Using elemental chemostratigraphy for high-resolution correlation and improved geosteering in Mid-Continent gas shales

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Elemental Applications for E&P

Mineralogy

Lithology

Depositional Facies

Diagenetic Facies

Reservoir Quality

Stratigraphy

Elemental Applications for E&P

✦ **Reservoir Development:** *Improved correlation, delineation, fairway recognition, and model input*

✦ **Wellbore Positioning:** *Critical picks for casing point, coring point, TD, and Chemosteering®*

✦ **Formation Evaluation:** *Prediction of lithology, mineralogy, and potentially reservoir quality*

✦ **Frac Design (in development):** *Prediction of critical mechanical properties in gas shales*

Elemental Chemostratigraphy

✦ *A proven correlation technique that utilizes changes in the inorganic geochemical composition of siliciclastic and carbonate sediments.*

✦ *Data for up to 50 elements are determined in the laboratory using ICP-OES/MS and XRF instruments, allowing the "fingerprinting" of sedimentary rock units.*

✦ *Particularly useful where:*

- *Fossils are sparse or absent*
- *High sedimentation rates reduce biostratigraphic resolution*
- *Petrophysical log signatures are ambiguous*

✦ *Highly successful for correlation* *on scales ranging from individual reservoirs within a field to thick sequences across a region.*
