Sequence Stratigraphic and Geochemical Insights into Paleoceanography and Source Rock Development in the Shublik Formation and Adjacent Units, Northern Alaska*

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Abstract

The Fire Creek Siltstone, Shublik Formation, and Karen Creek Sandstone in northern Alaska record four third-fourth order depositional sequences. The Shublik, a proven Prudhoe Bay source rock, records geochemical, ichnologic, and facies evidence of significant variation in bottom water redox conditions, detrital input, and biological productivity. Low oxygen conditions facilitated both the accumulation of organic matter and development of abundant phosphatic facies that include both granular and nodular phosphorites. The Shublik is extremely heterogeneous containing claystone, organic-rich shale, bioclastic wackestone and packstone, sandstone, nodular and pebbly phosphorite, and phosphatic and glauconitic silt/sandstone. Facies are commonly stacked in shoaling upward cycles that evolve from organic-rich shales through phosphatic silt/sandstones to more carbonate rich facies. Total Organic Carbon (TOC) data in conjunction with redox sensitive trace metal concentrations, geochemical indicators of detrital input and bioproductivity, and ichnofabric analysis provide insight into the paleoceanographic changes concomitant with the development of different systems tracts during relative sea level change.

The most organic rich facies (up to 4%) are usually contained within the Transgressive Systems Tract (TST) that commonly display the lowest ichnofabric indices. Redox sensitive geochemical indicators of low oxygen environments (Mo, V, U, Ni) are also concentrated over background levels within transgressive facies. Some HST facies, however, record relatively high TOC contents (1-2%) even when fairly coarse grained. Also, while these facies usually display much lower concentrations of redox-sensitive trace metals, they are commonly still elevated over background levels. This points to at least intermittent development of low oxygen conditions even during sea level highstand. The Shublik is commonly interpreted to represent deposition under upwelling conditions. We, however, also observe that some TOC-rich intervals display concentration of geochemical indicators of detrital input (Al, Si, Ti) and bioproductivity (Cu, Ni, Zn) above background levels. These relationships could point toward productivity driven by detrital input rather than upwelling of nutrients from deeper water.

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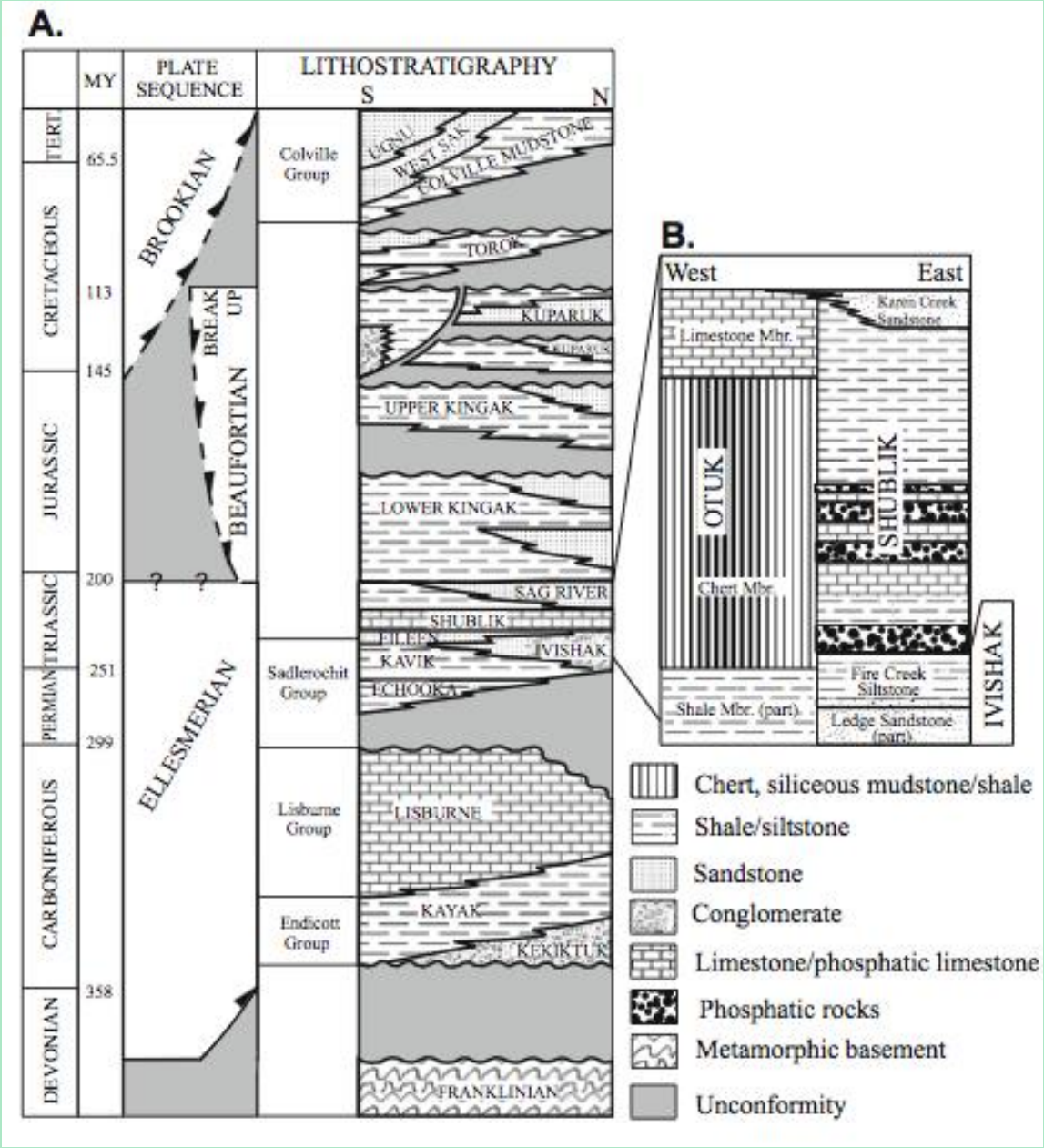
Outline

- Introduction
  - Geologic Setting of the Shublik Fm. and Related Units
- Data & Methods
- Results
  - Sequence Stratigraphy
  - Geochemistry
  - Implications for Source Rock Development and Paleoceanography

Shublik Formation



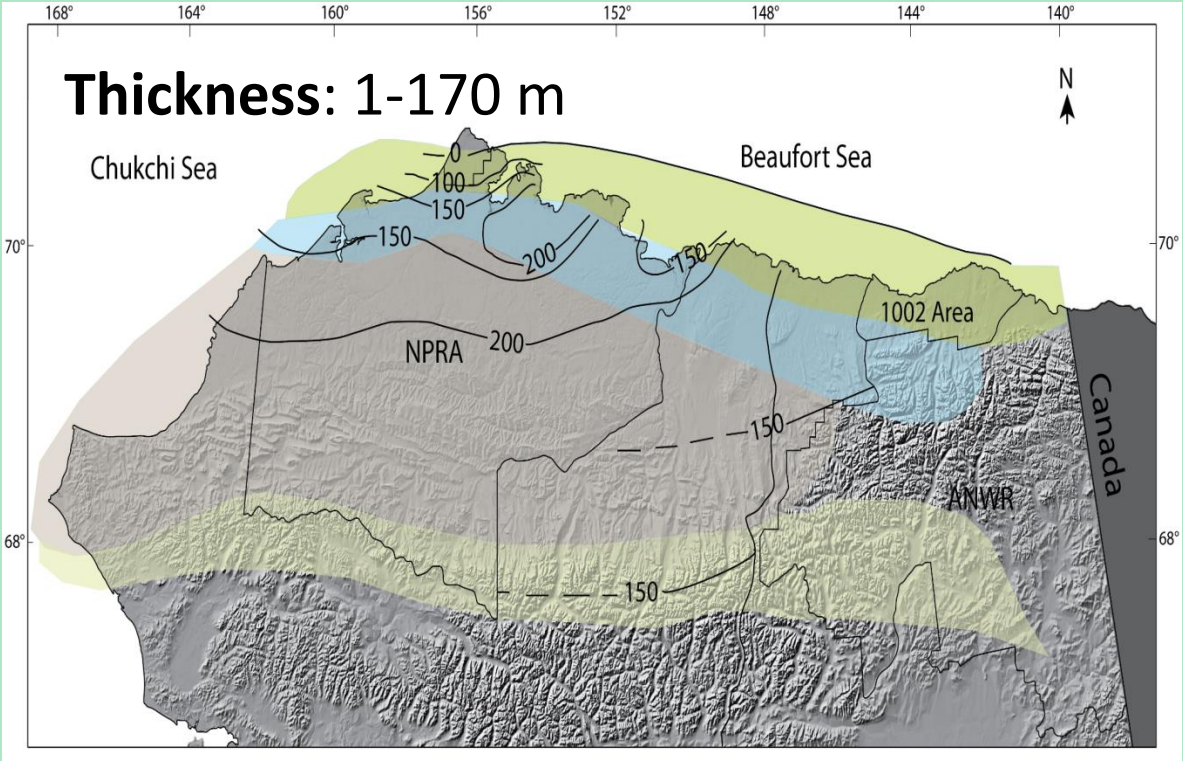
- Part of the upper Ellesmerian sequence
- Middle to Upper Triassic in age
- Heterogeneous laterally and vertically
- Interpreted to indicate deposition under the influence of marine upwelling

Shublik Formation

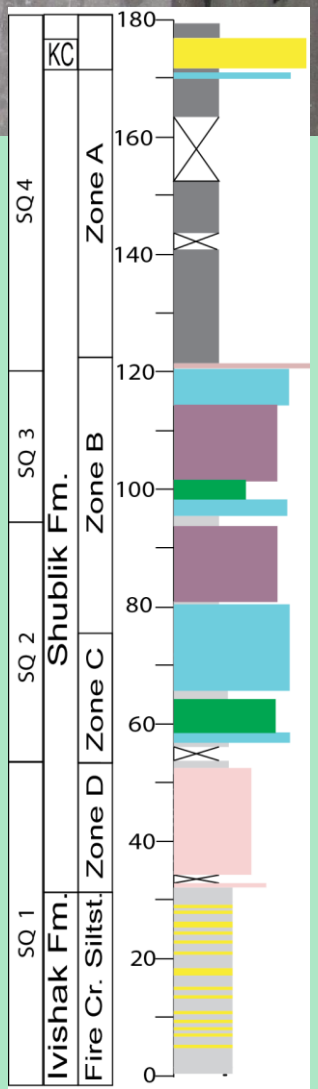
- Proven source rock for the conventional North Slope petroleum system
- Four depositional sequences
- Source rocks mainly deposited in TST bus some in HST
- Geochemistry indicates intermittent low oxygen conditions during TST and locally during HST
- Recent interest in unit as an unconventional target

Shublik Fm.

Lateral and vertical facies heterogenetiy



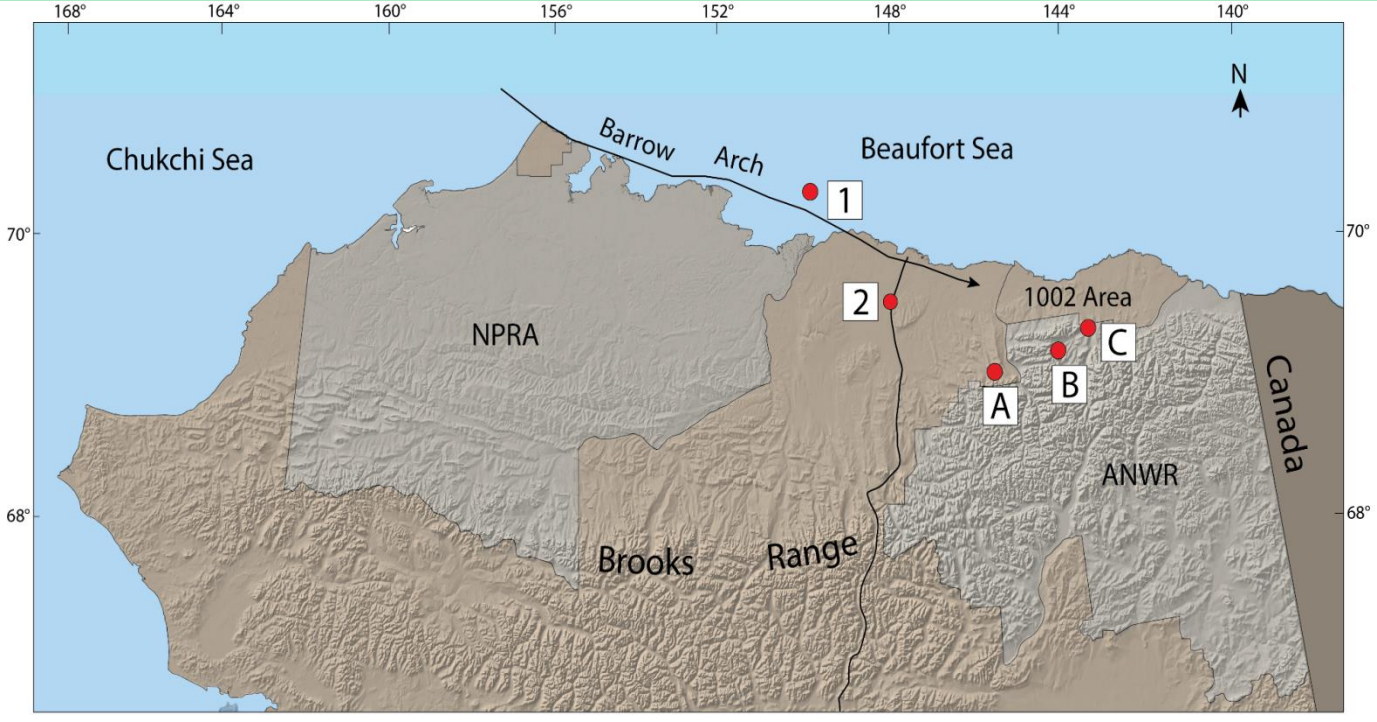
(Modified from Kelly et al., 2007)



