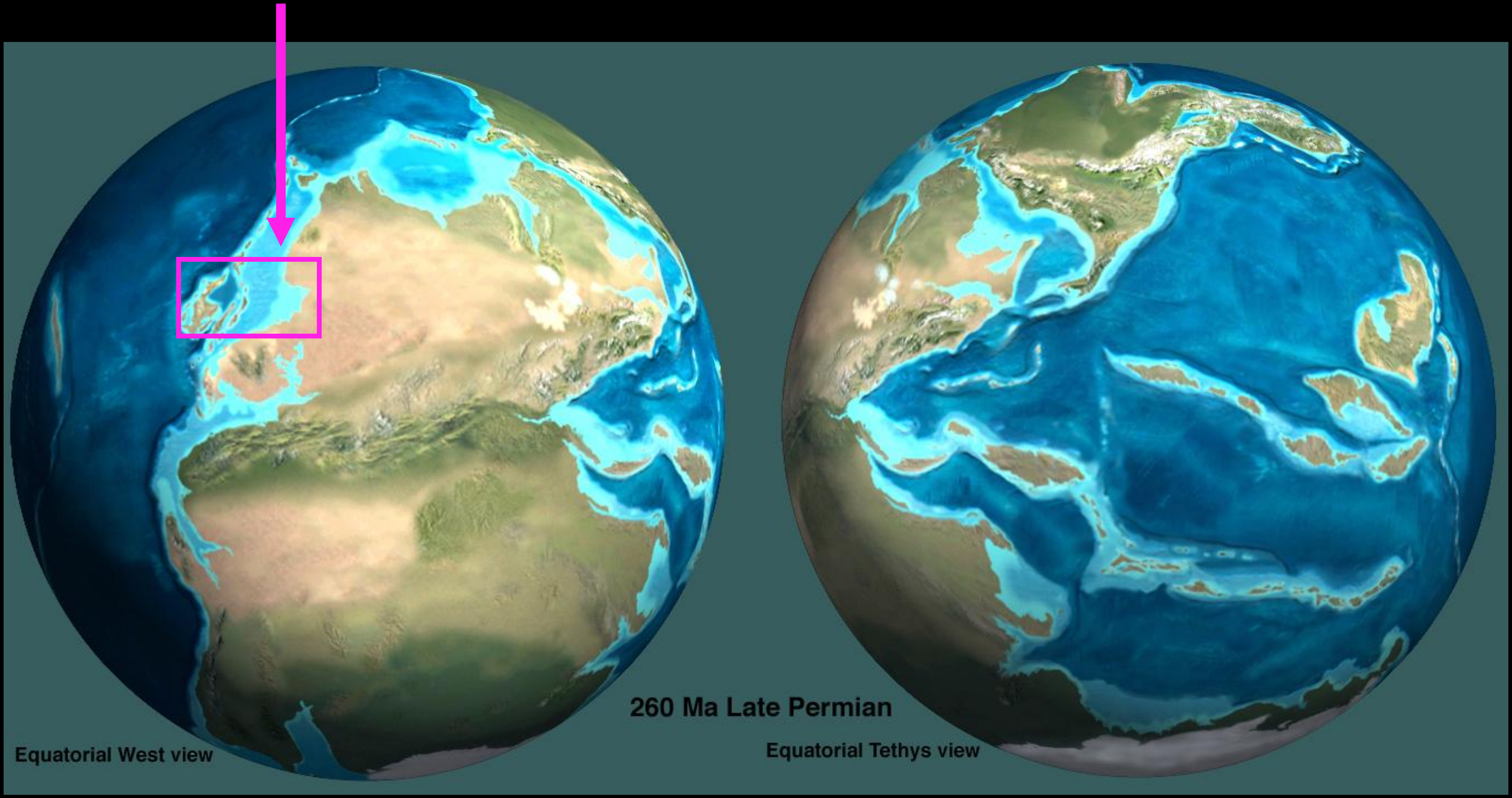


(Modified from Scotese and Langford (1995); paleowind vectors are based on Kutzbach and Ziegler (1994); Summer: 5.0 m/s and Winter: 1.8 m/s)

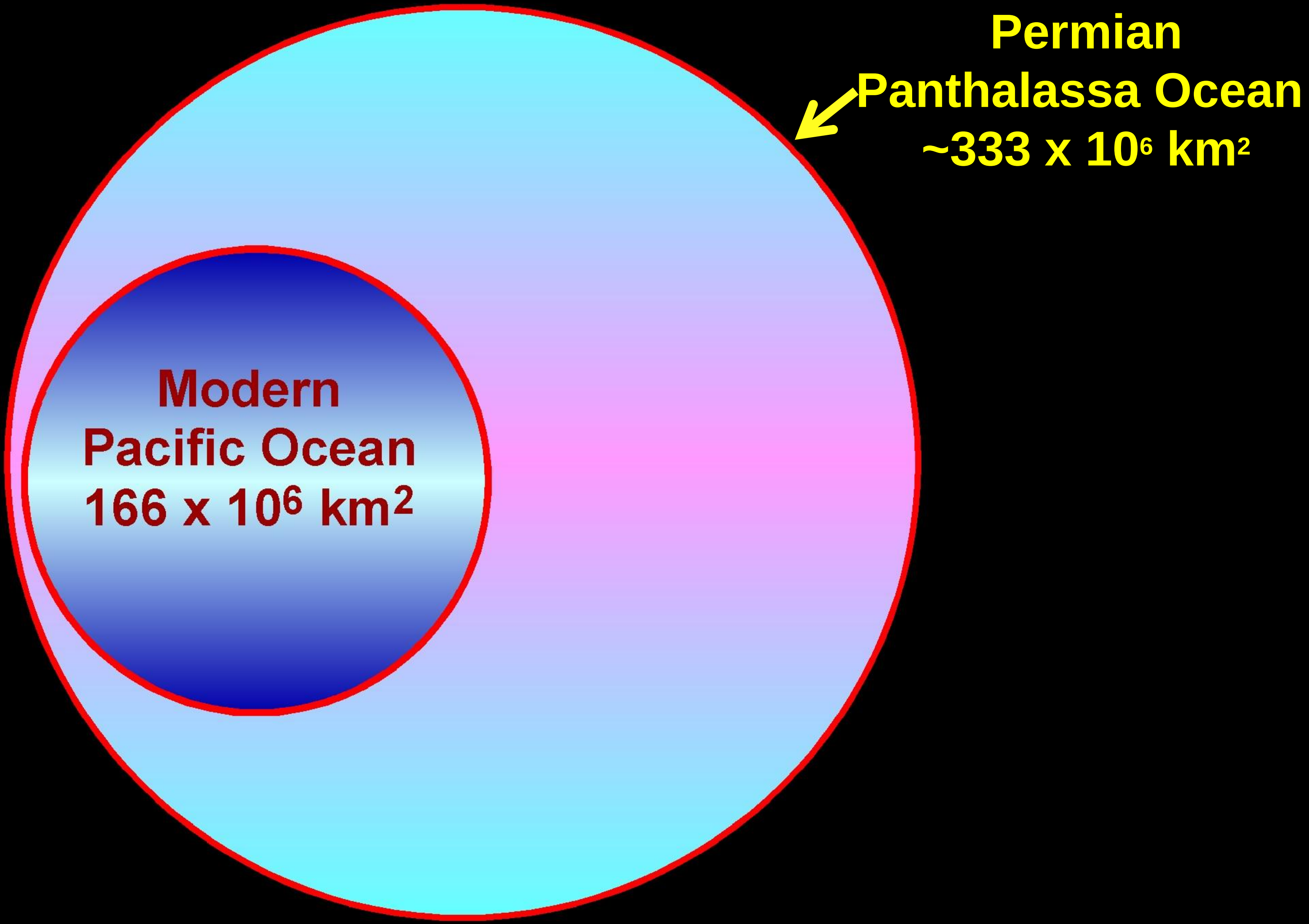
Eperic Sea Setting vs. Modern:



Phosphoria Sea



Modified from Blakey, 2006



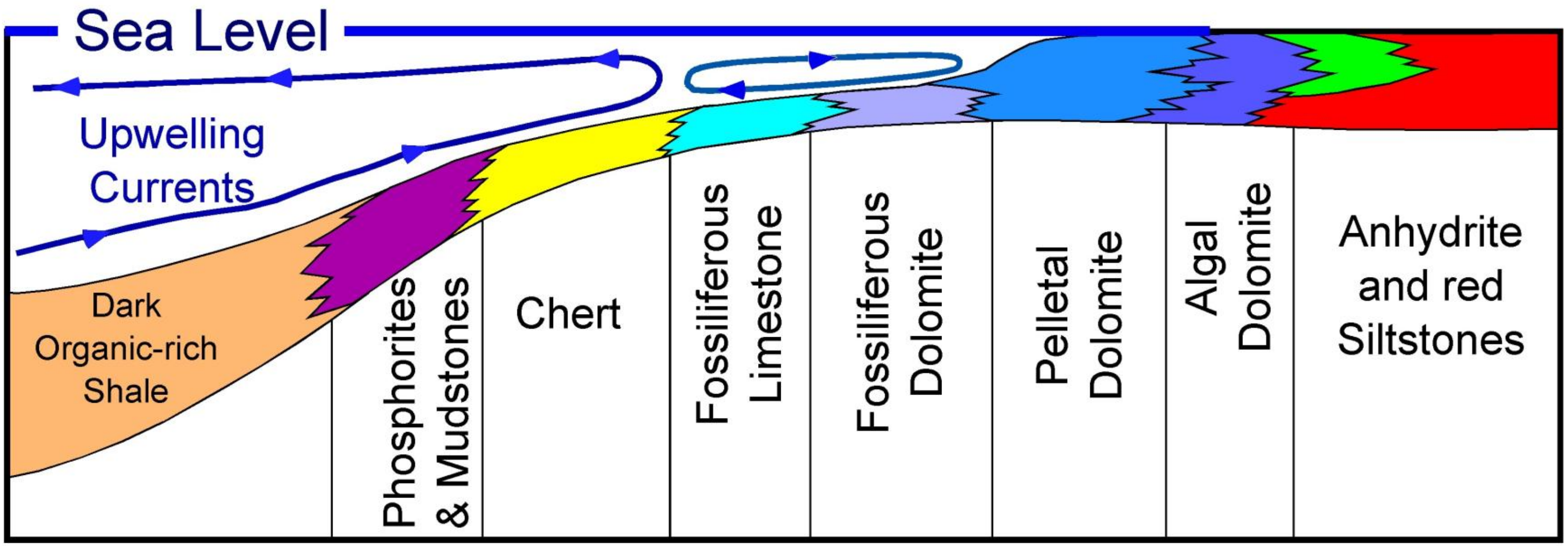
Permian
Panthalassa Ocean
~333 x 10^6 km^2
Modern
Pacific Ocean
166 x 10^6 km^2