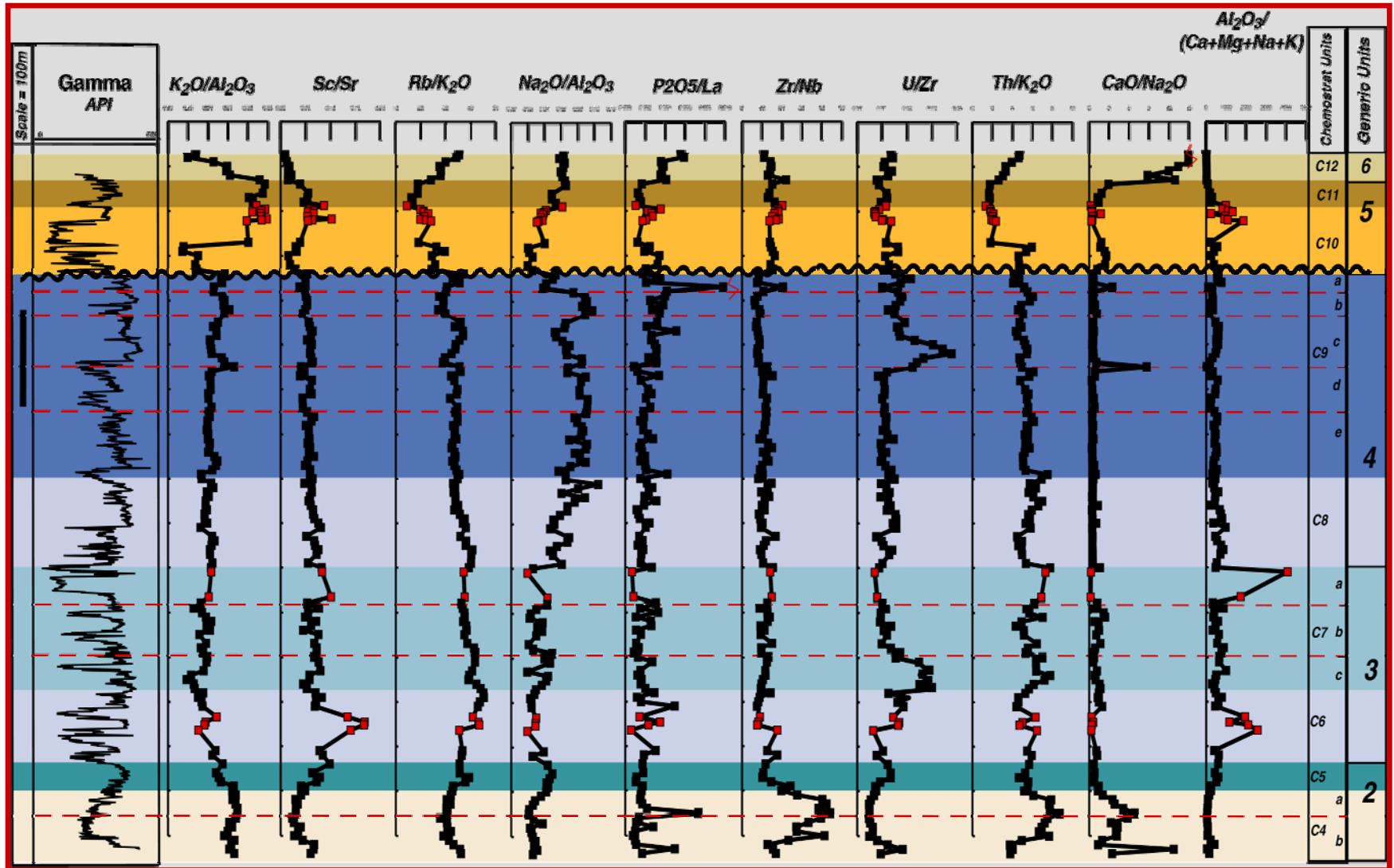
Problem: Poor Field-Scale Correlation
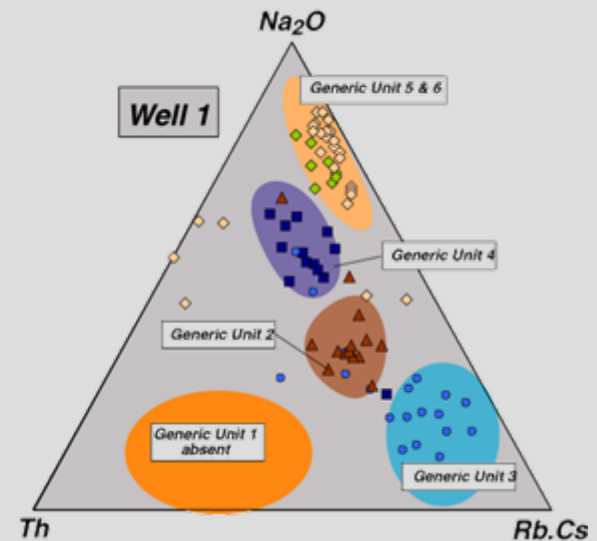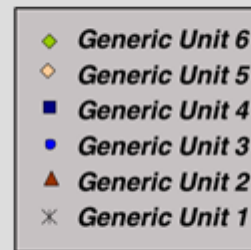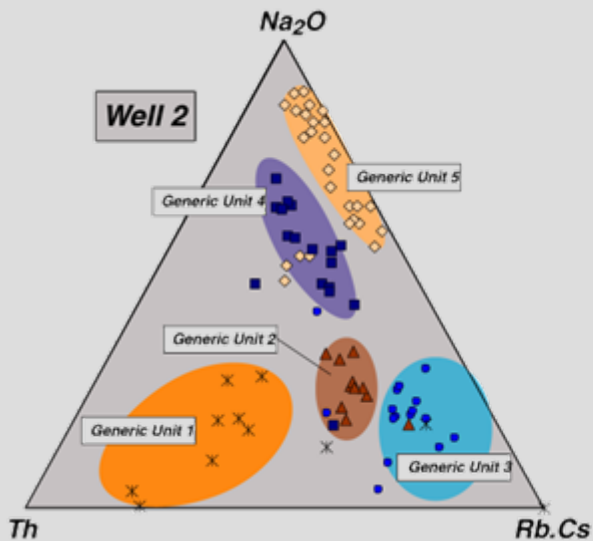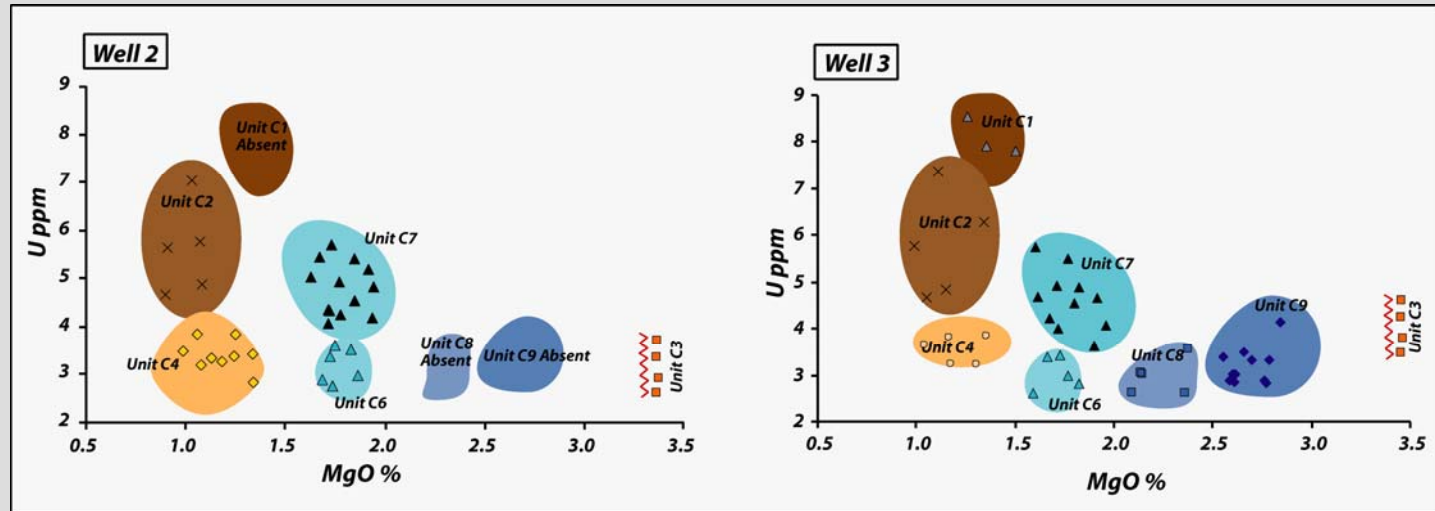# Carboniferous Shallow-Marine Gas Sands in Algeria
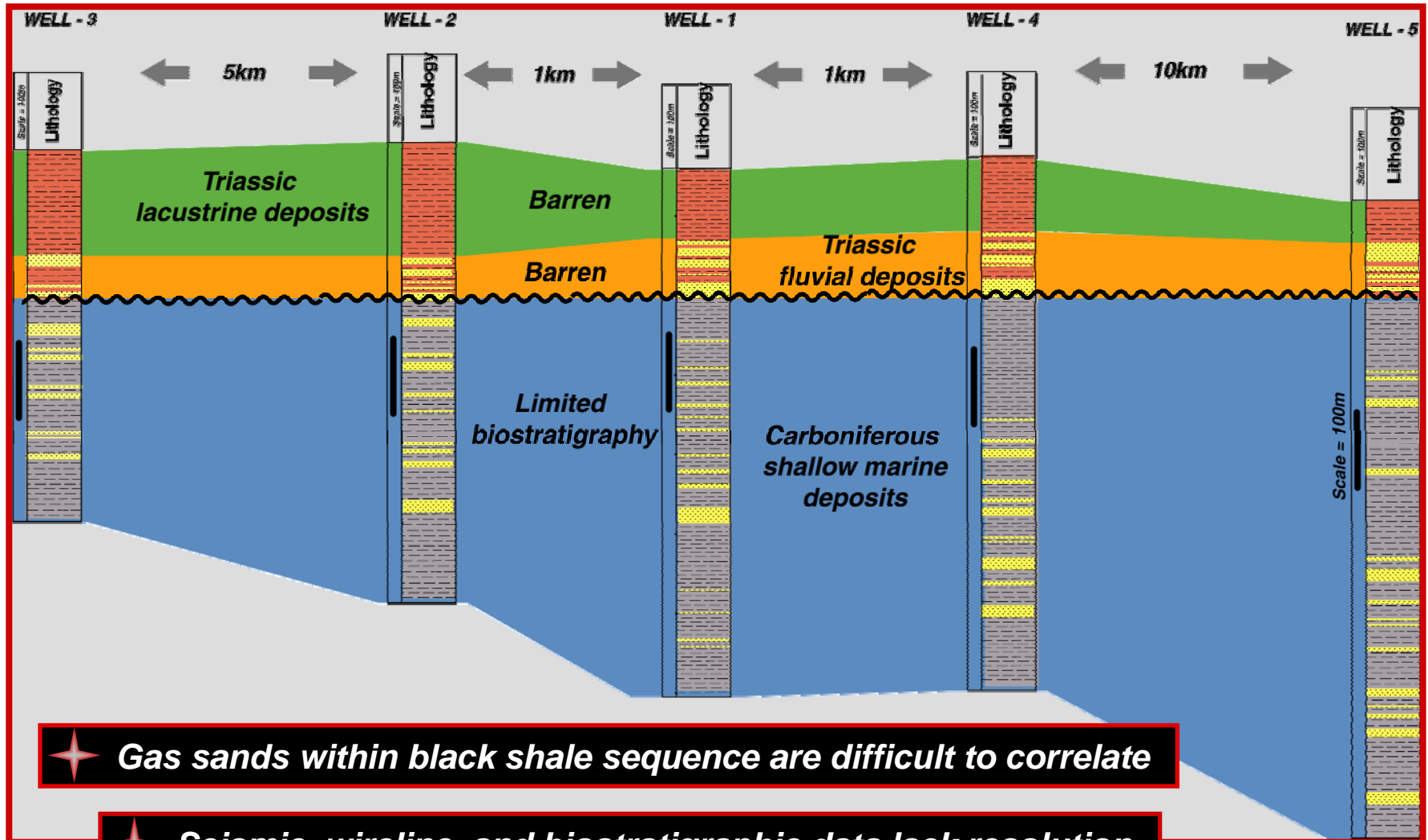
Key Elemental Ratio Profiles
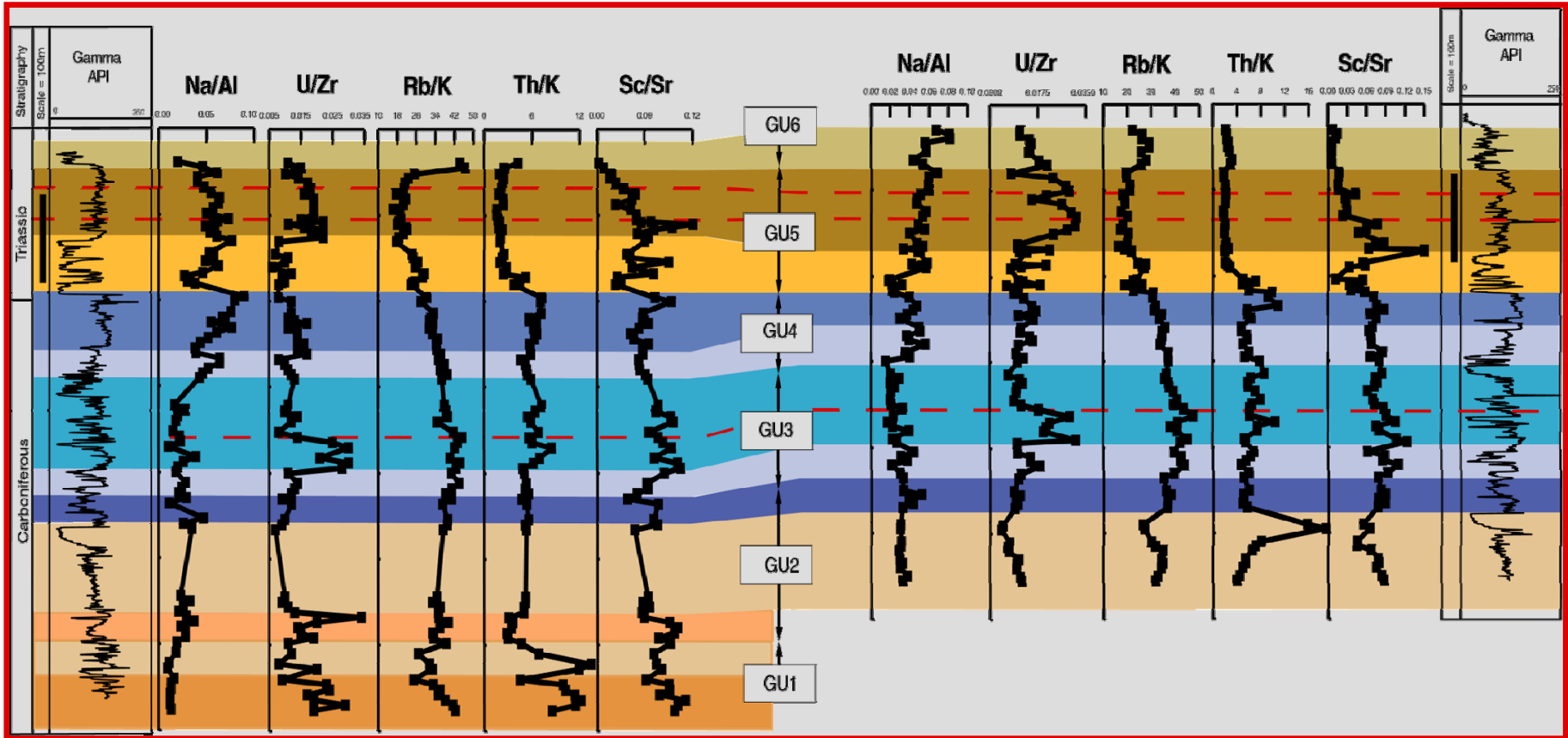## Chemostratigraphic Zonation Based on Shales