- Glauconitic/sandy
- Phosphatic/organic-rich
- Organic-rich mudstone/ limestone
- Chert and mudstone

- Sandstone
- Limestone
- Silty Shale
- Shale
- Flat Clam facies
- Phosphatic Limestone
- Phosphatic Siltstone
- Nodular Phosphate
- Conglomerate

Data: Outcrop and Core



Outcrops

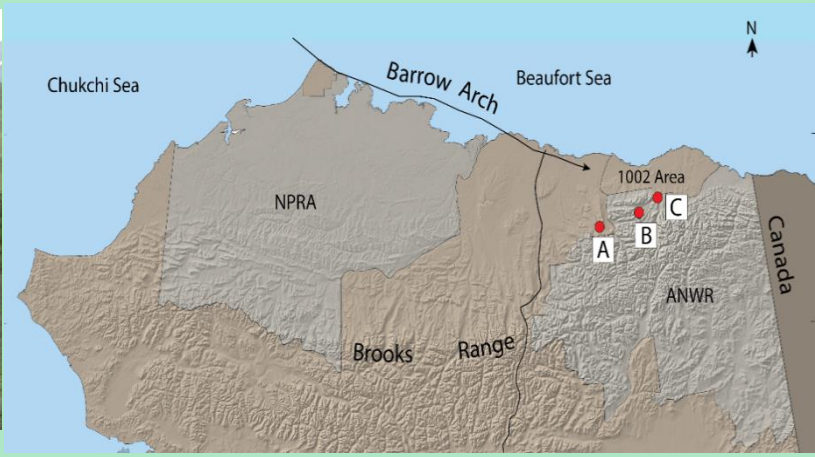
- A Kavik Creek
- C Fire Creek
- B Last Creek

Cores

- 1 Phoenix Tenneco #1
- 2 Great Bear Petroleum Merak #1V

Outcrops

A: Kavik Creek

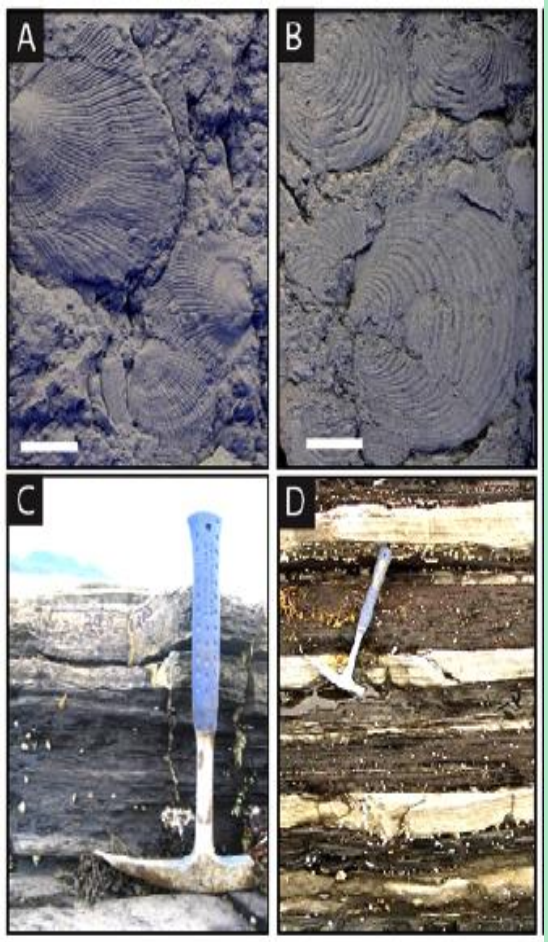


B: Fire Creek

C: Last Creek

Methods

- Sequence Stratigraphy & Facies Stacking Patterns
- Surface to Subsurface Correlation, G-ray
- Geochemistry
  - Major & Trace Element
  - TOC
  - C isotopes



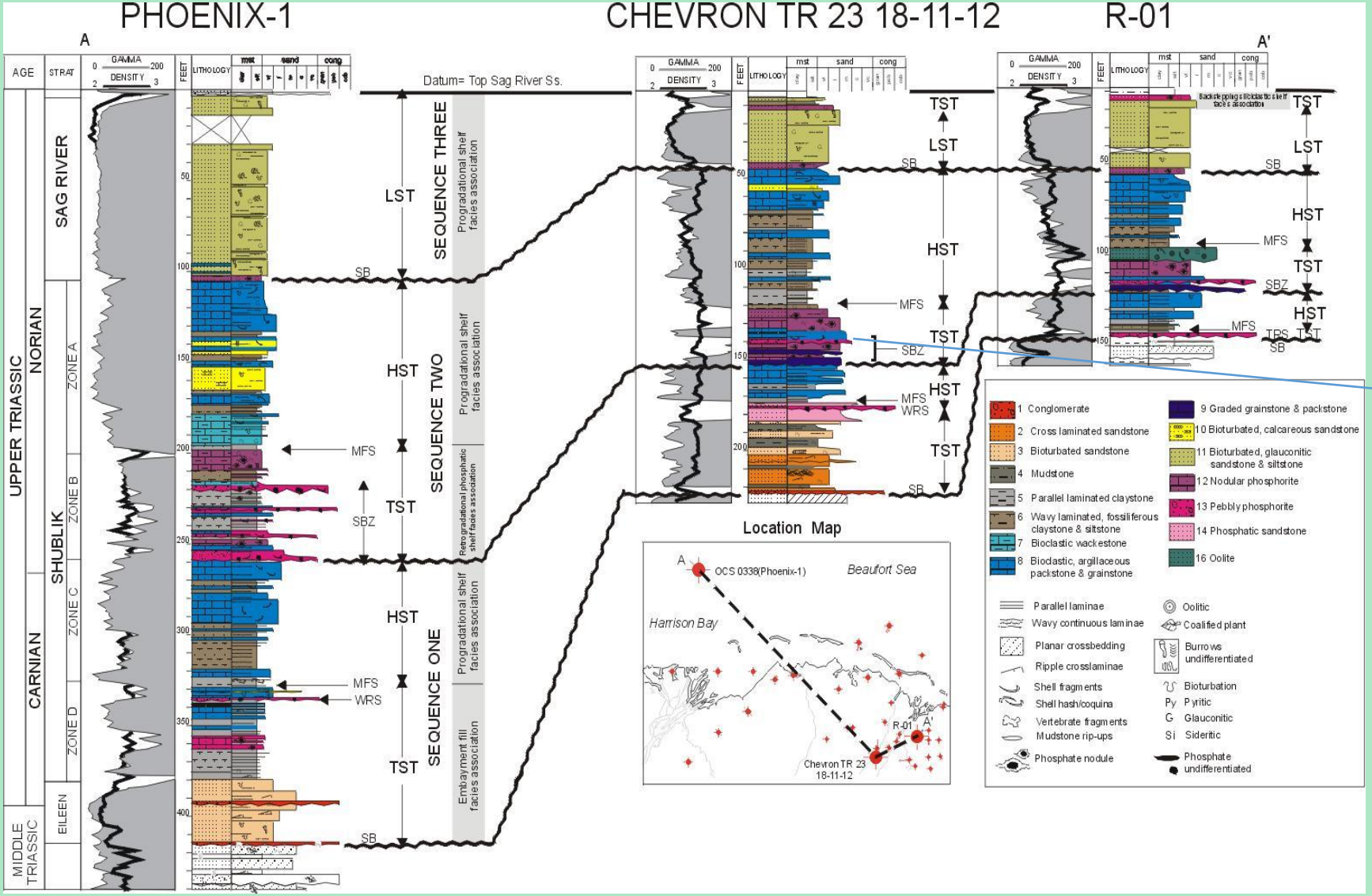
Methods: Multiproxy Analytical Data

- XRF (UAF Advanced Instrumentation Lab)
  - Major elements in %
  - Trace elements in ppm
- ICP-MS, XRAL
  - Trace elements in ppm
- Stable Carbon Isotopes (Rutgers, USGS)
  - $\delta^{13}C$ in ‰ (relative to VPDB)