1. Lithostratigraphy:

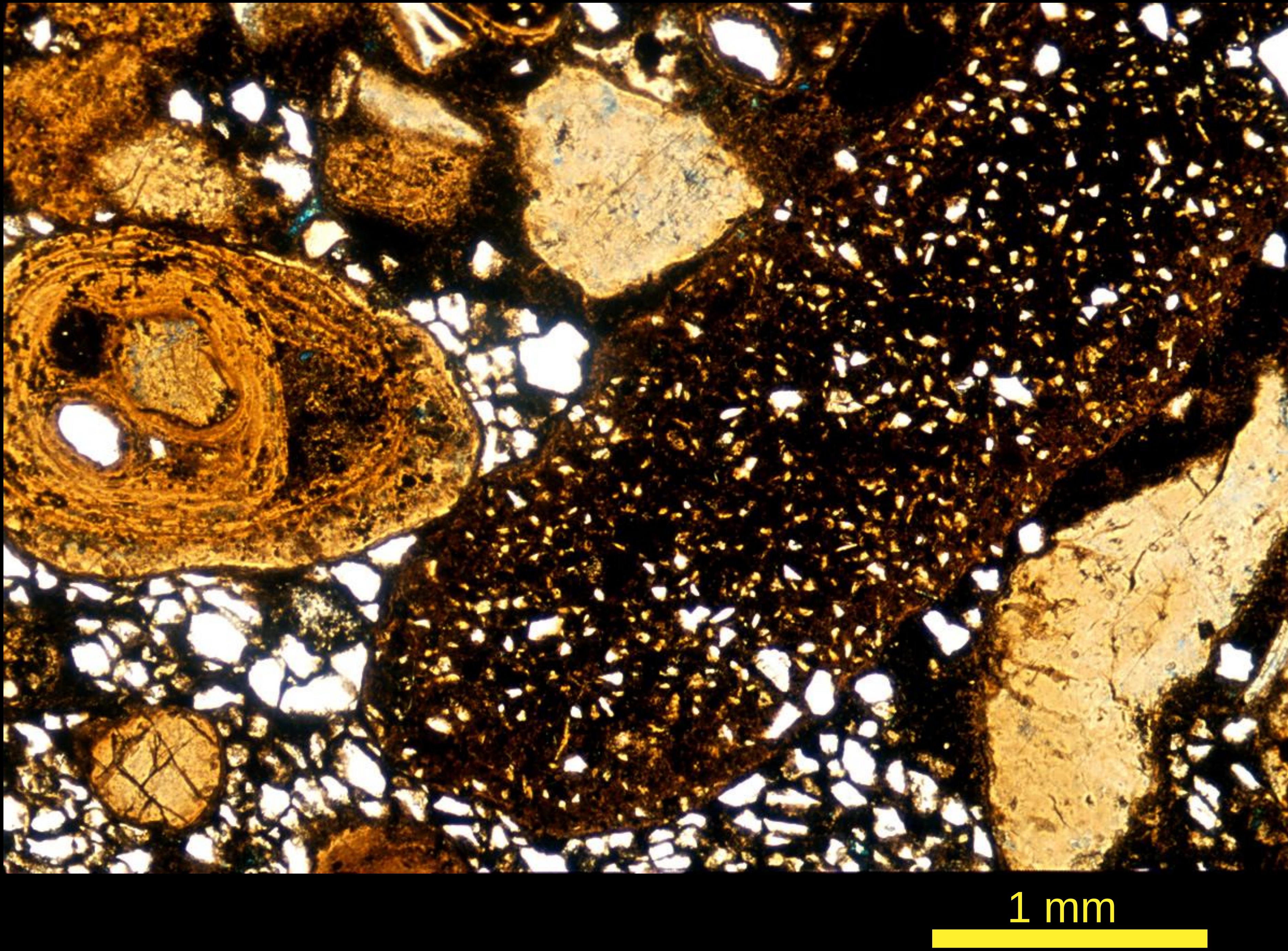
Historic Lithostratigraphic Model:

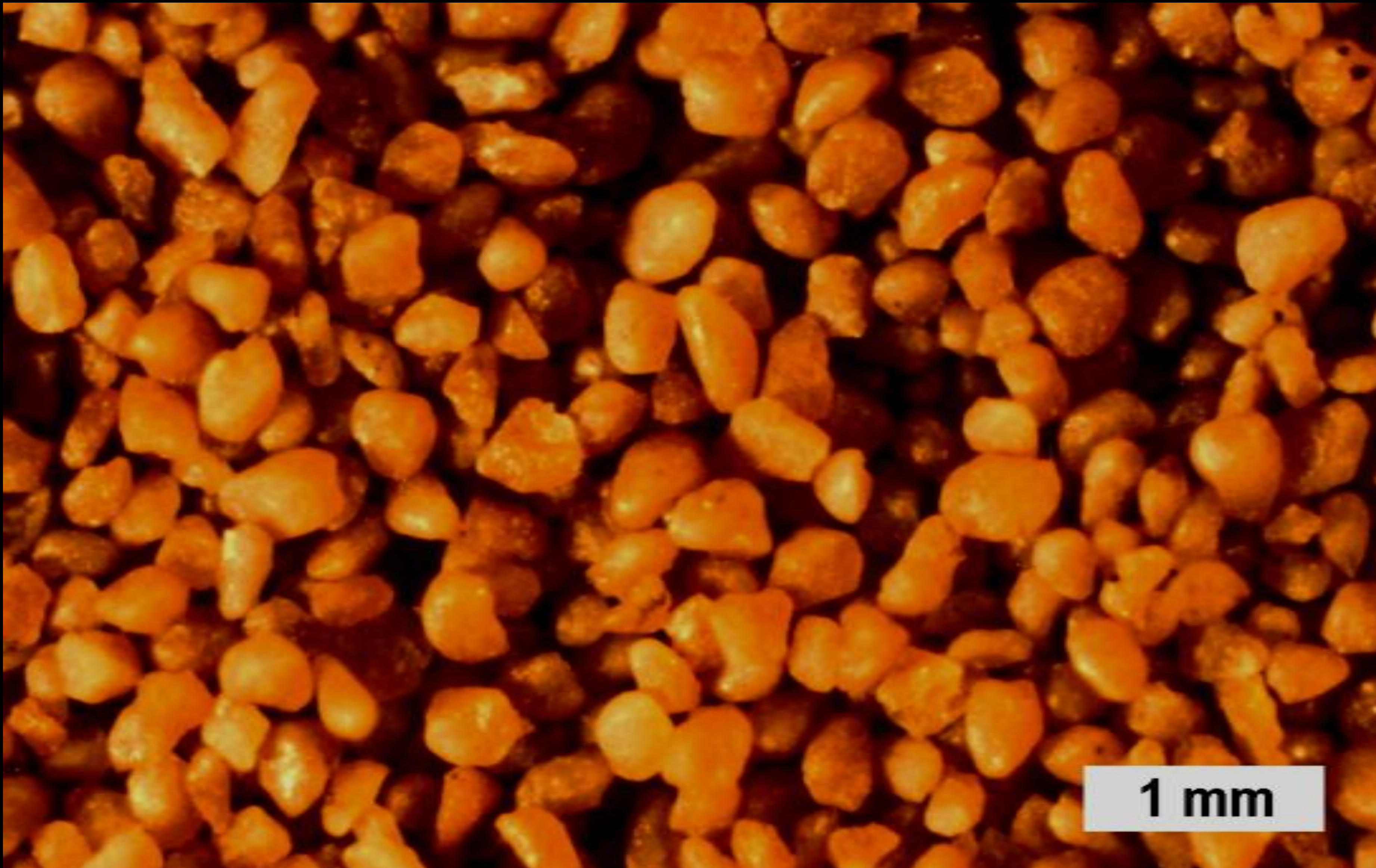
Southeast Idaho

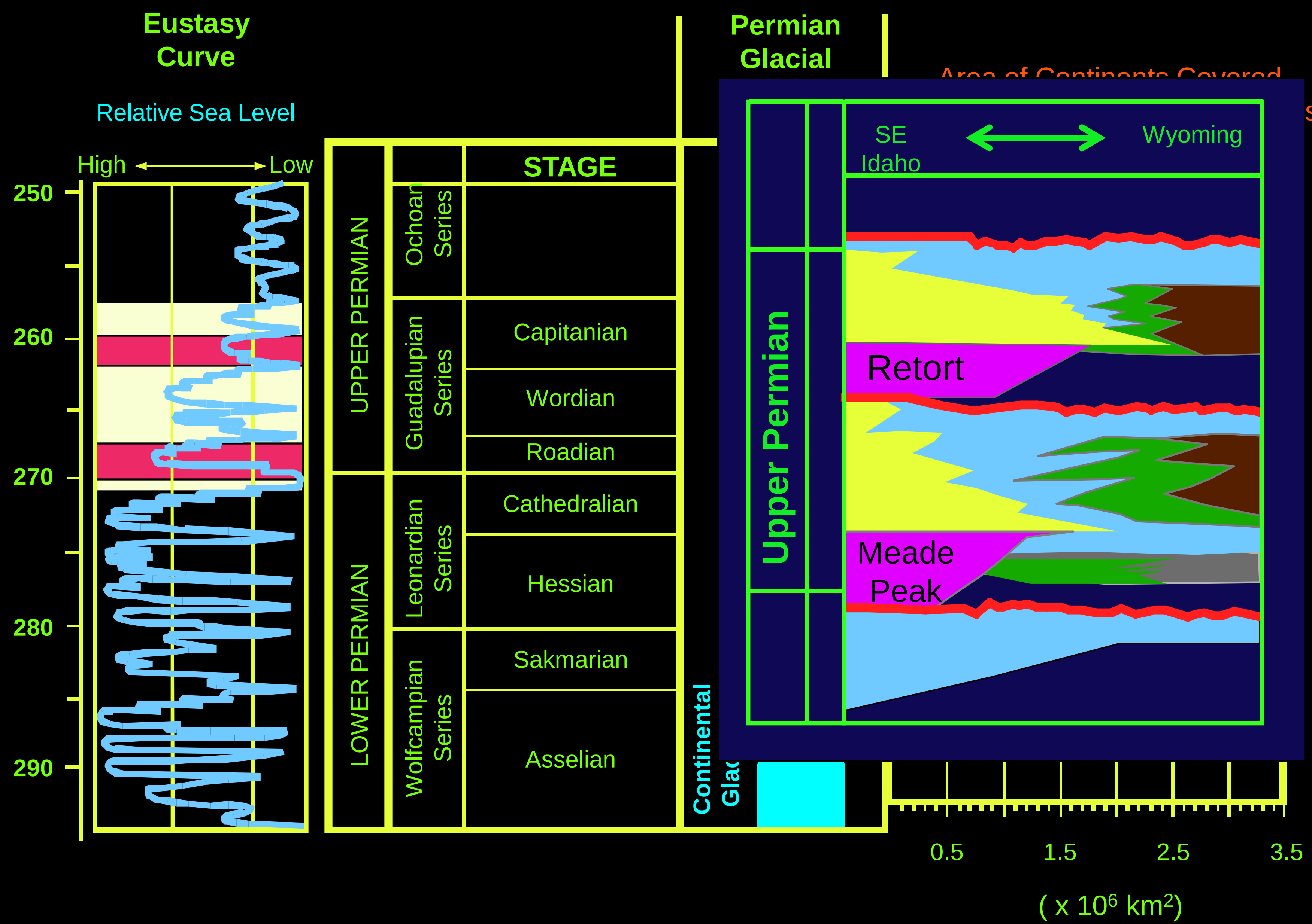
Central Wyoming



Modified from Sheldon (1963)



1 mm


1 mm

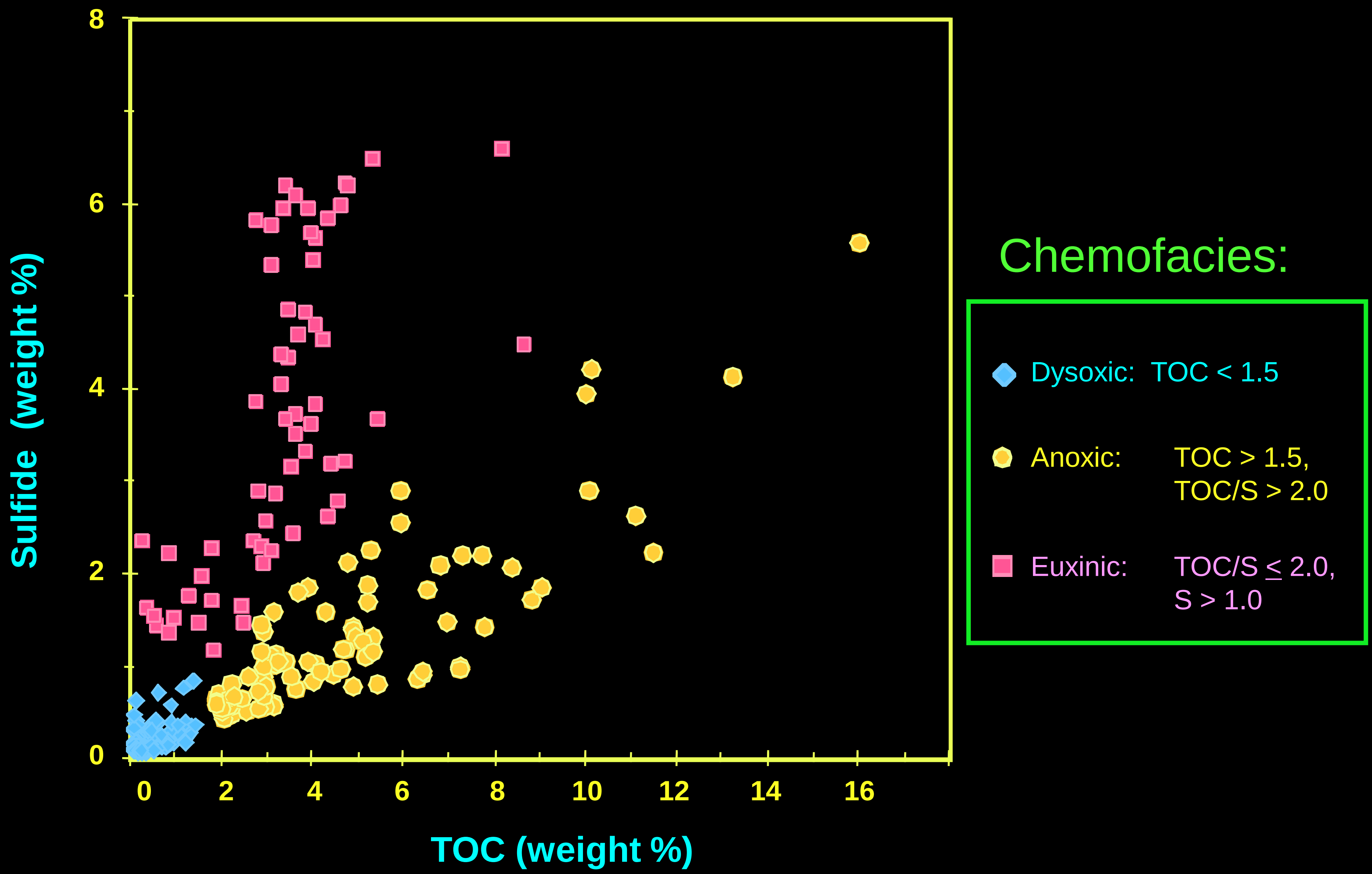


(SL and age relationships from Ross et al., 1994; sulfate data from Zarkov, 1984)

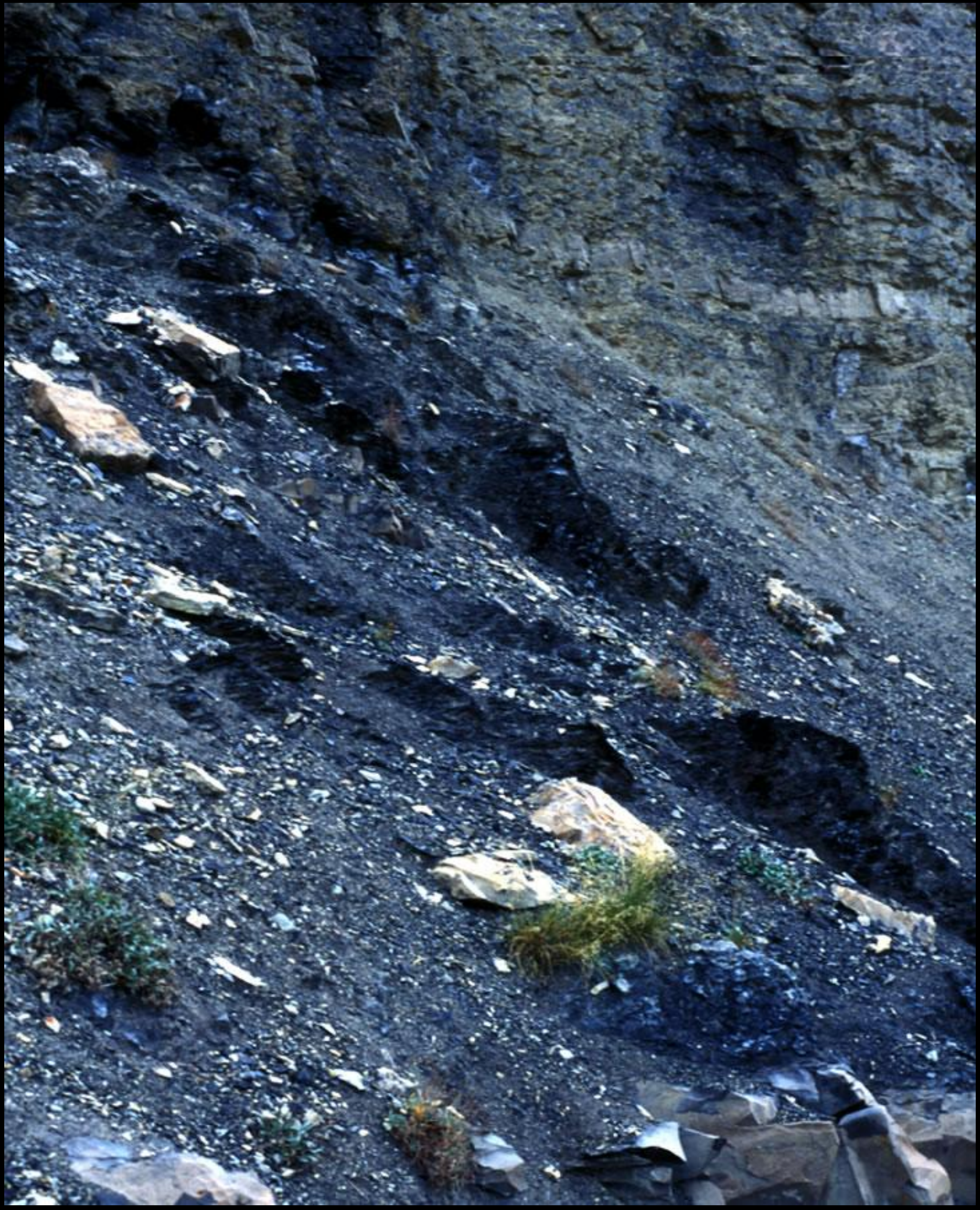
1. Lithostratigraphy:

2. Chemostratigraphy:

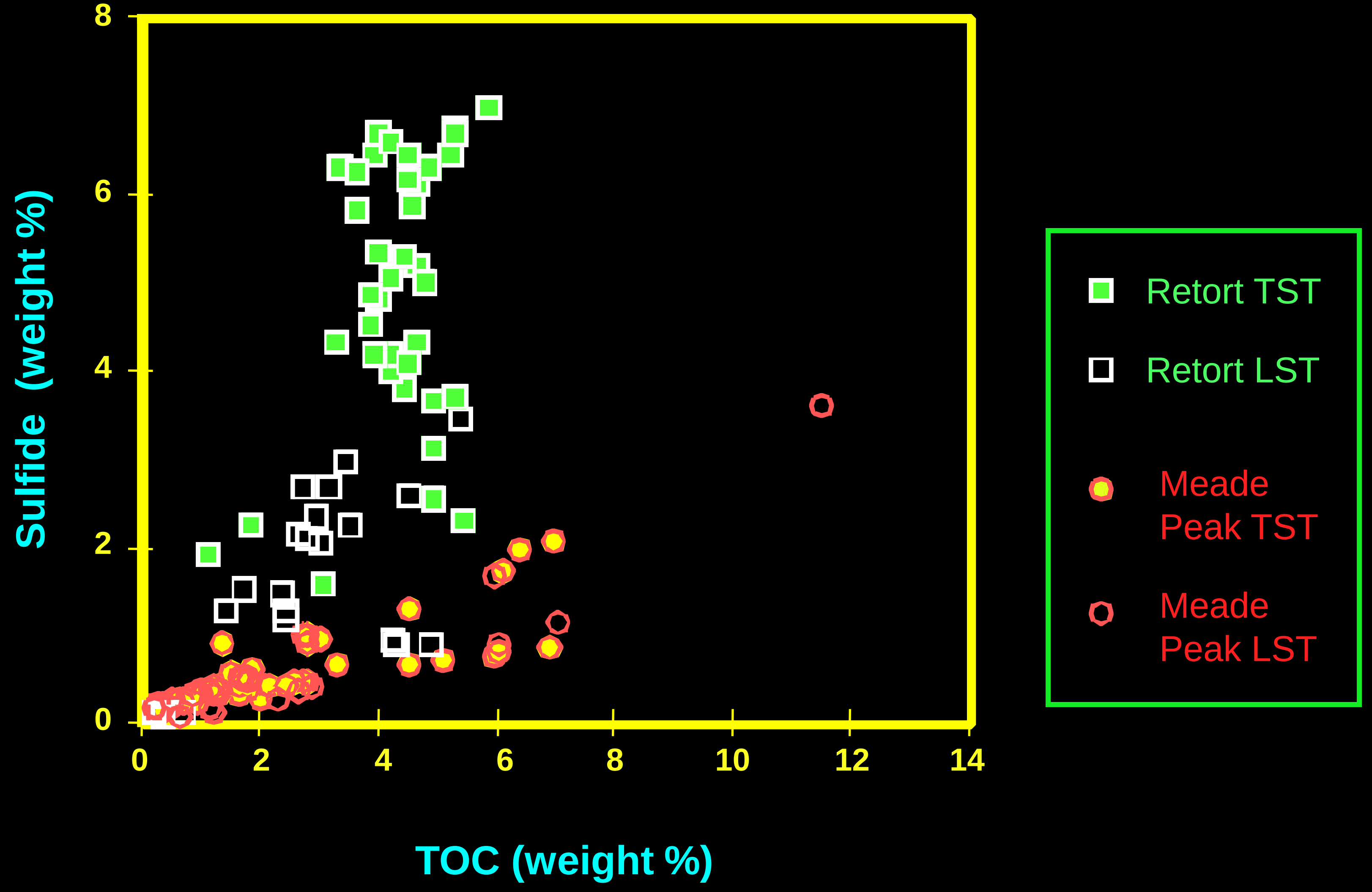
Organic Carbon and Sulfur Data from the Retort and Meade Peak