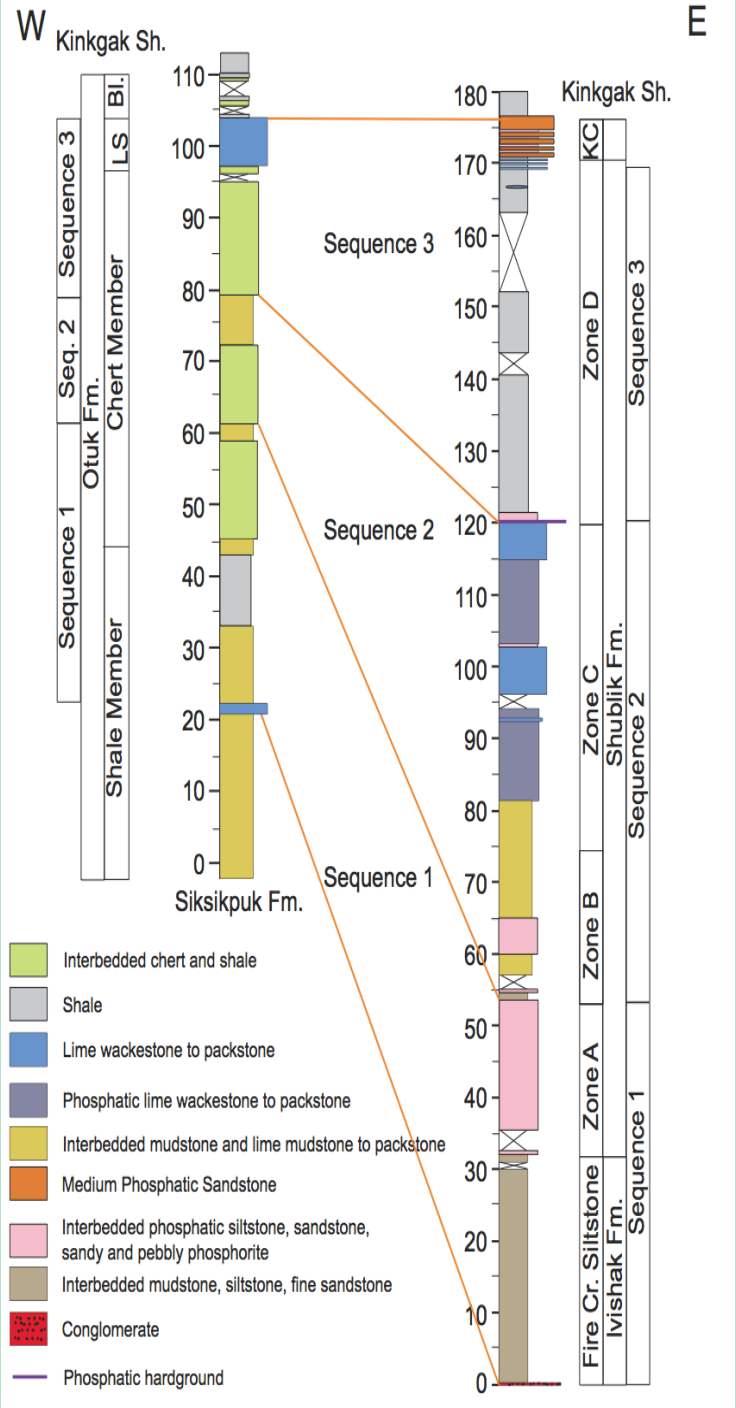
Sequence Stratigraphy

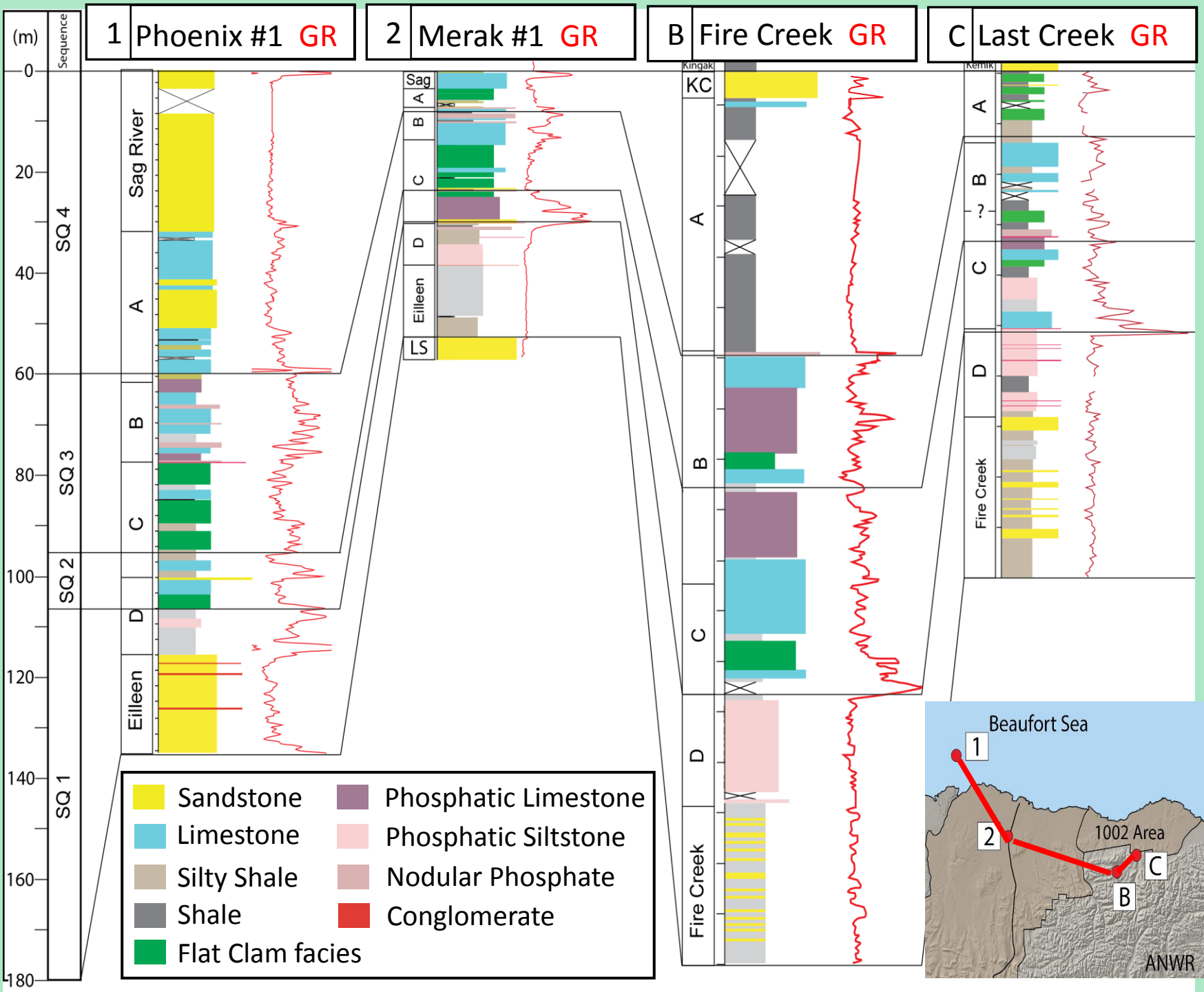
- 1 Depositional Sequence
- Kupecz (1995) – Shublik only in Prudhoe Bay Unit
- Robison (1996) – Eileen & Shublik in Phoenix Well
- 2+ Depositional Sequences
- Hulm (1999) – Subsurface analysis of cores/well logs from NPRA & Prudhoe Bay Unit – Eileen, Shublik, and Sag River interpreted as two full depositional sequences and LST of a third
- 3 Depositional Sequences
- Kelly et al. (2007) – Correlation of Shublik & related units and more distal Otuk Fm. Identified three full depositional sequences
- 4 Depositional Sequences
- Hutton (2013) & this study – Break out an additional sequence for a total of four including Eileen/Fire Creek Siltstone, Shublik, and Sag River/Karen Creek Sandstone

Subsurface Sequence Stratigraphy (Hulm 1999)

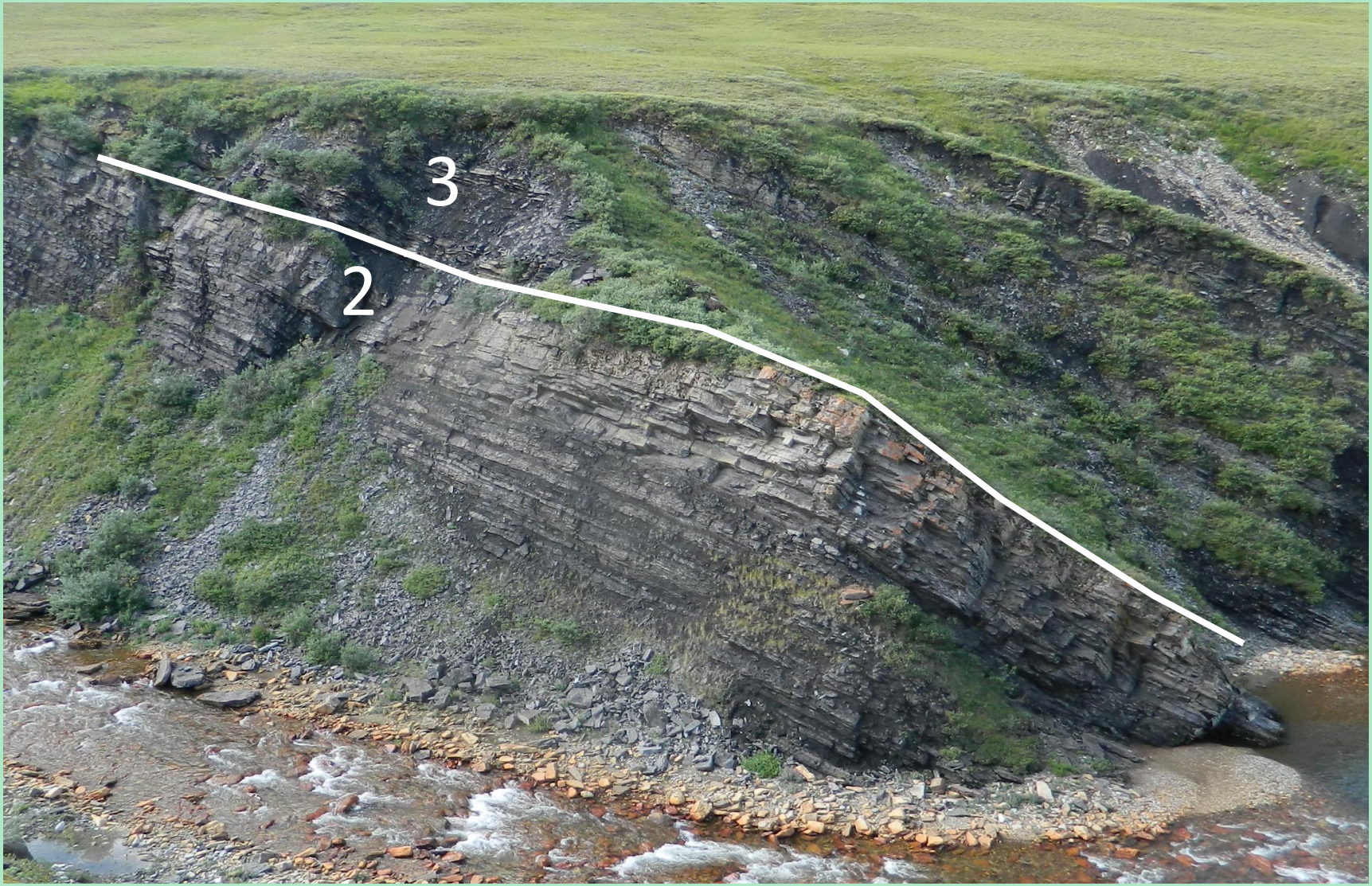


Simplified Sequence Stratigraphy: Shublik to Distal Otuk (Kelly et al. 2007)



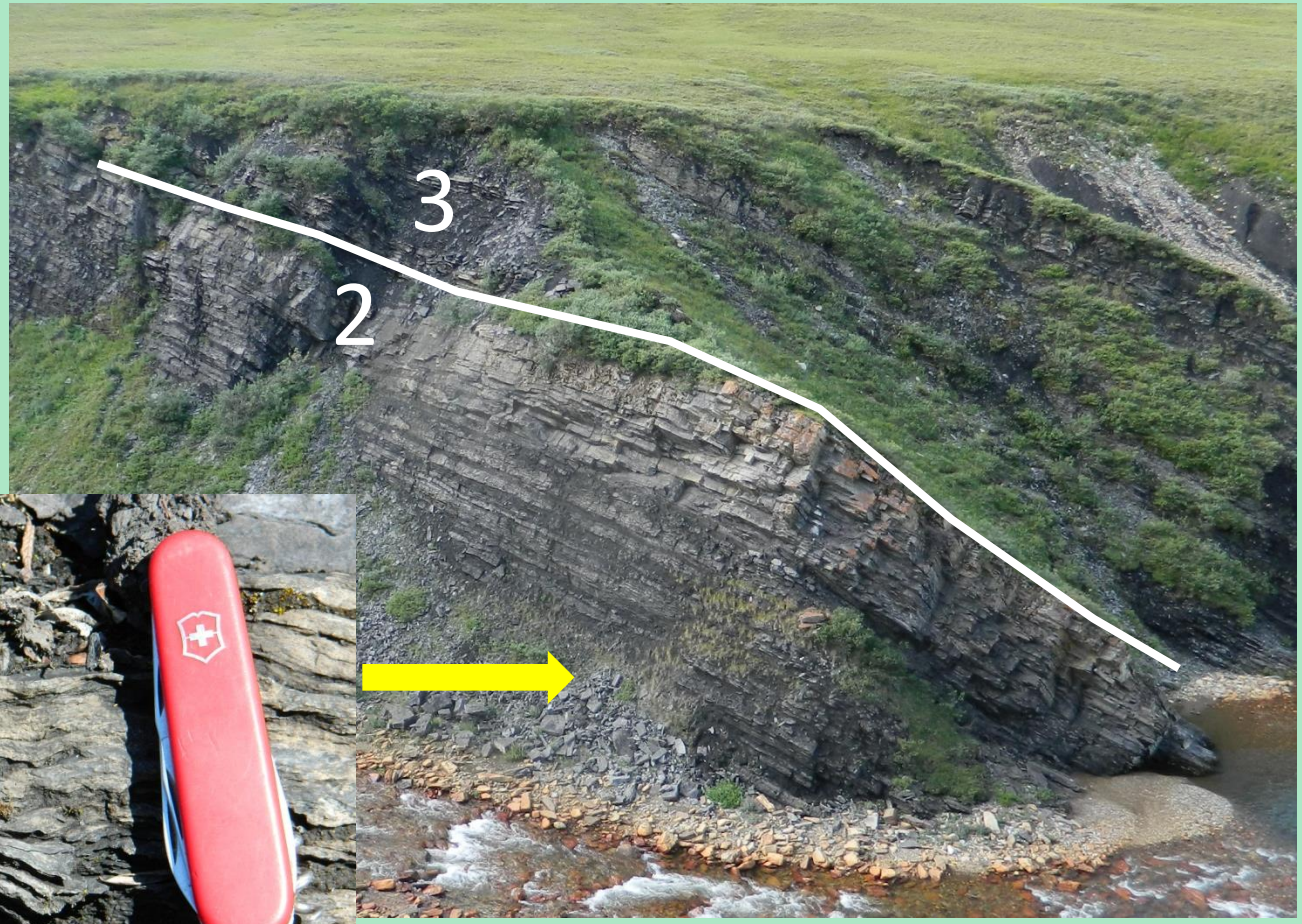

(m)
Sequence
1 Phoenix #1 GR
2 Merak #1 GR
B Fire Creek GR
C Last Creek GR
0
20
40
60
80
100
120
140
160
180
SQ 4
SQ 3
SQ 2
SQ 1
Sag River
A
B
C
D
Eilleen
Sag
LS
Kingak
KC
Fire Creek
Kemik
?
Sandstone
Limestone
Silty Shale
Shale
Flat Clam facies
Phosphatic Limestone
Phosphatic Siltstone
Nodular Phosphate
Conglomerate
Beaufort Sea
1002 Area
ANWR

Shublik Parasequences



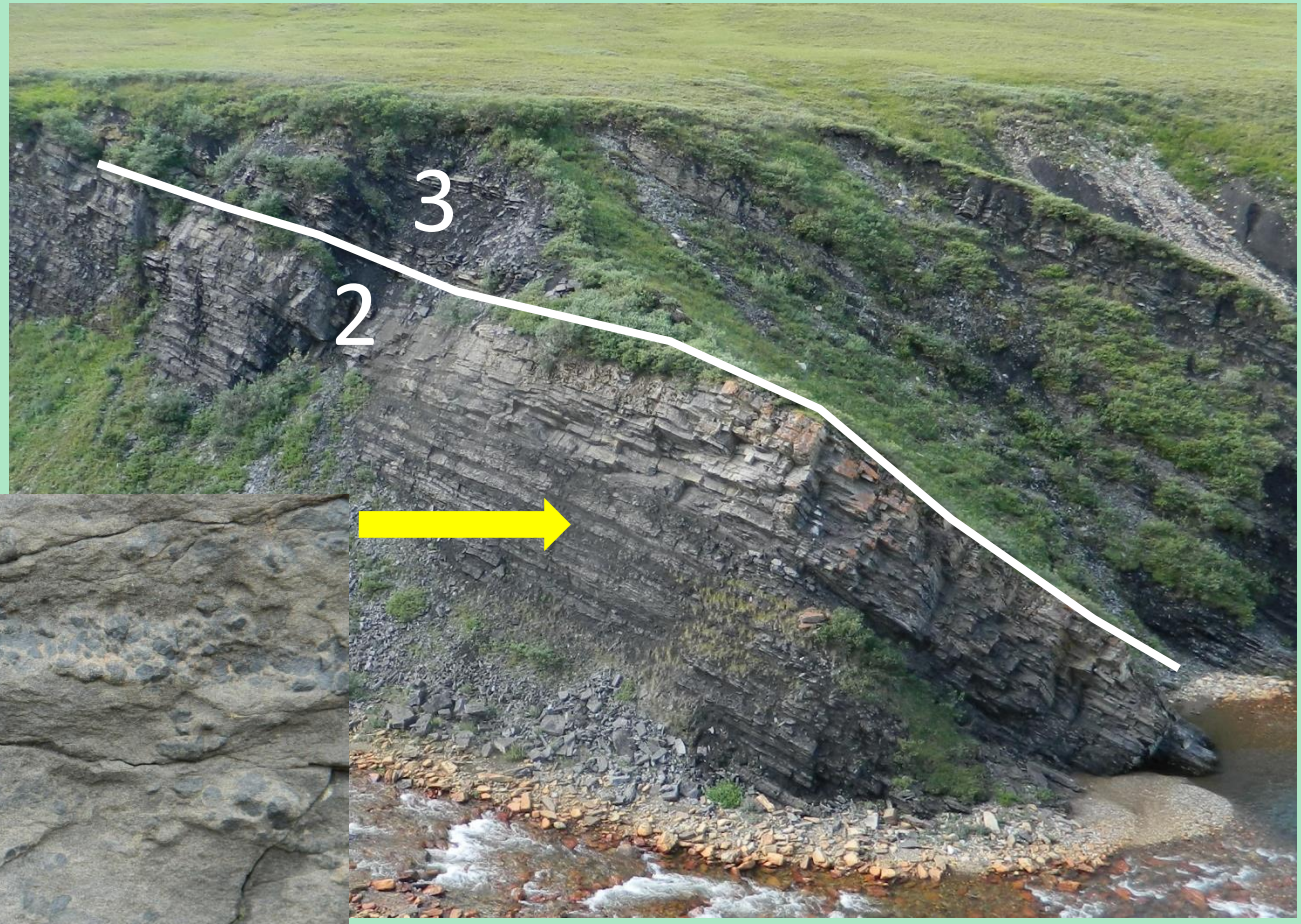
Shublik Parasequences

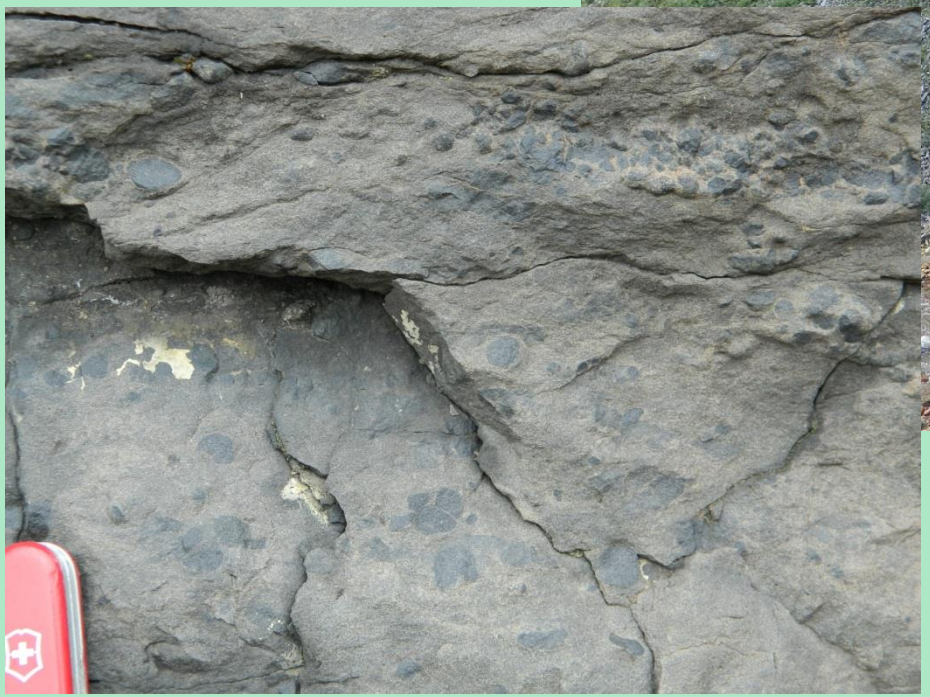
Base – Black paper shale interbedded with flat calm facies



Shublik Parasequences

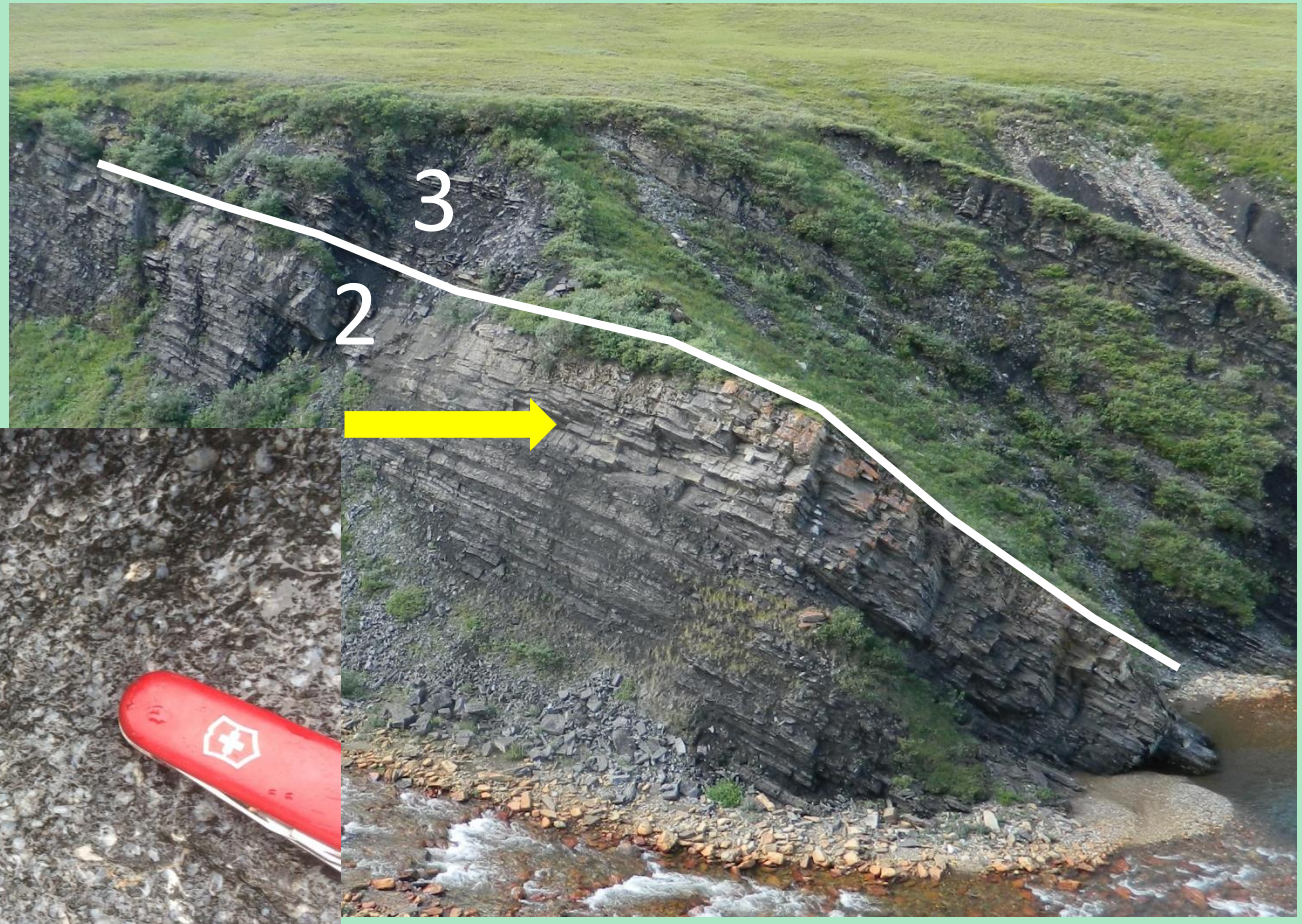
Mid - Interbedded nodular phosphatic mudstone, siltstone, sandstone