Retort Member: phosphorites and mudstones

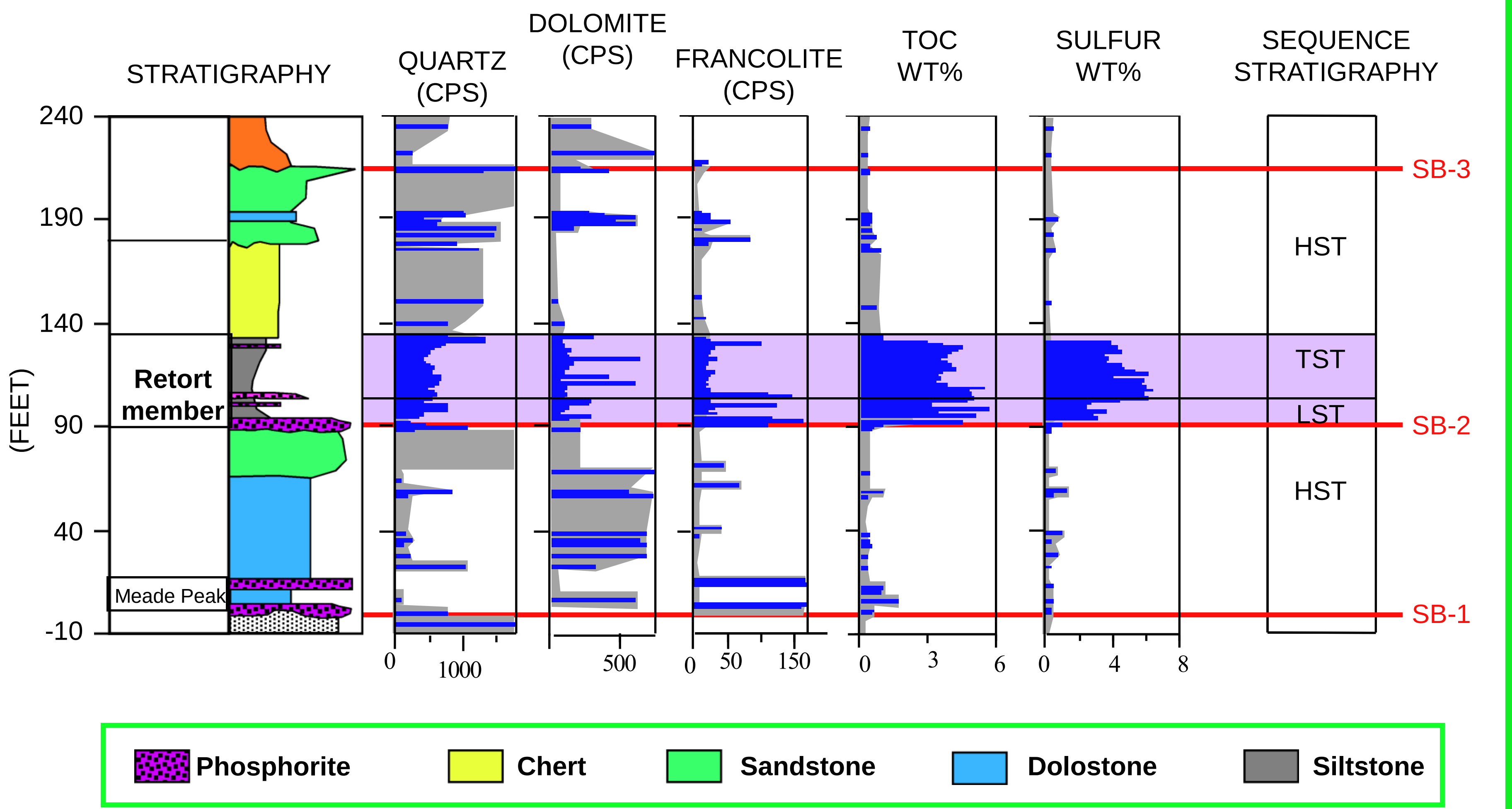


Data from"Basin Facies" of Retort and Meade Peak

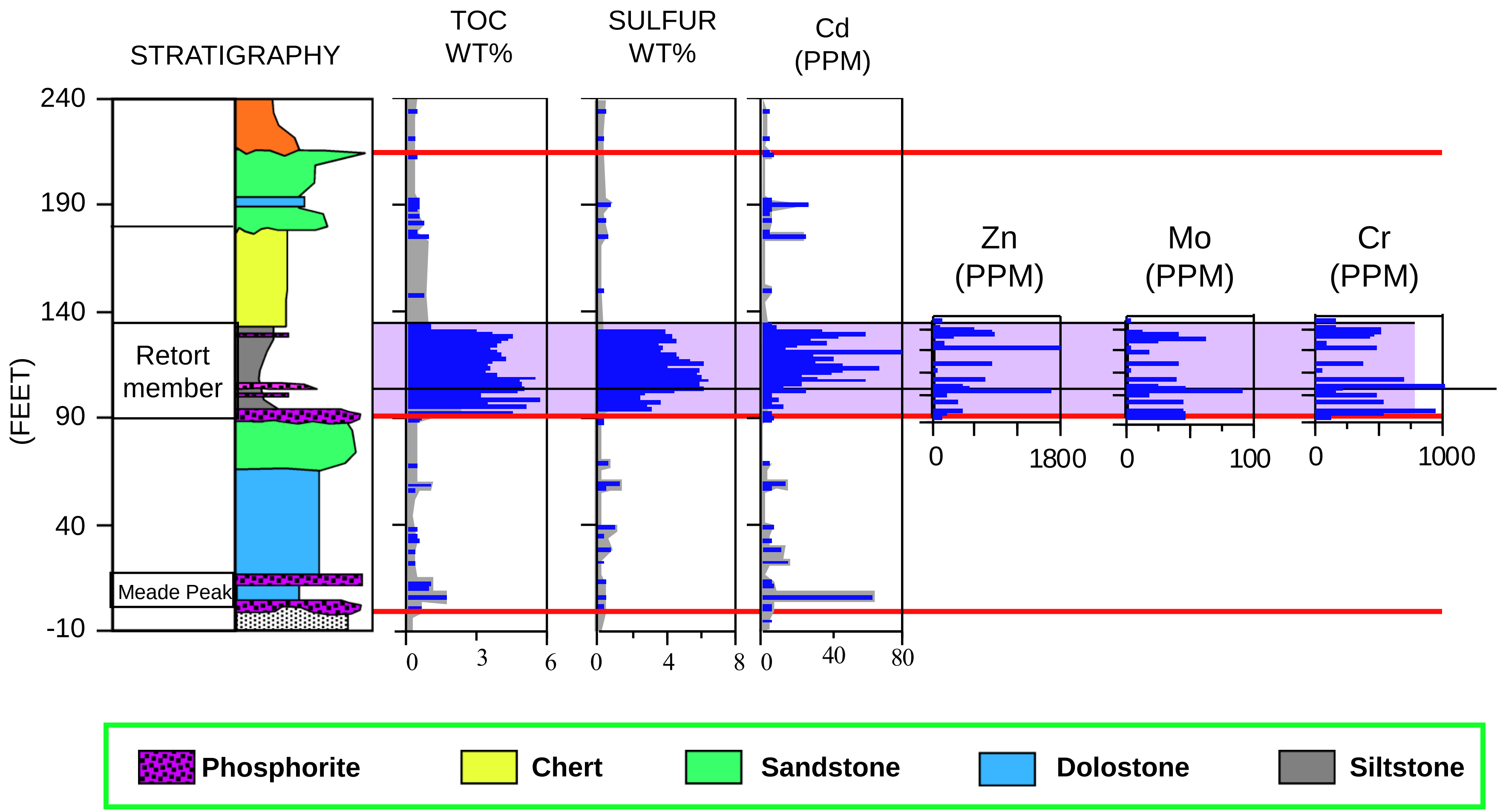


Mid-ramp during Retort deposition: western Wyoming

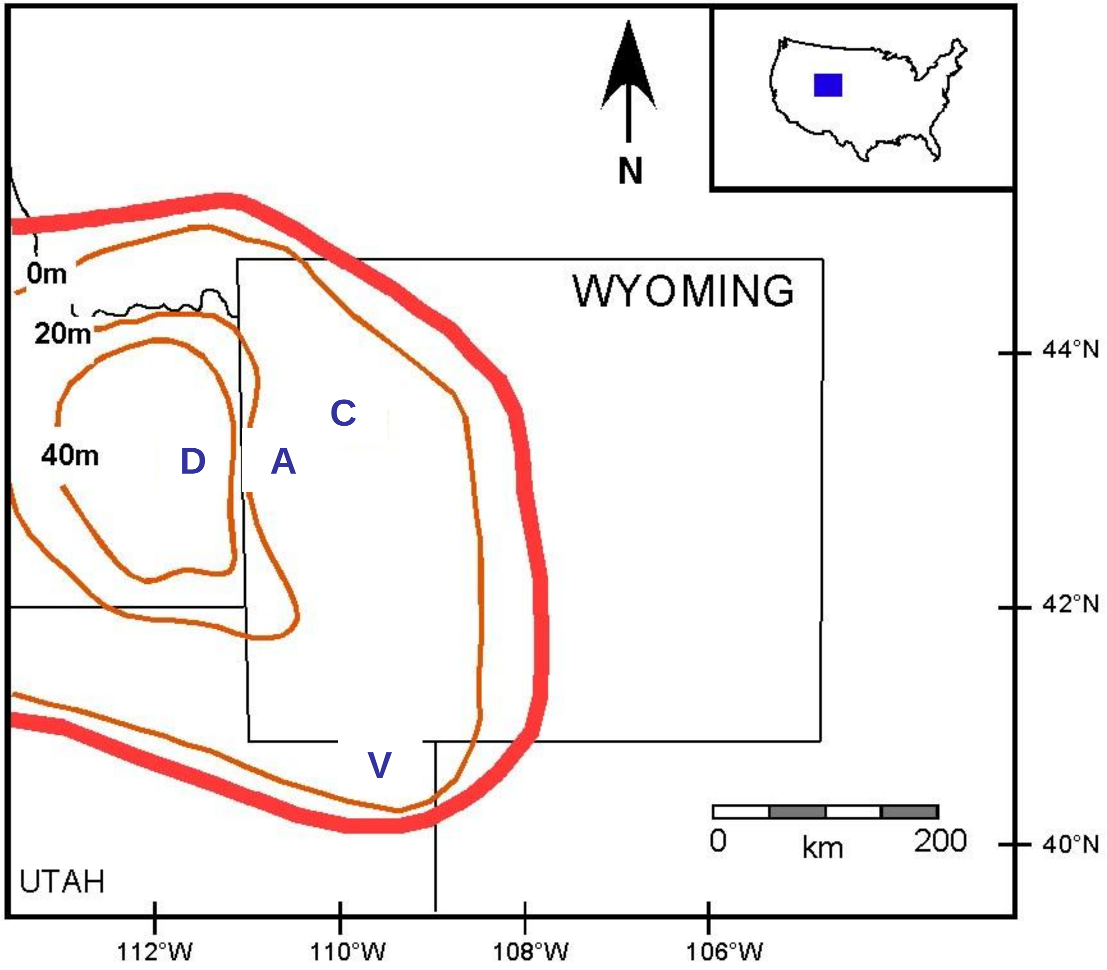
Phosphoria Lithostratigraphy and Chemostratigraphy