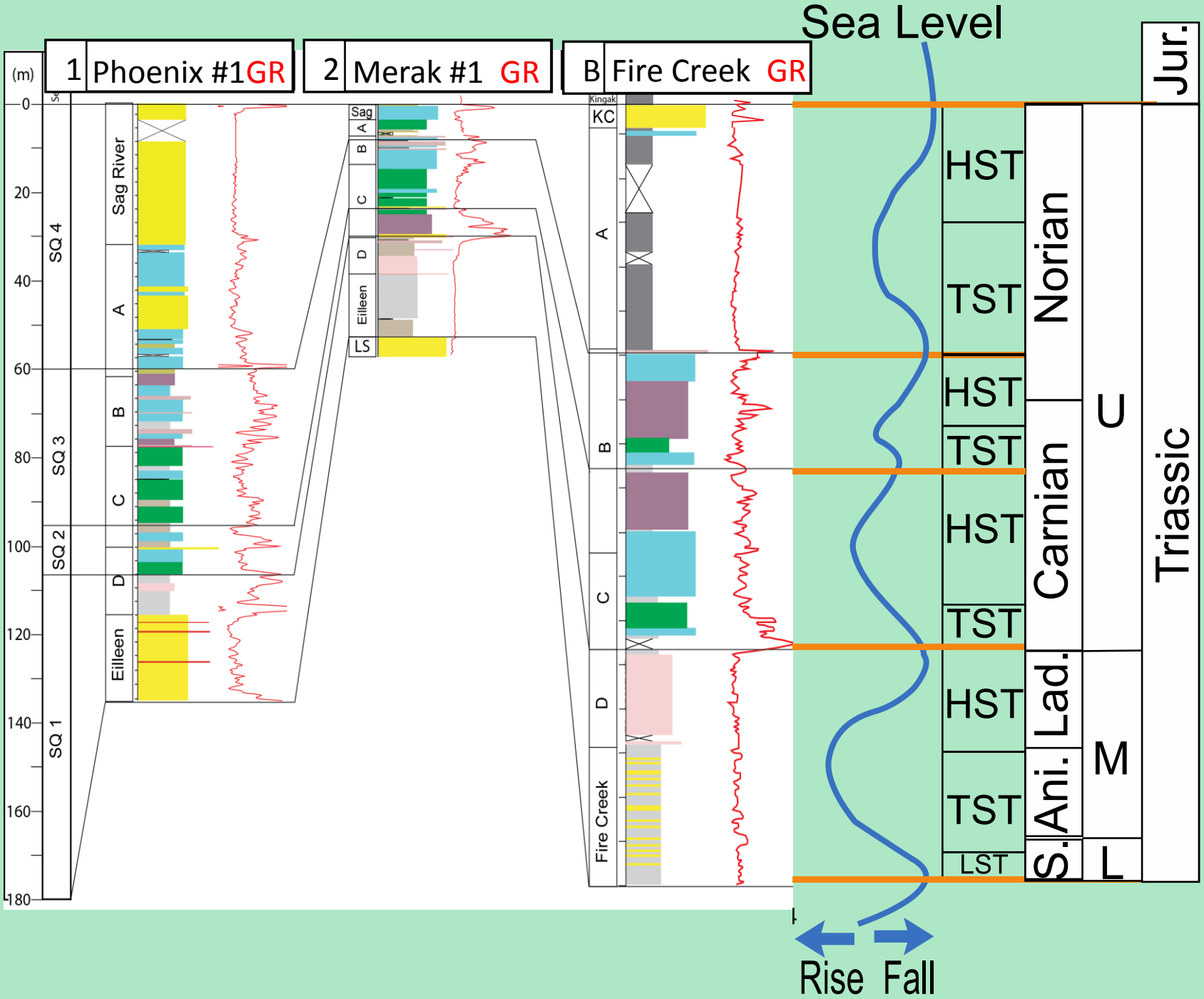




Shublik Parasequences

Top – Phosphatic sandstone or Lime packstone & coquinas



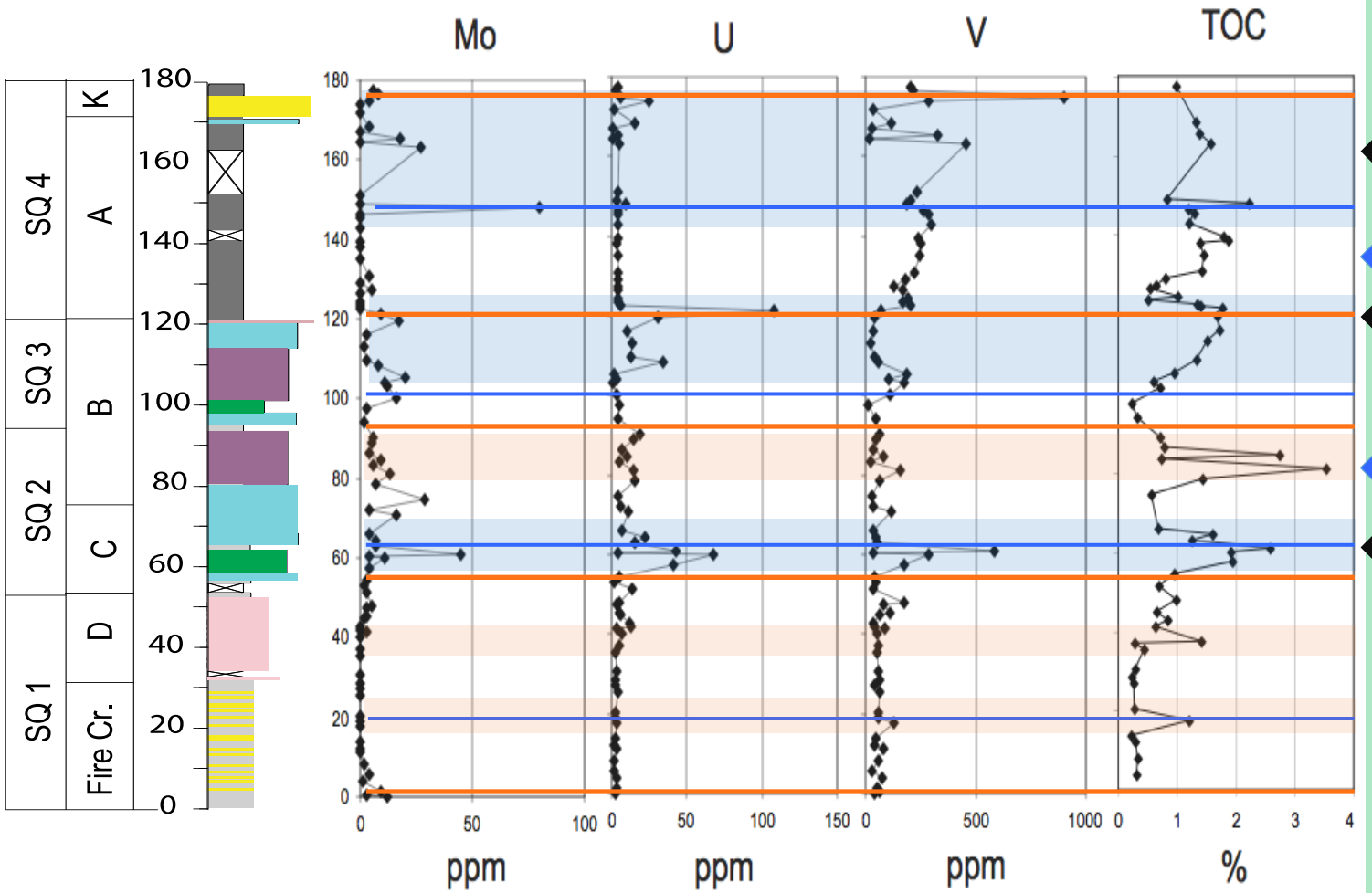

Sea Level
1 Phoenix #1 GR
2 Merak #1 GR
B Fire Creek GR
(m)
0
20
40
60
80
100
120
140
160
180
SQ 4
SQ 3
SQ 2
SQ 1
Sag River
A
B
C
D
Eilleen
Sag
Eilleen
LS
Kingak
KC
Fire Creek
HST
TST
HST
TST
HST
TST
HST
TST
LST
Norian
Carnian
Lad.
Ani.
S.
U
M
L
Triassic
Jur.
Rise
Fall

Shublik Formation

Elemental Geochemistry

- Redox proxies
  - Mo, V, & U
- Detrital proxies & organics
  - Si, Ti, Zr, & TOC
- Water column productivity proxies
  - Cu, Ni, & Zn

Shublik Redox Proxies & TOC



TOC enriched

Dysoxic

Oxic

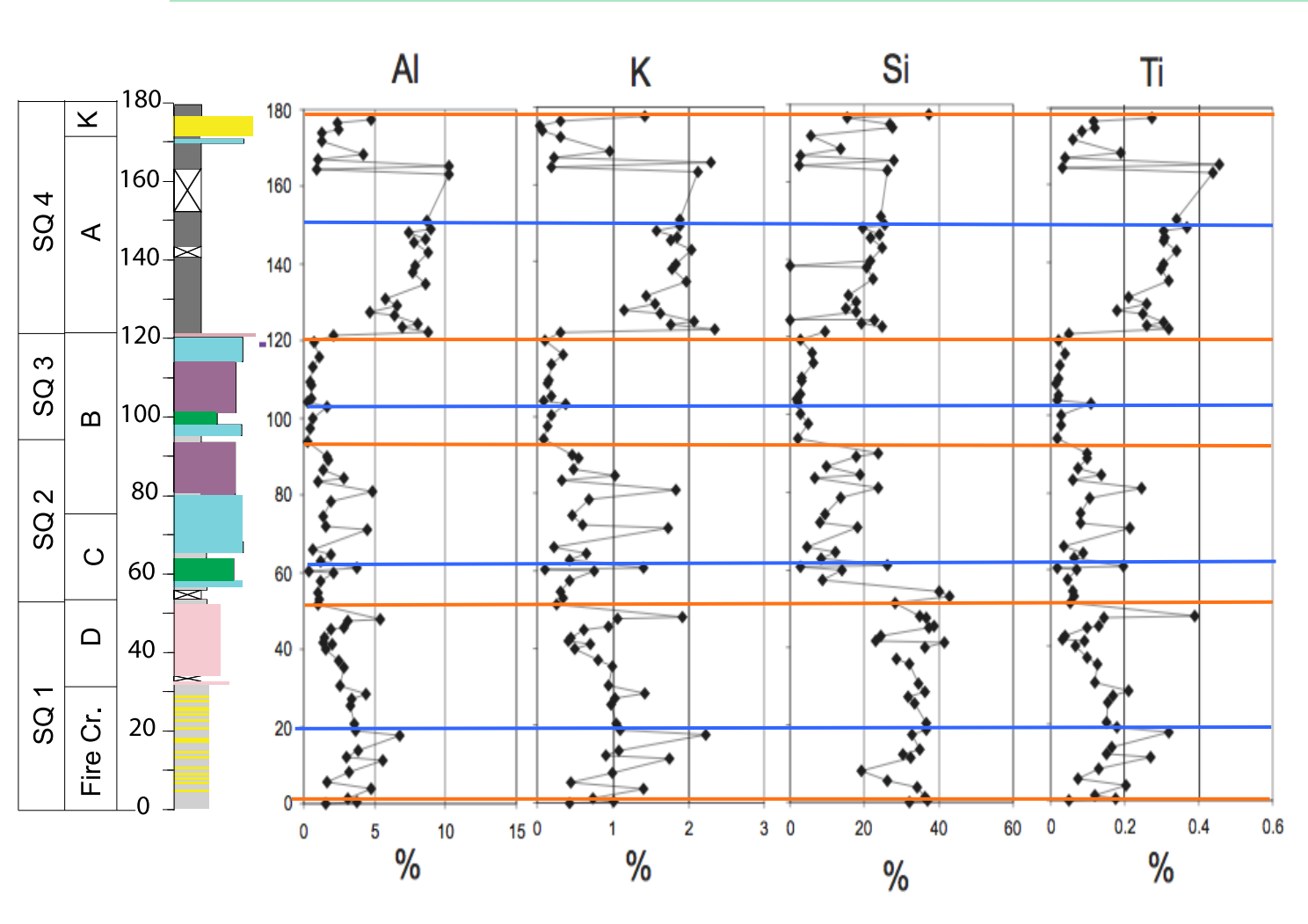
?

SB

mfs

TOC and redox proxies correlated or anti-correlated

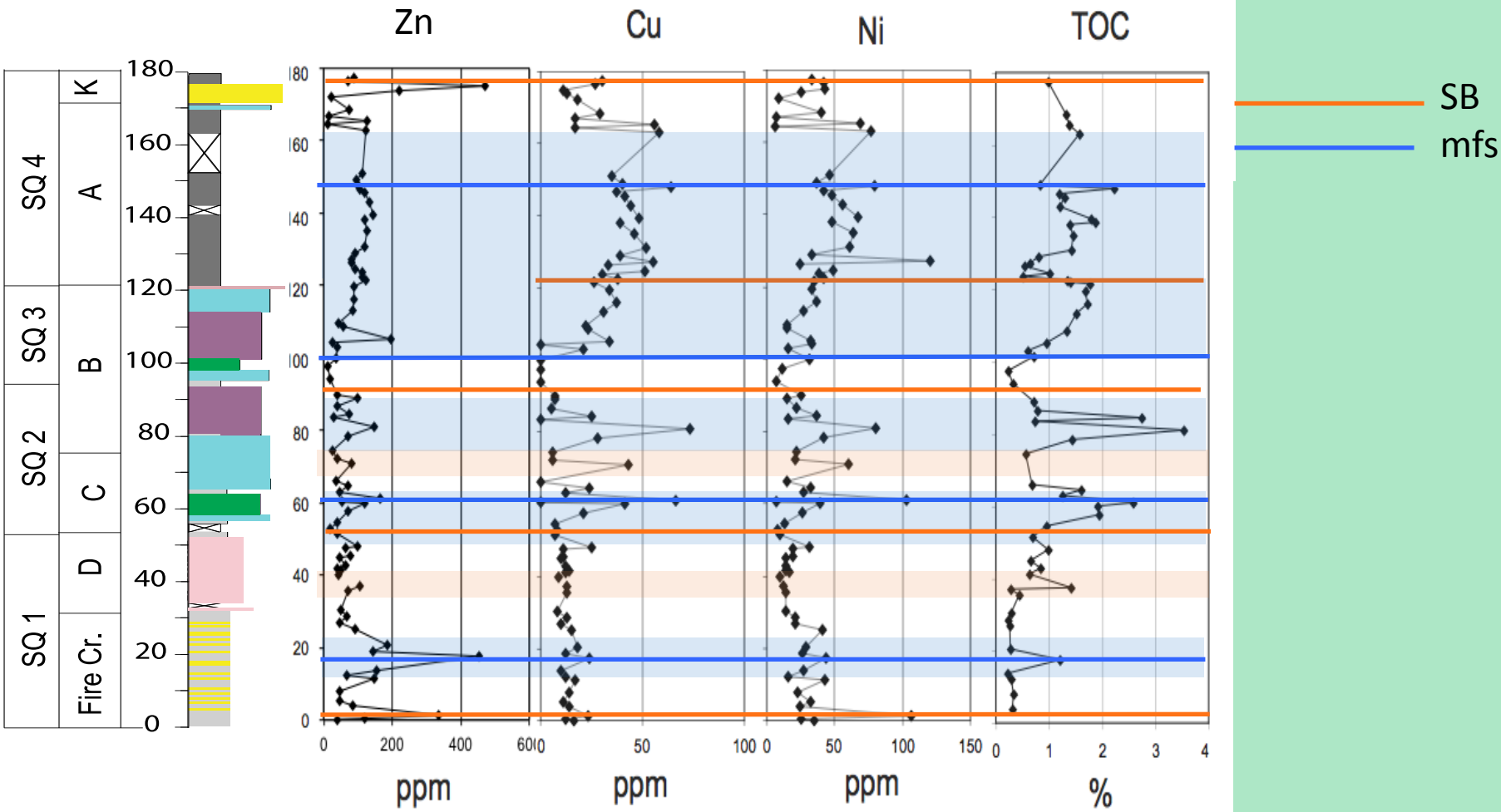
Shublik Detrital Proxies



Sequnece boundary

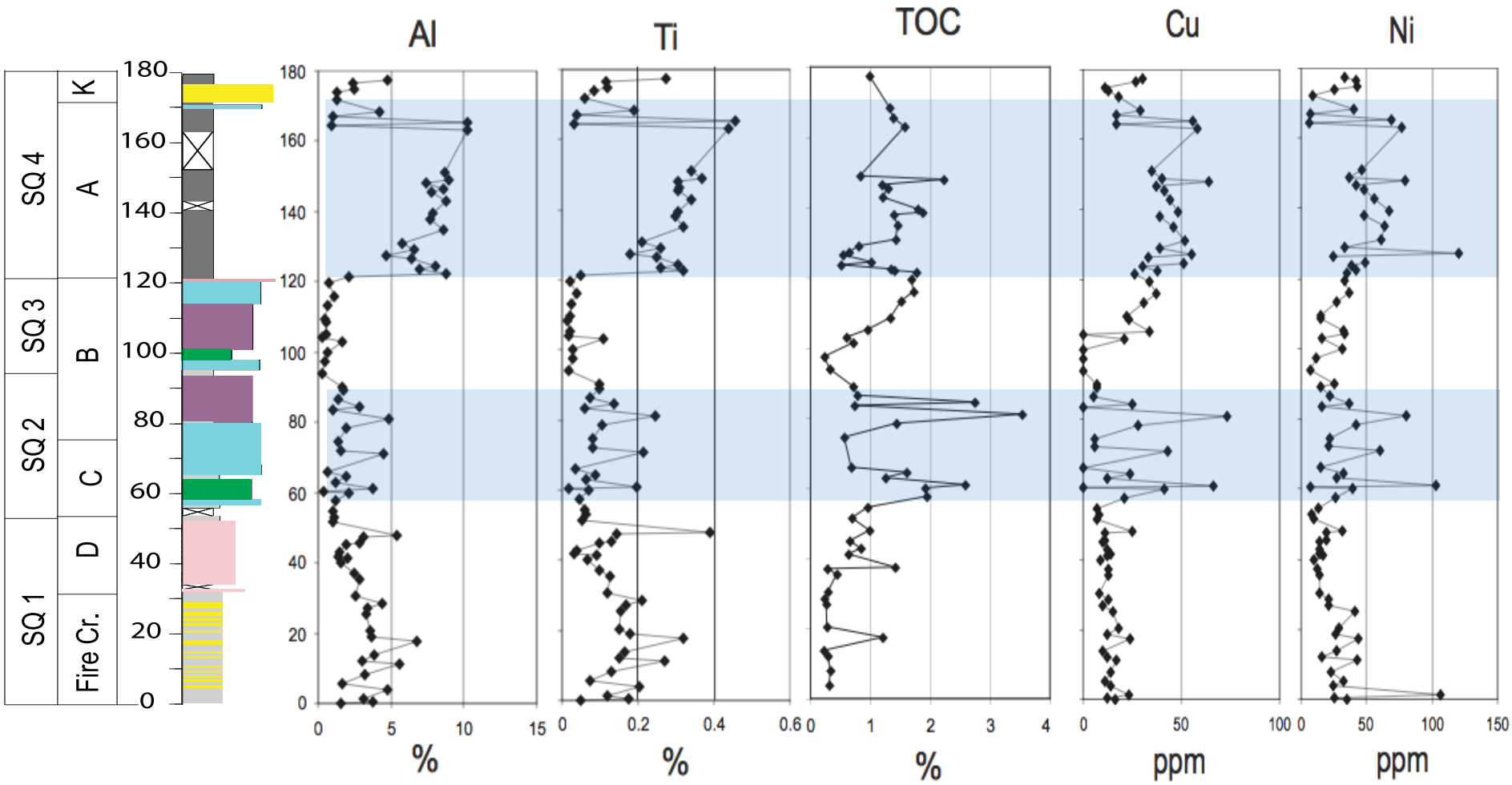
mfs

Shublik Productivity Proxies & TOC



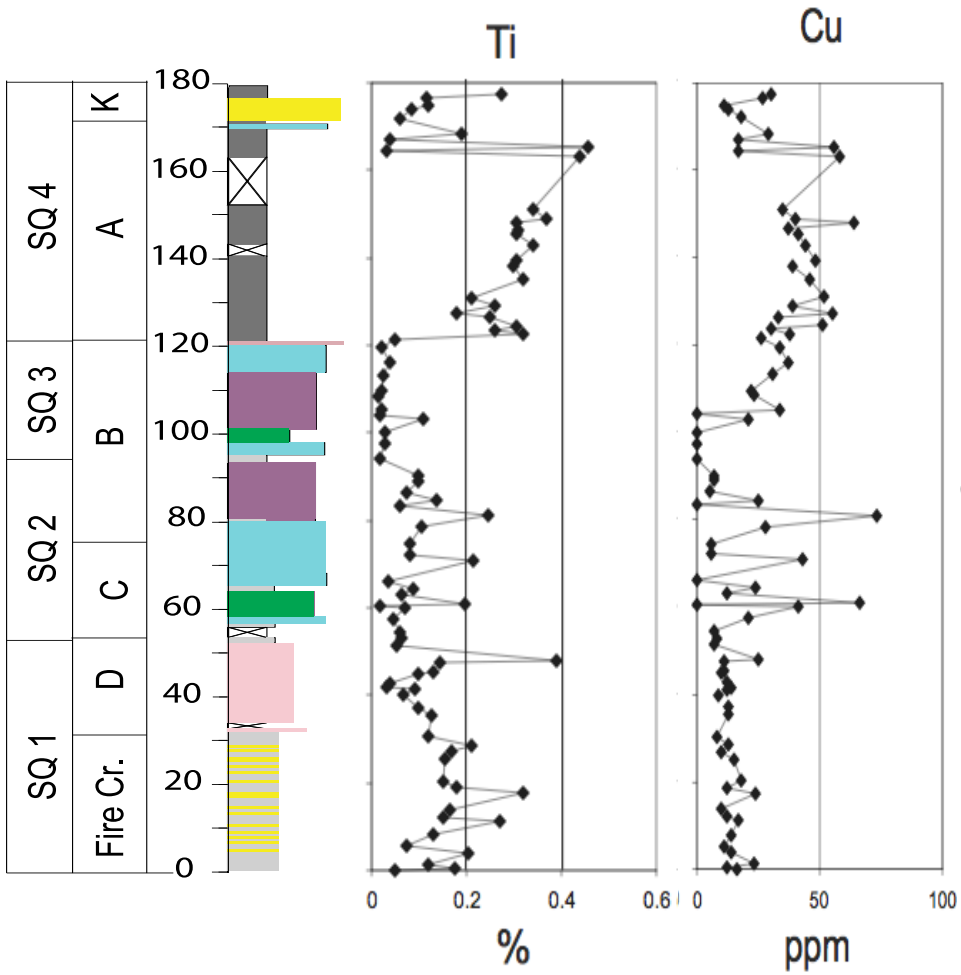
TOC and productivity proxies correlated or anti-correlated

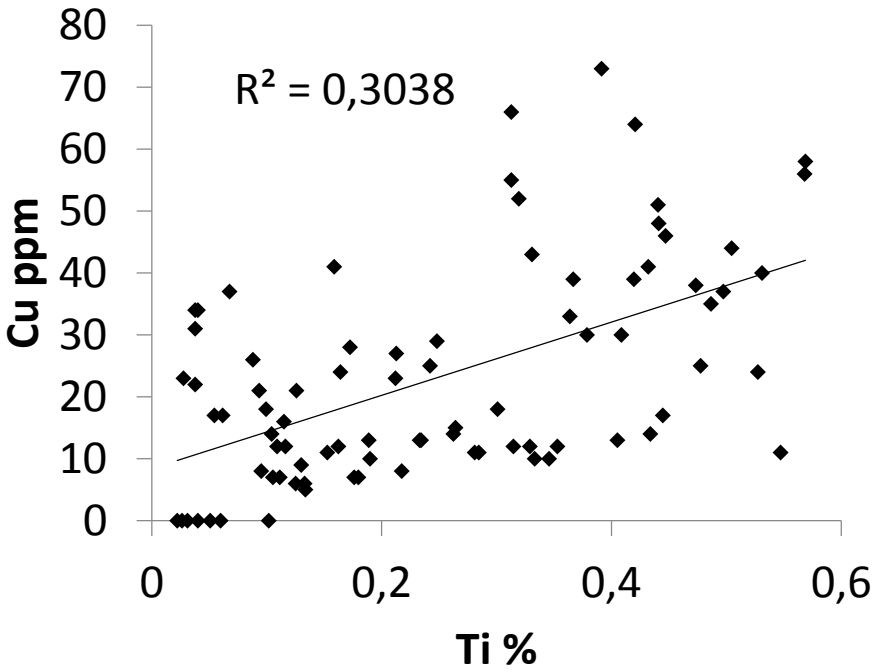
Shublik Detrital, Productivity Proxies & TOC



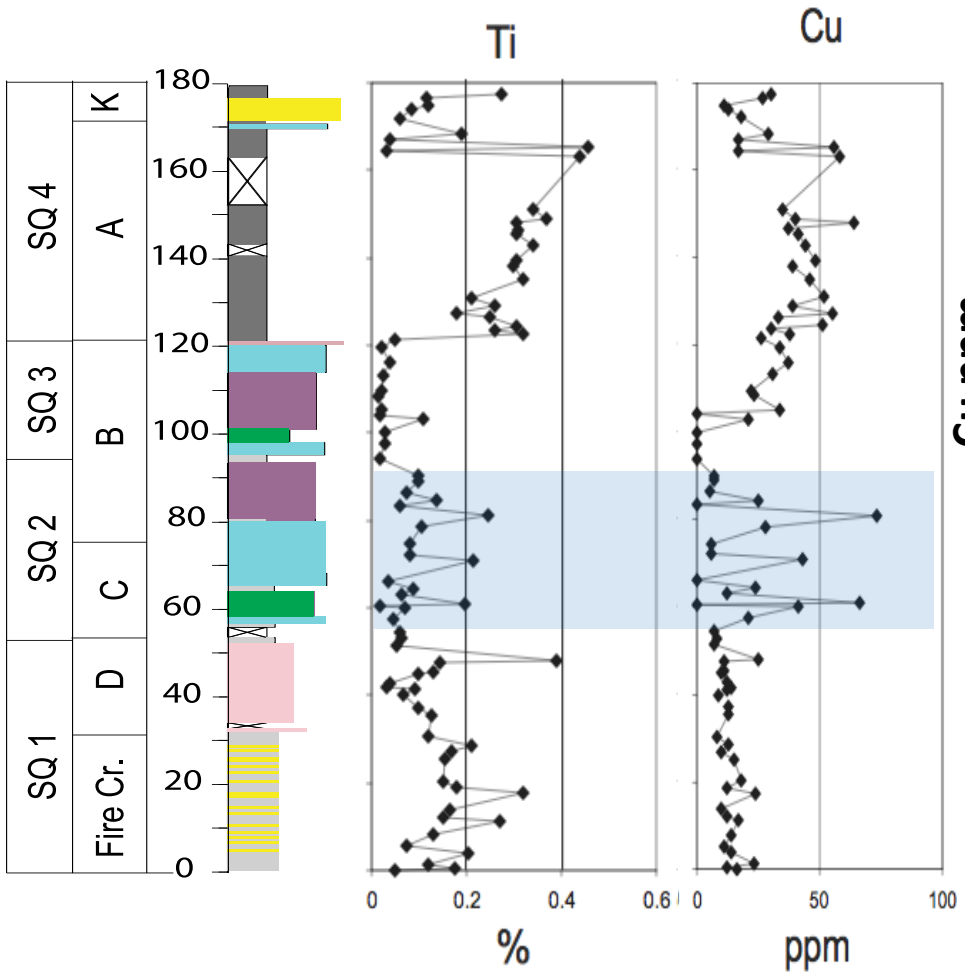
TOC, detrital & productivity proxies correlated

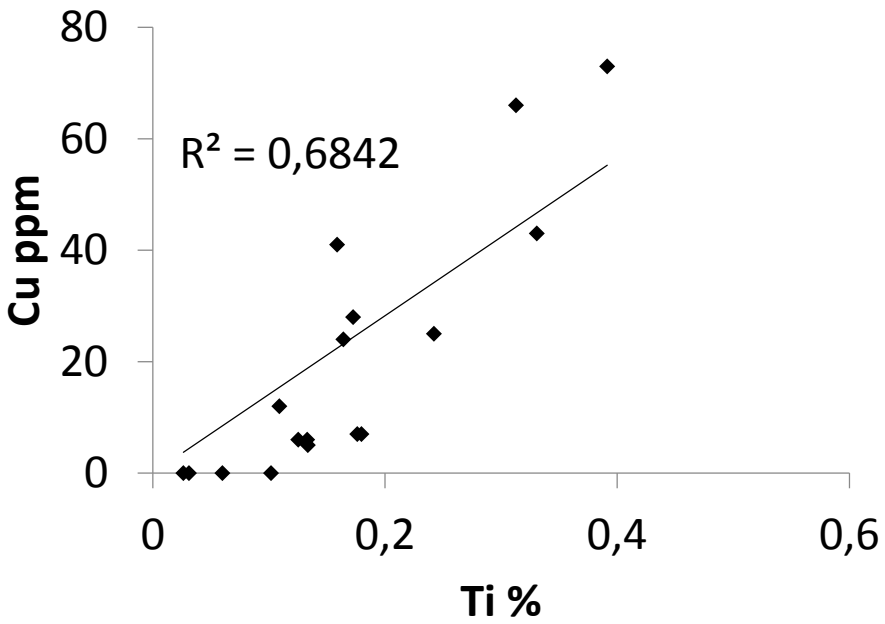
Shublik Detrital & Productivity Proxies
Entire Section



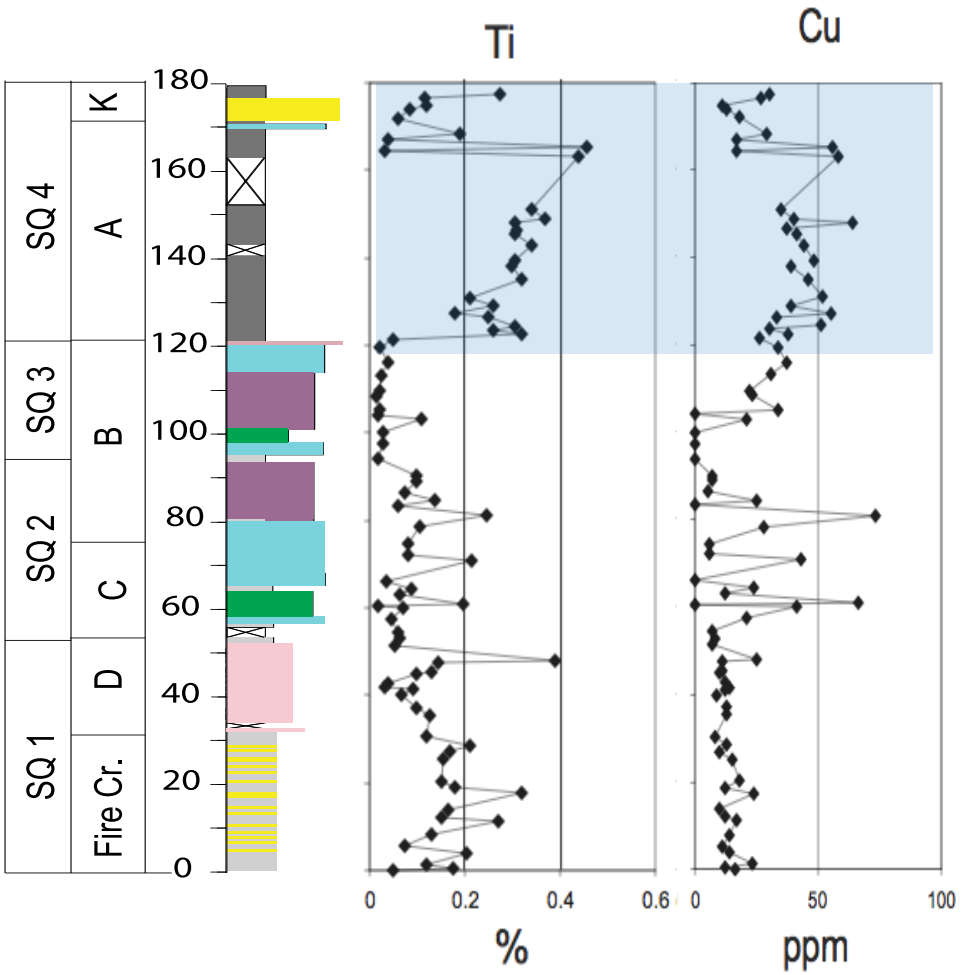


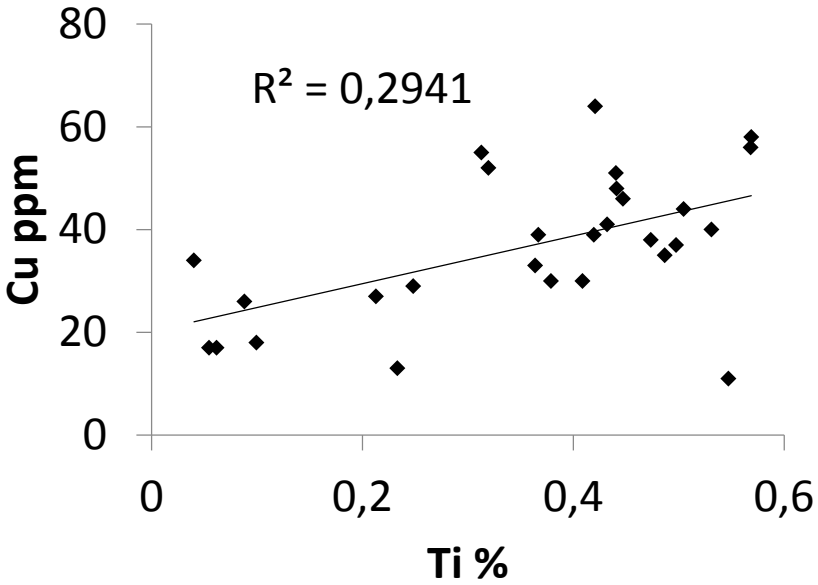
Shublik Detrital & Productivity Proxies
Sequence 2 – Highest TOCs