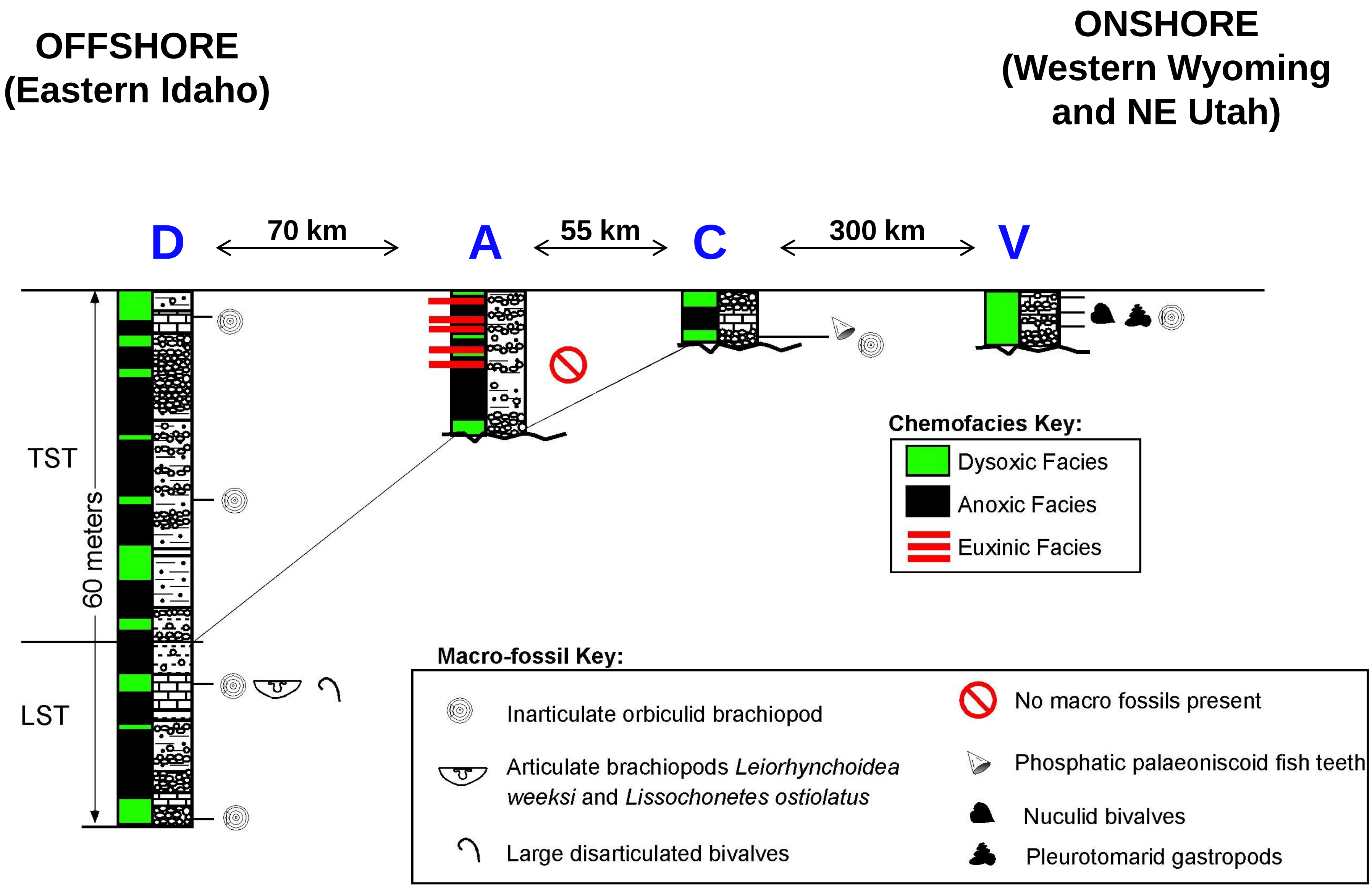


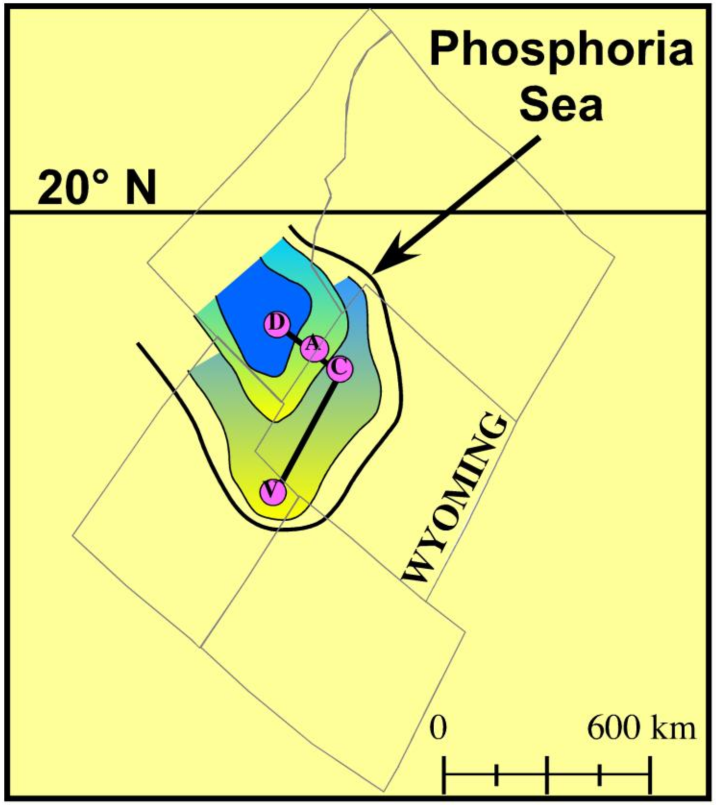
Chemostratigraphy: Redox-Controlled, Bio-essential Trace Elements: Cd, Zn, Mo, & Cr



Lower Phosphorite: Meade Peak member transect

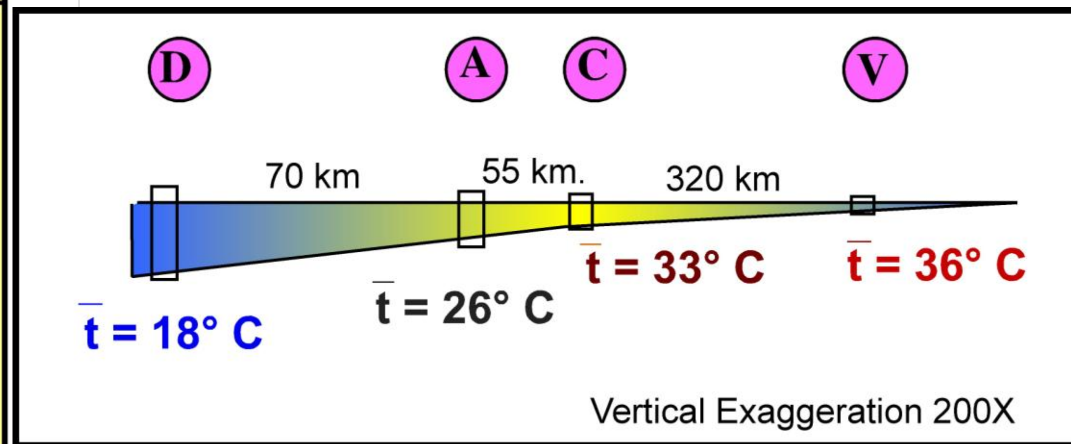



OFFSHORE
(Eastern Idaho)
ONSHORE
(Western Wyoming
and NE Utah)
D
70 km
A
55 km
C
300 km
V
TST
LST
60 meters
Chemofacies Key:
Dysoxic Facies
Anoxic Facies
Euxinic Facies
Macro-fossil Key:
Inarticulate orbiculid brachiopod
Articulate brachiopods *Leiorhynchoidea weeksi* and *Lissochonetes ostiolatus*
Large disarticulated bivalves
No macro fossils present
Phosphatic palaeoniscoid fish teeth
Nuculid bivalves
Pleurotomarid gastropods

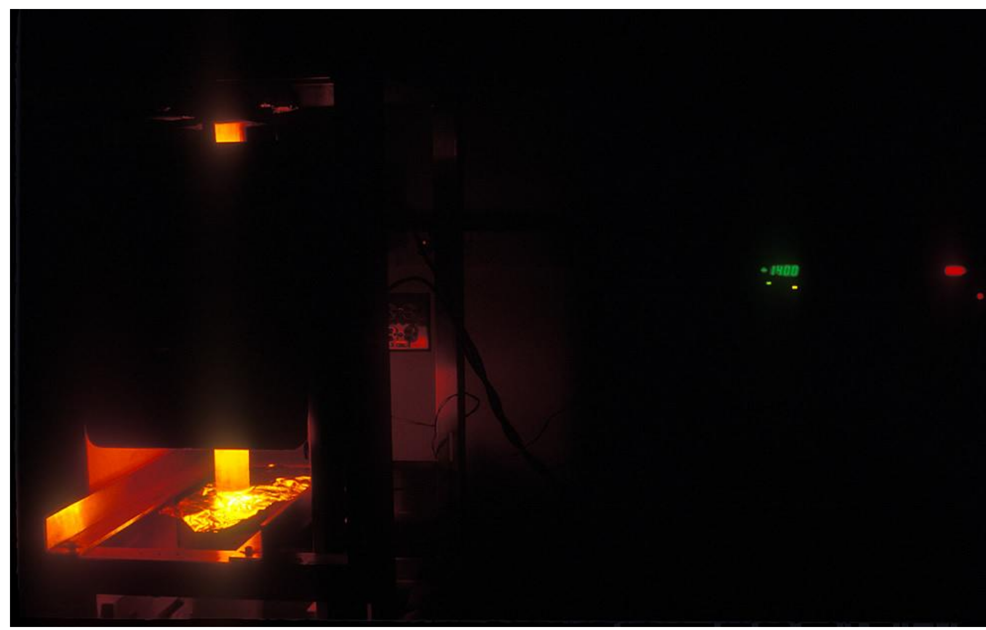


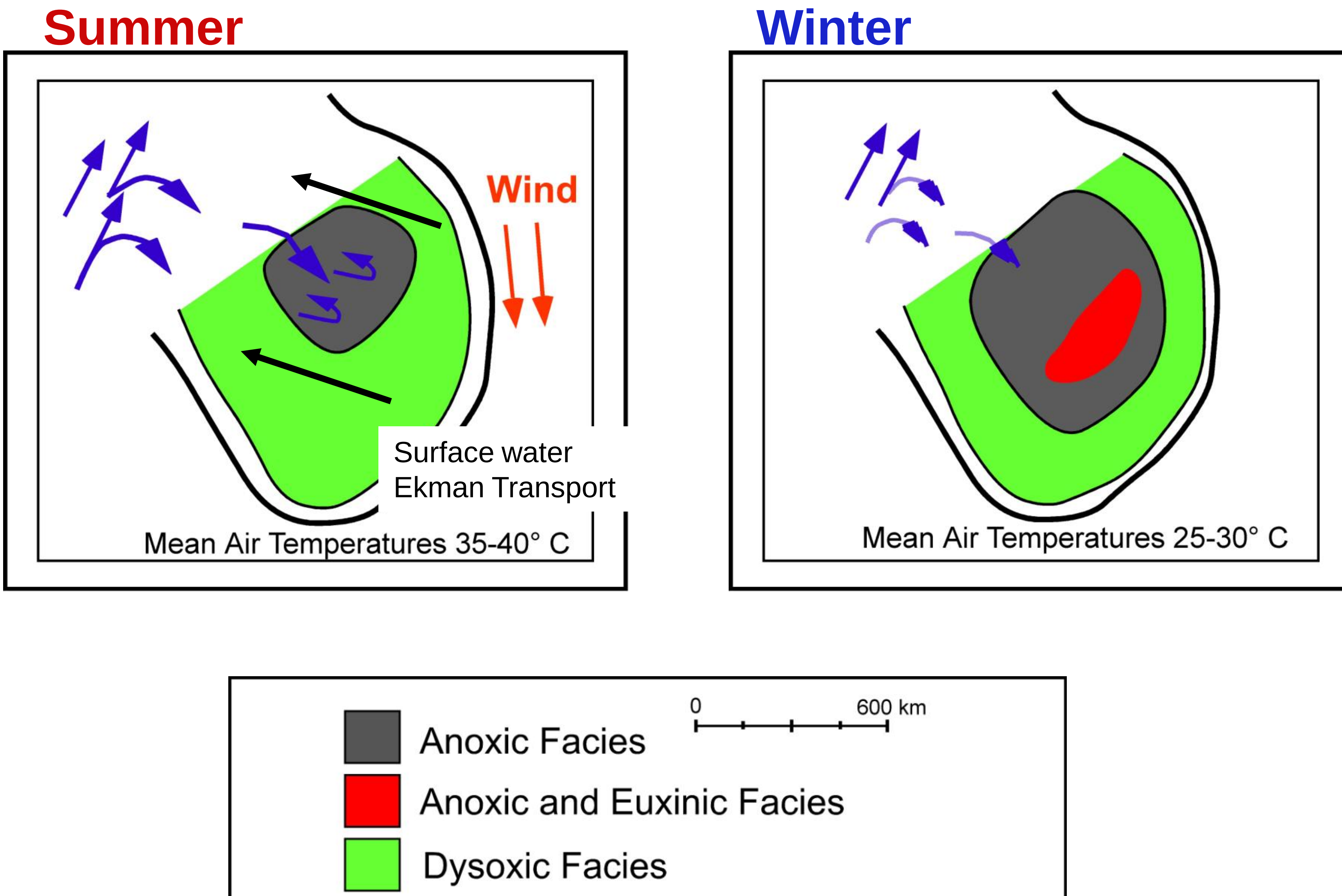
(Base map modified from Scotese and Langford, 1995)