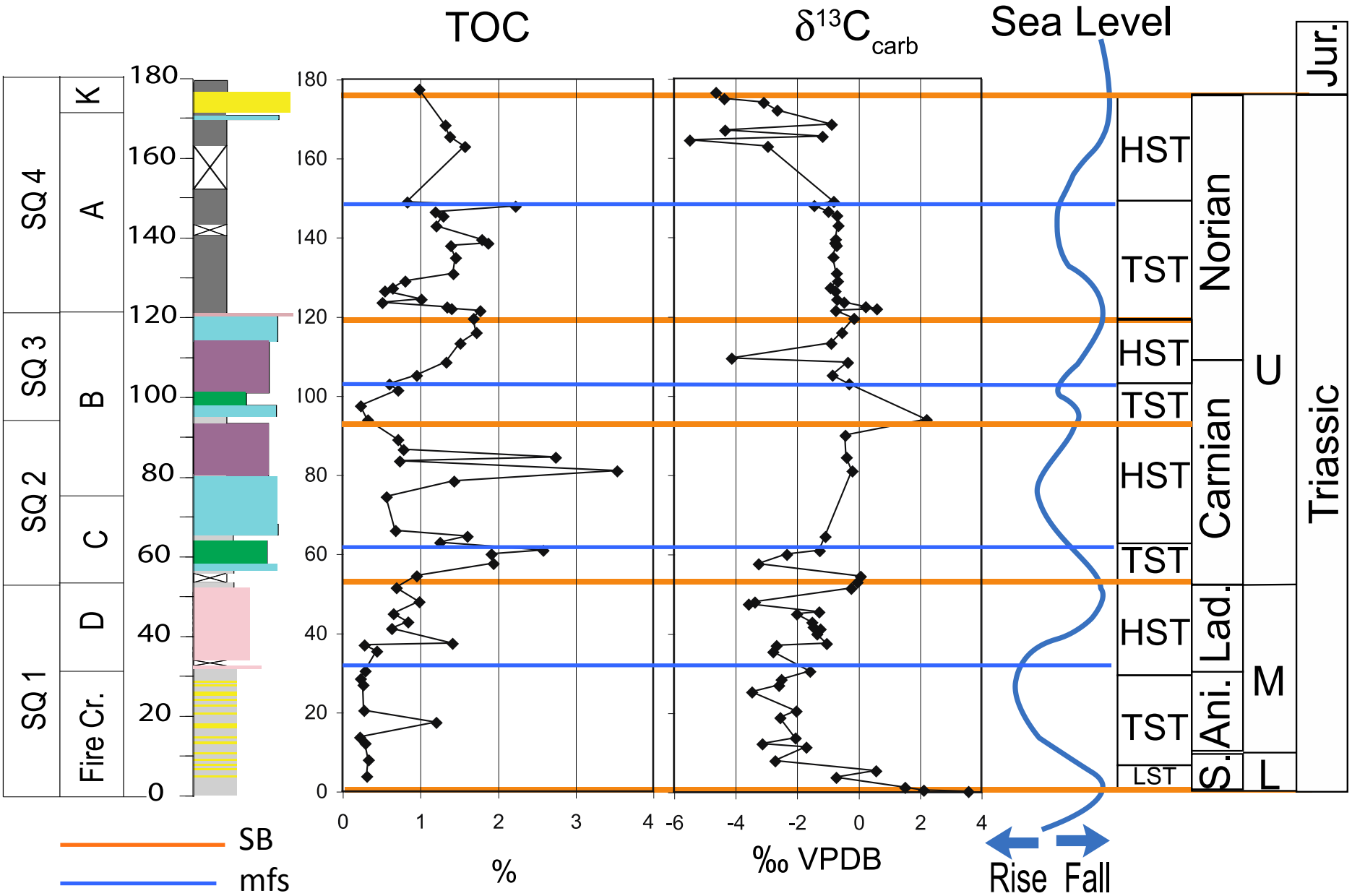


Shublik Detrital & Productivity Proxies Sequence 4

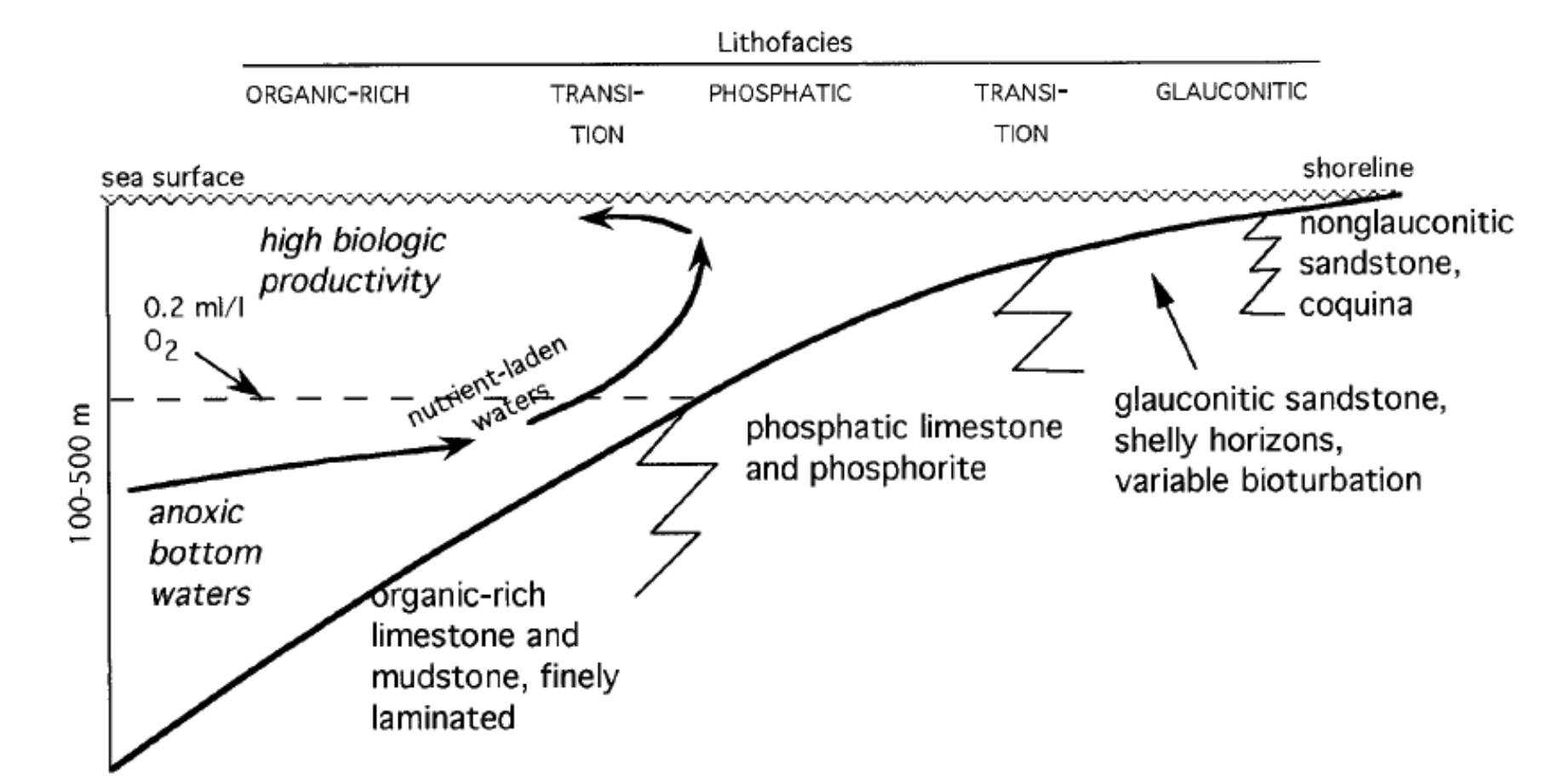




Sea Level Change, TOC & $\delta^{13}C$



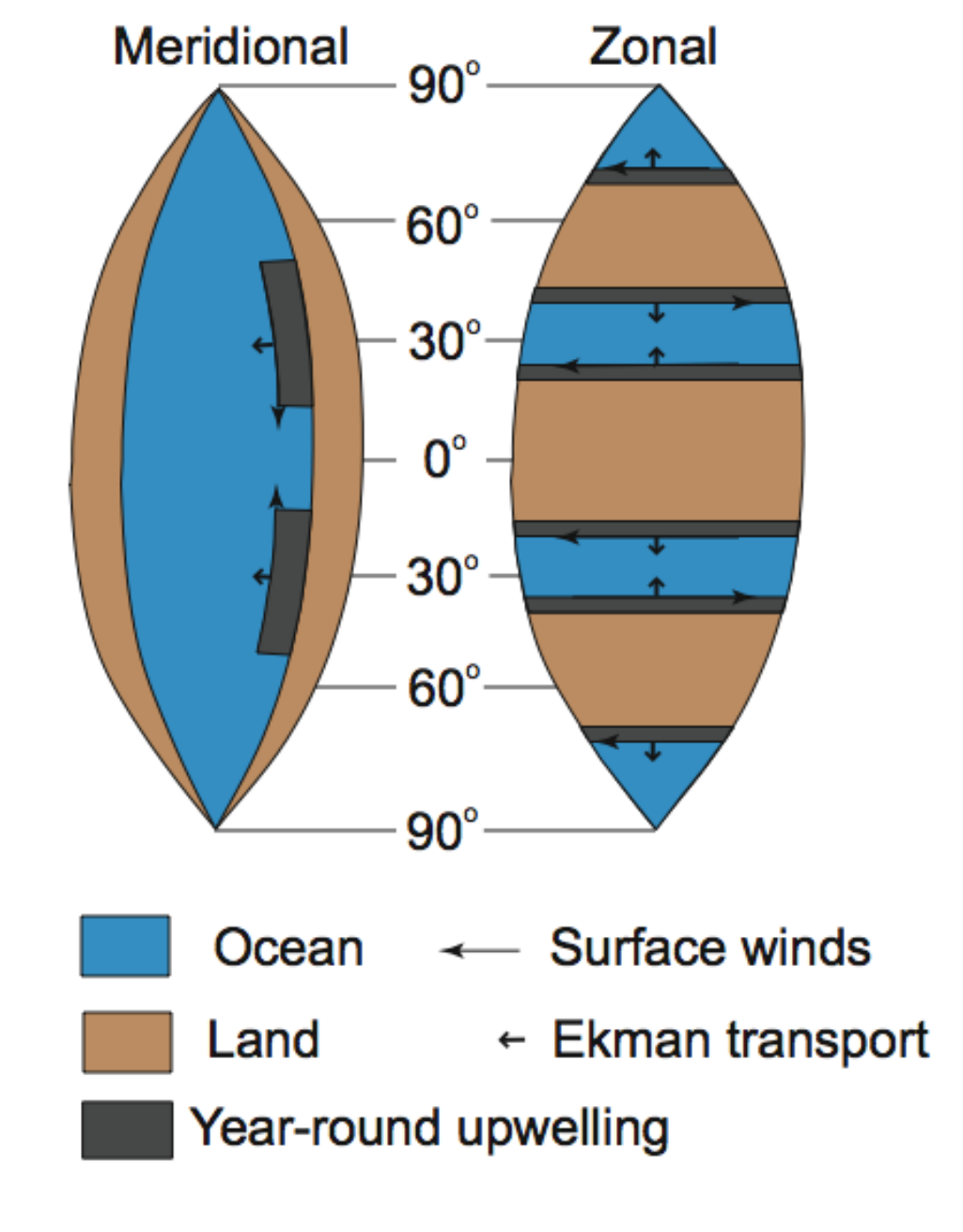
Upwelling Model



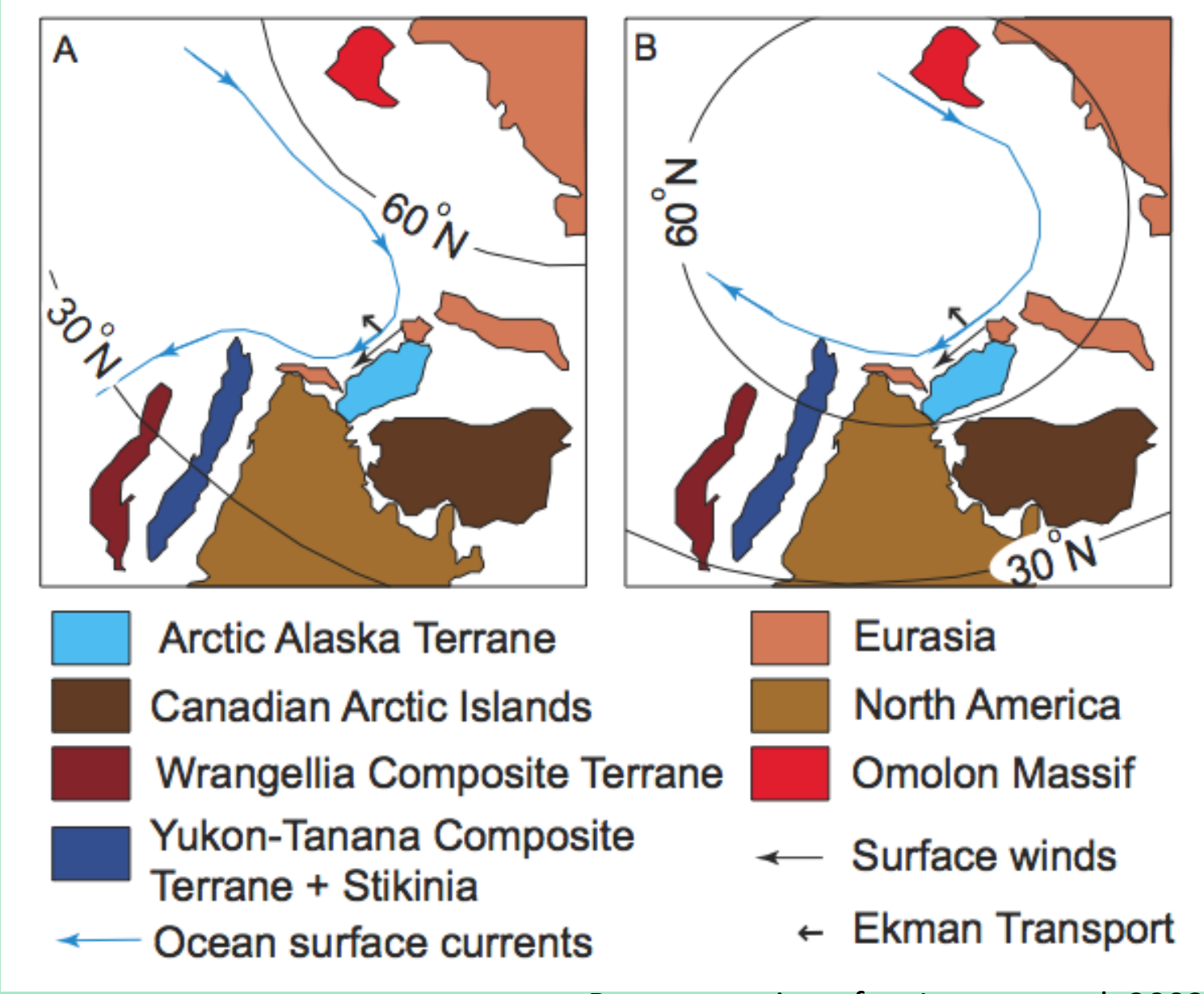
From Parrish et al., 2001

Upwelling Patterns

- Upwelling largely controlled by atmospheric circulation patterns
- Meridional along the western margins of continents
- Zonal along the boundaries between major atmospheric circulations cells

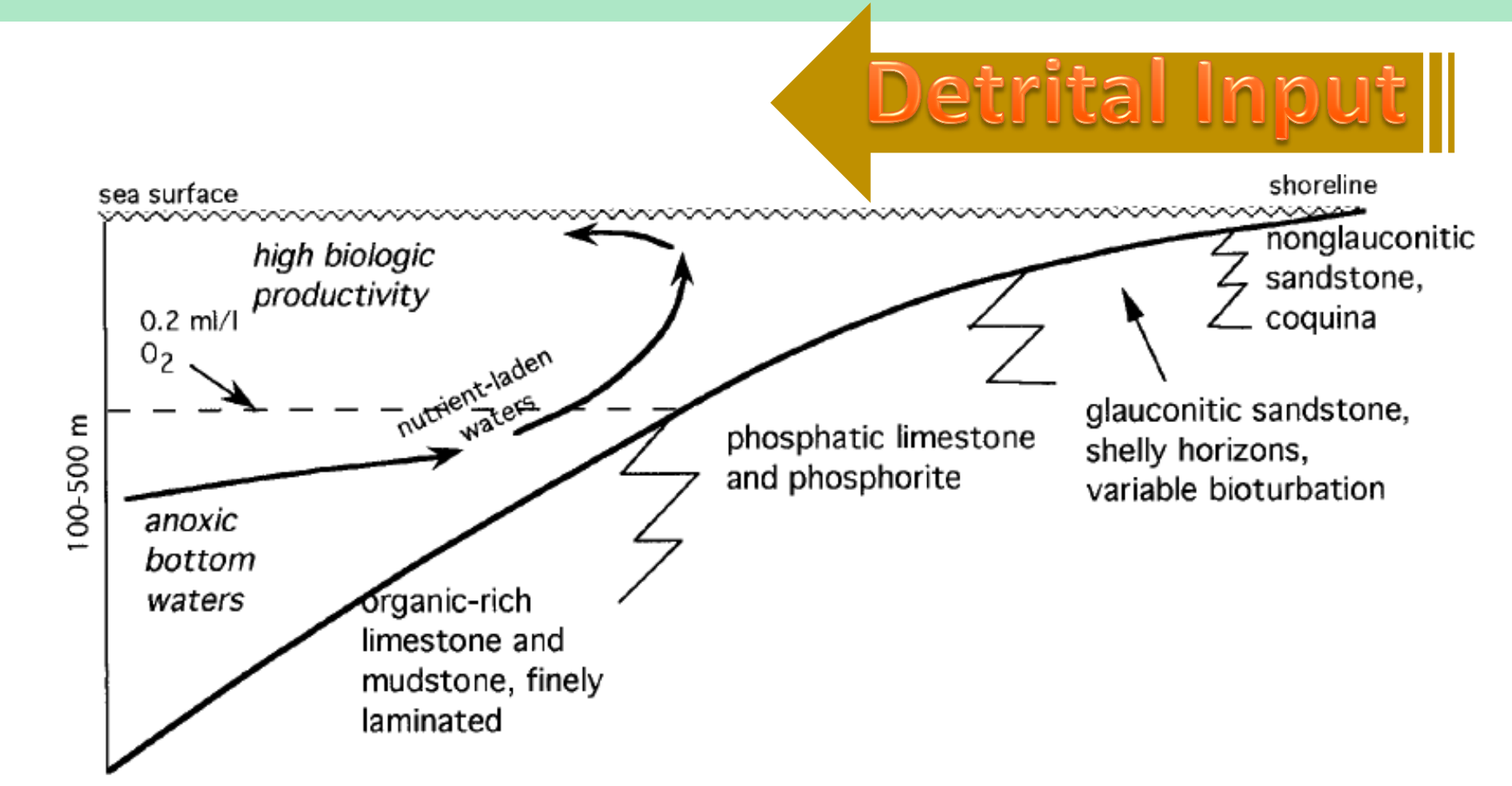


Paleogeography & Oceanic Circulation

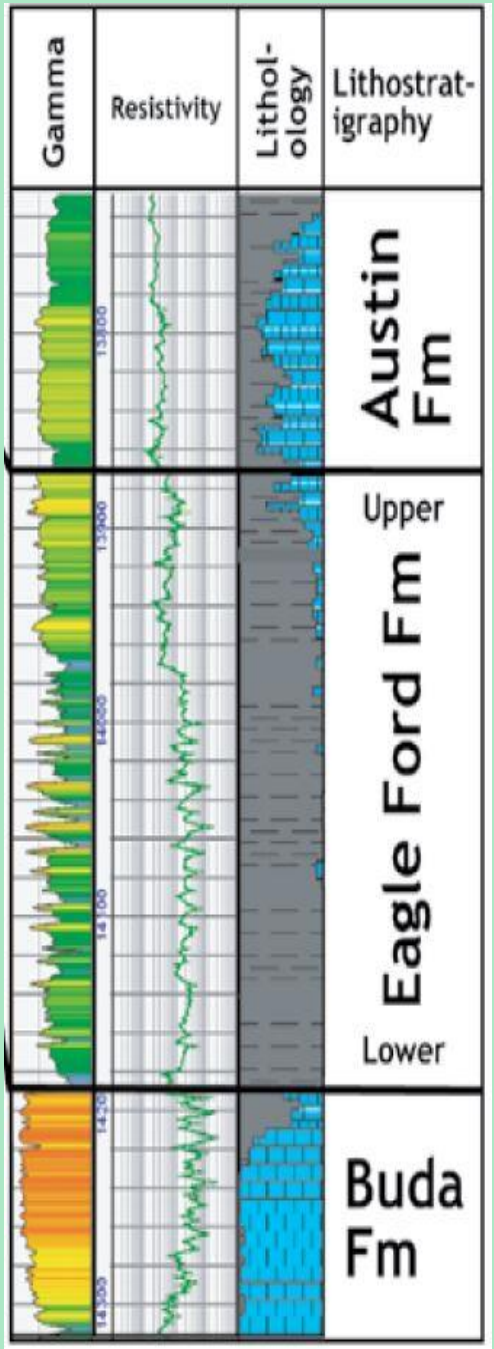


Reconstruction after Lawver et al. 2002

Upwelling + Detrital Input



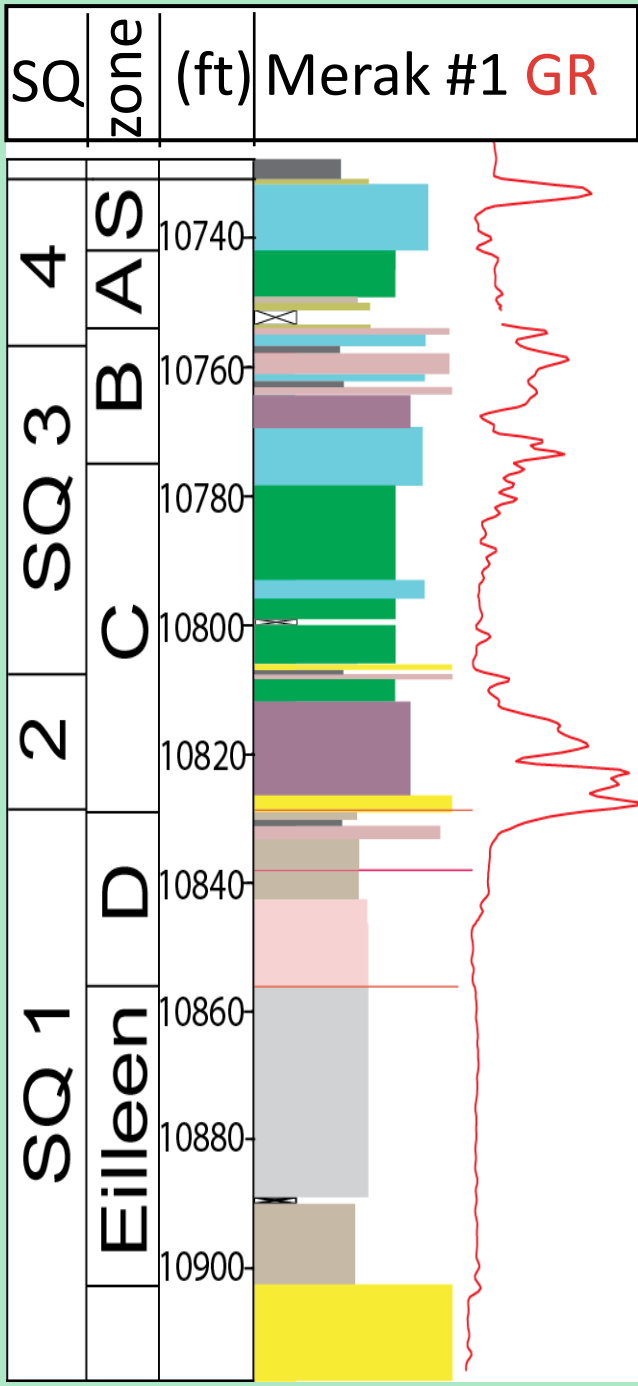
From Parrish et al., 2001



(Ratcliffe et al. 2012)

Shublik as an Unconventional Resource?

- Not your **"typical"** unconventional resource system
- Complex interbedded assemblages of varying lithofacies and rock properties
- Should not be called the Shublik "shale"



Conclusions

- Mid-Upper Triassic Shublik and associated units deposited as four depositional sequences
- High productivity and source Rock accumulation under both low oxygen and oxic conditions and in both TST, HST
- Upwelling likely drove high productivity but detrital input also important
- Heterogeneity of Shublik facies differs from most unconventional plays like the Eagle Ford, Bakken, or Marcellus making it an unconventional unconventional resource

Acknowledgements

- Department of Natural Resources - Alaska Division of Geological and Geophysical Surveys for funding and field logistical support
- Great Bear Petroleum for access to core and subsurface data
- K. Bird and, U.S. Geological Survey, Analytical analyses and encouragement to take project on
- R.C. Burrus,U.S. Geological Survey, unpublished C isotopic data
- M. Katz, RPI; L. Godfrey, Rutgers, A. Milligan, Oregon State; unpublished C isotopic data