$$Ca_{10-a-b}Na_aMg_b(PO_4)6\text{-}x(CO_3)_{x-y-z}(CO_3,F)_y(SO_4)_zF_2$$

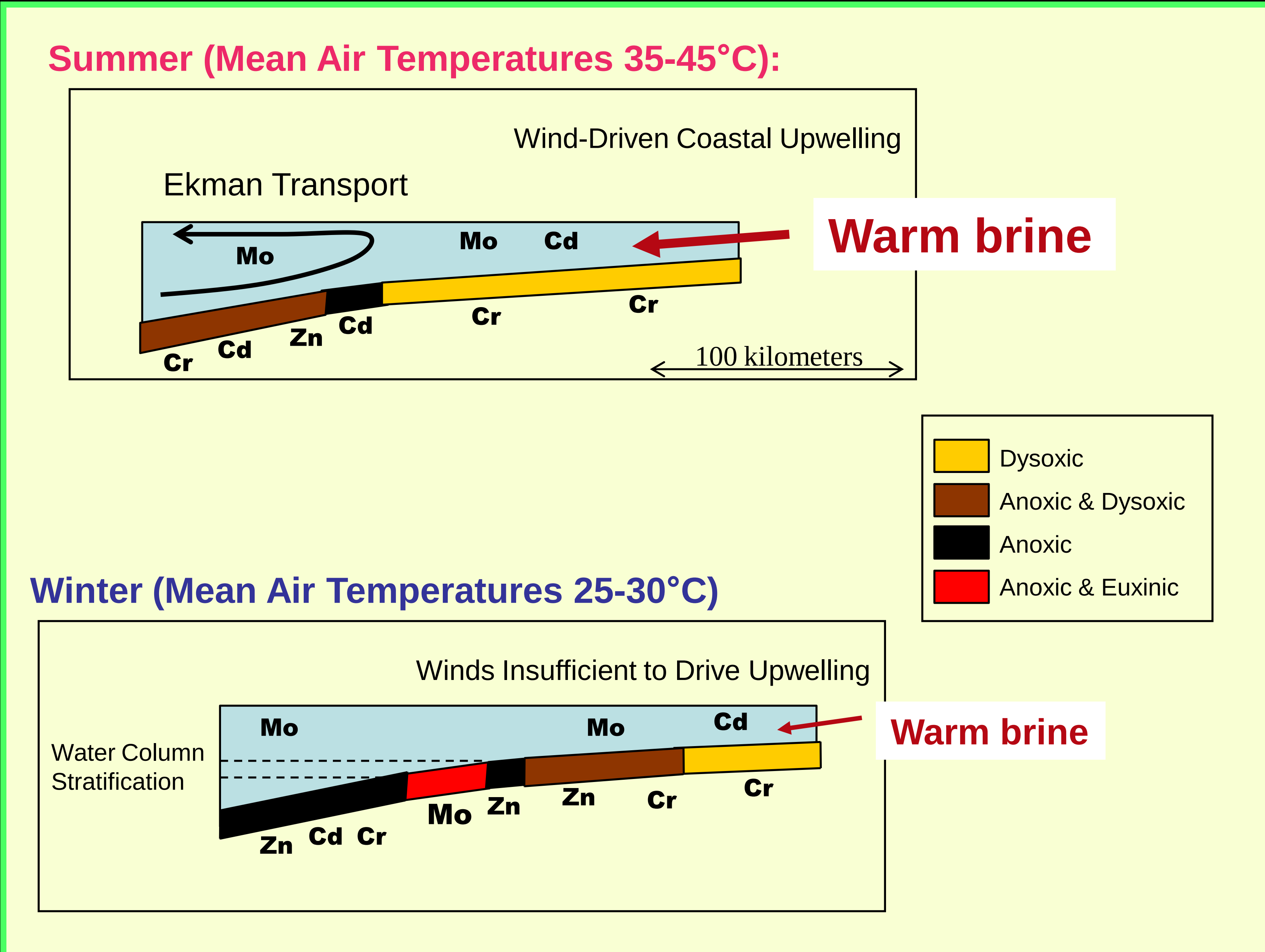


(modified from Hiatt and Budd, 2001)





(Estimated mean air temperatures and air circulation patterns from Kutzbach and Ziegler, 1994)


Summer (Mean Air Temperatures 35-45°C):
Wind-Driven Coastal Upwelling
Ekman Transport
Mo
Mo
Cd
Warm brine
Cr
Cd
Zn
Cd
Cr
Cr
100 kilometers
Dysoxic
Anoxic & Dysoxic
Anoxic
Anoxic & Euxinic
Winter (Mean Air Temperatures 25-30°C)
Winds Insufficient to Drive Upwelling
Water Column Stratification
Mo
Mo
Cd
Warm brine
Zn
Cd
Cr
Mo
Zn
Zn
Cr
Cr

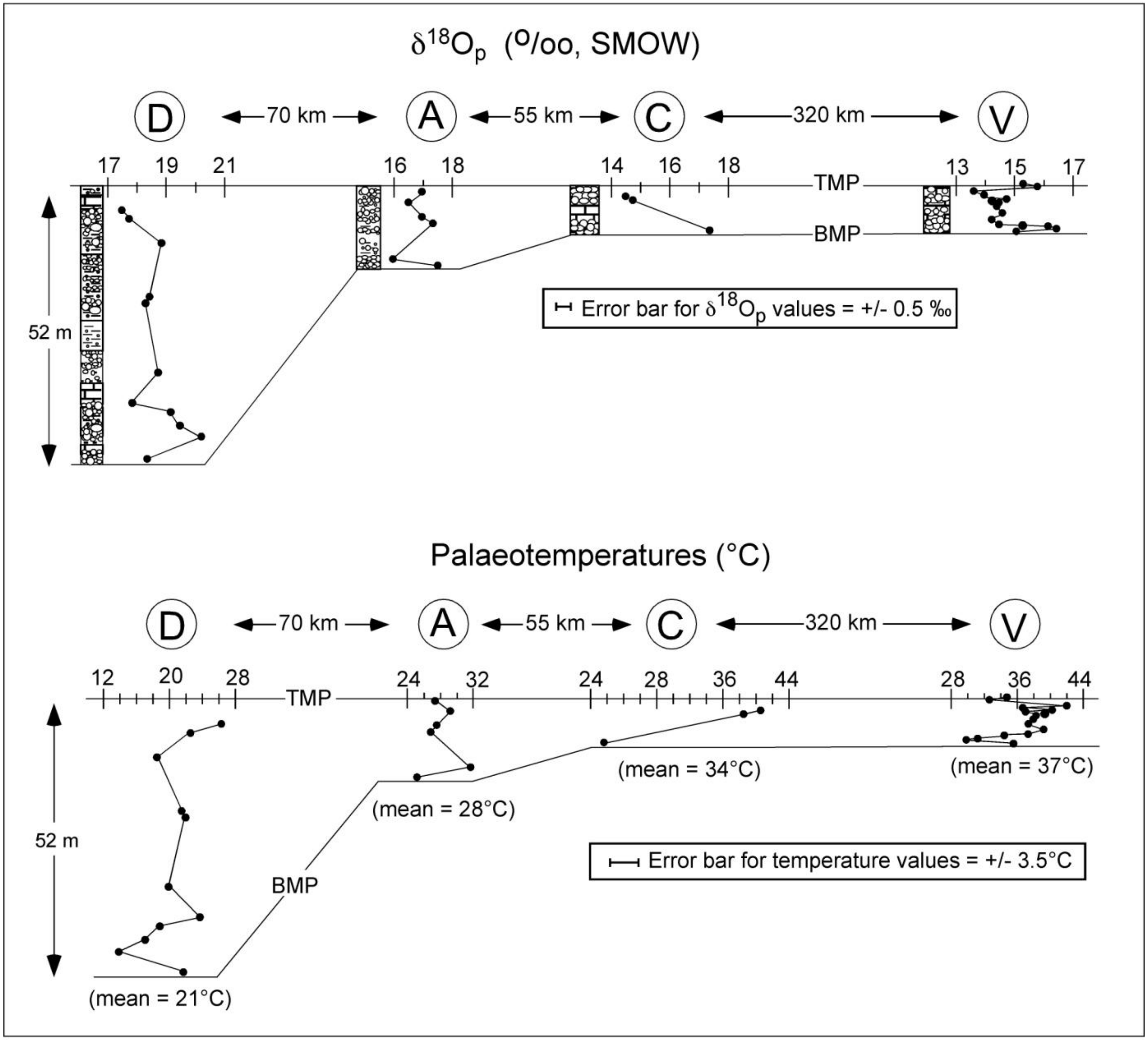
Conclusions:

1. High organic productivity and phosphogenesis occurred during relative SL lows and reached a maximum during transgression.

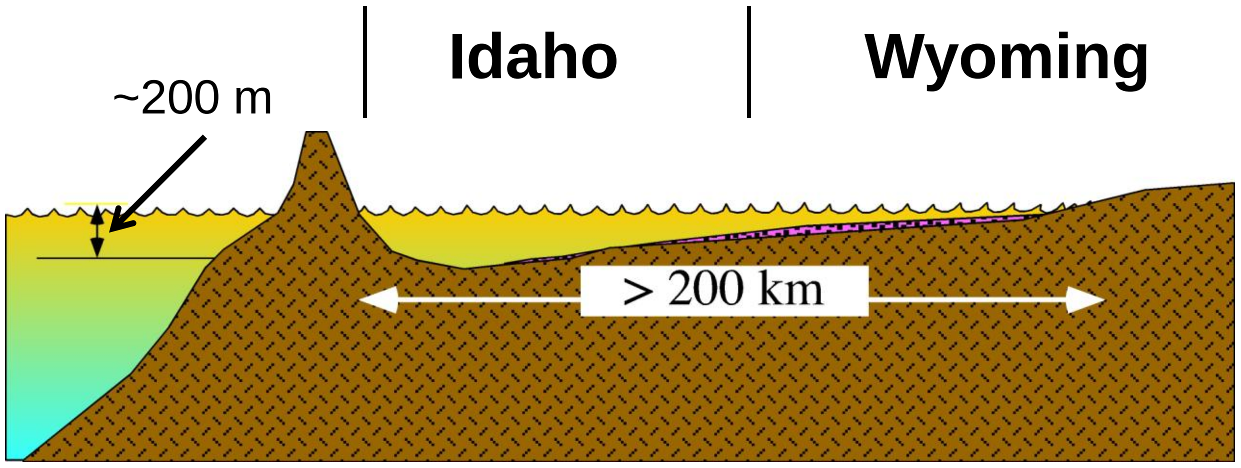
2. Phosphogenesis occurred under dysoxic to anoxic conditions -- unlike Cenozoic phosphorites, this included shallow, nearshore environments.

3. Chemostratigraphy, however, showed that the Phosphoria Sea was marked by dysoxic, anxoic to euxinic conditions that led to high concentrations of high concentrations of sulfides, metals, and organic carbon.

Muito obrigado.



From Hiatt and Budd (2001)


Idaho
Wyoming
~200 m
> 200 km

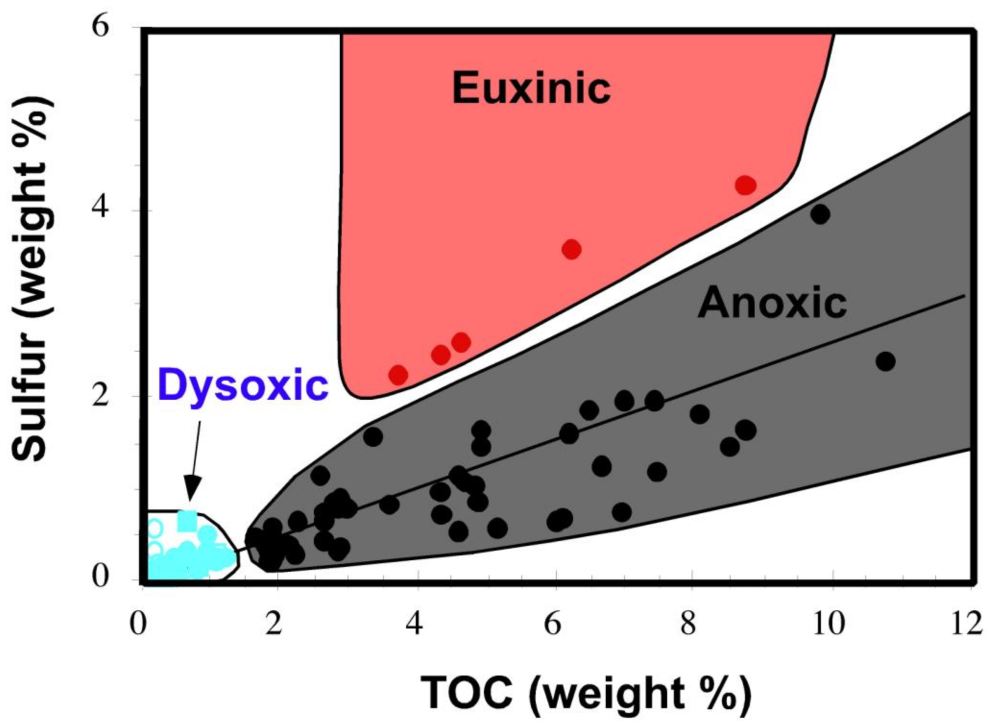
Phosphorite-Metal Associations:

Enrichment Factors:

Ave. Phosphorite Relative to Ave. Shale	Phosphoria Phosphorite Relative to Ave. Shale
Ag = 30x	Ag = 43x
Cd = 60x	Cd = 133x
Mo = 4x	Mo = 7x
Se = 8x	Se = 17x
U = 30x	U = 24x
Zn = 2x	Zn = 3x

Data from Altschuler (1980)

Organic Carbon and Sulfur Data from Phosphorites



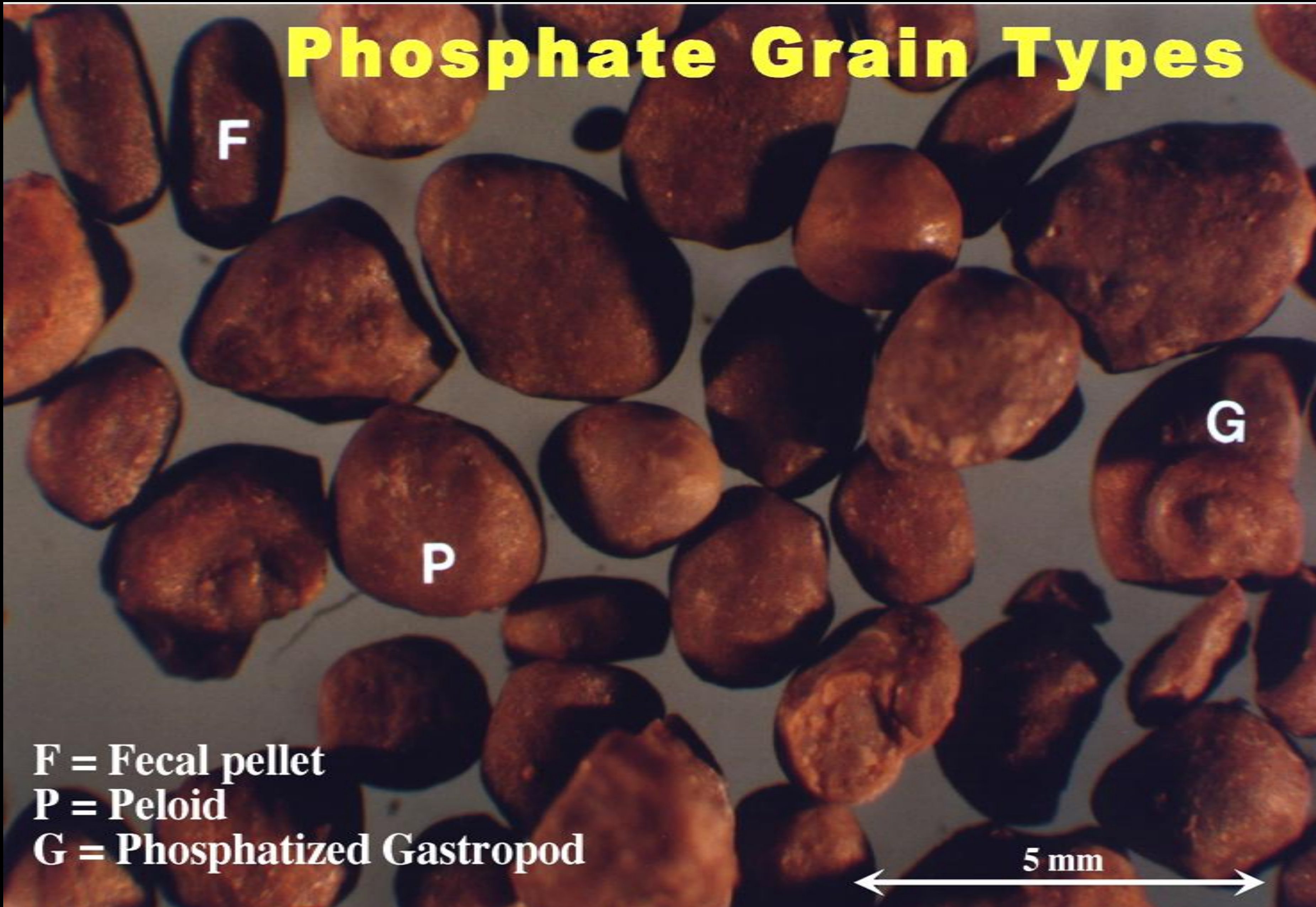
Dysoxic: TOC < 1.5

Anoxic: TOC > 1.5, TOC/S > 2.0

Euxinic: TOC > 1.5, TOC/S ≤ 2.0

O_2 Respiration	
Denitrification	$Cr(OH)3$
Sulfate Reduction	ZnS CdS MoS_2 FeS

(Based on Piper, 2001)


Phosphate Grain Types
F
G
P
F = Fecal pellet
P = Peloid
G = Phosphatized Gastropod
5 mm