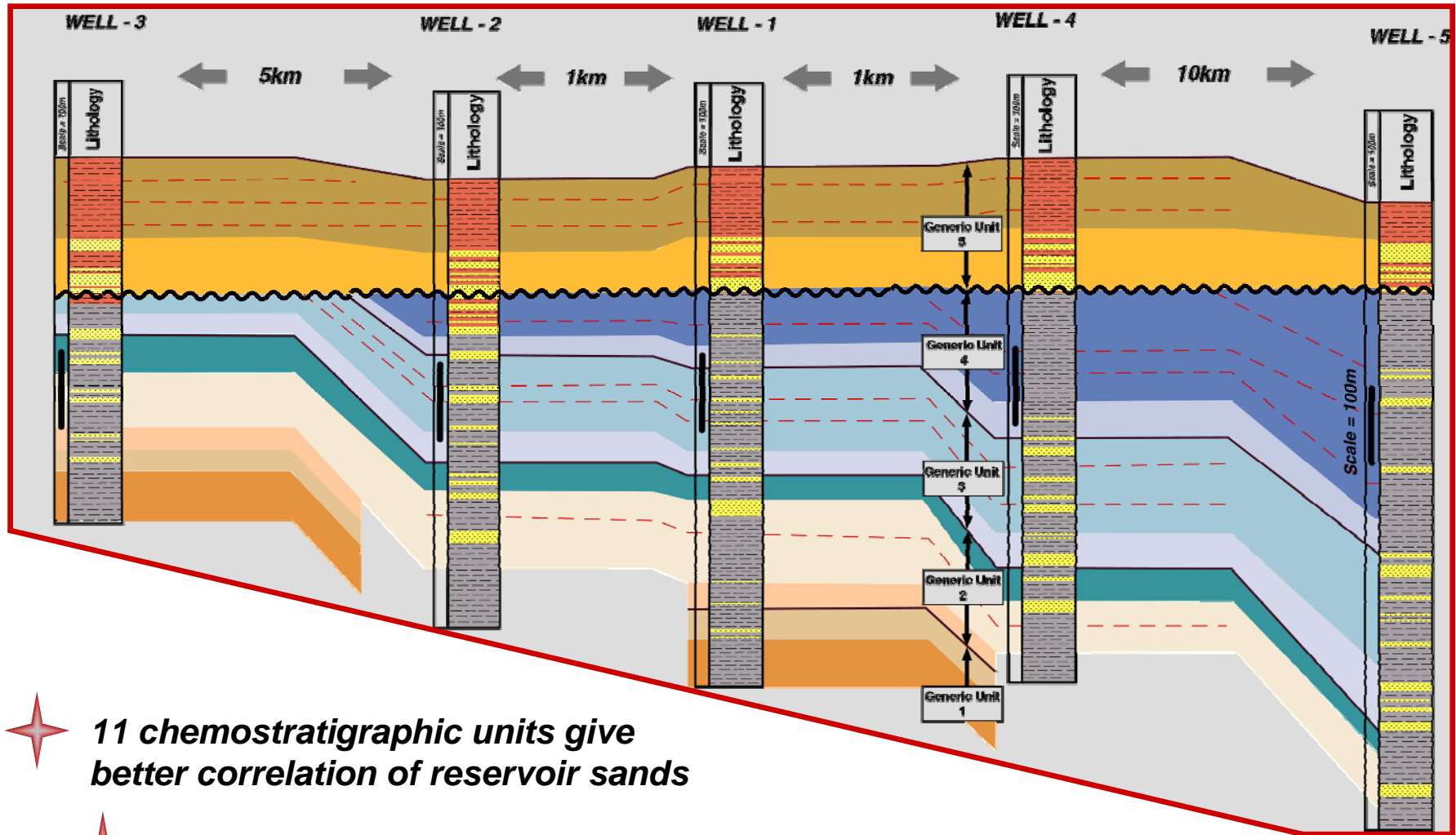# Binary & Ternary Plots Allow Discrimination of Chemostratigraphic Units

Two-Well Correlation
Chemostratigraphic Zonation Based on Shales

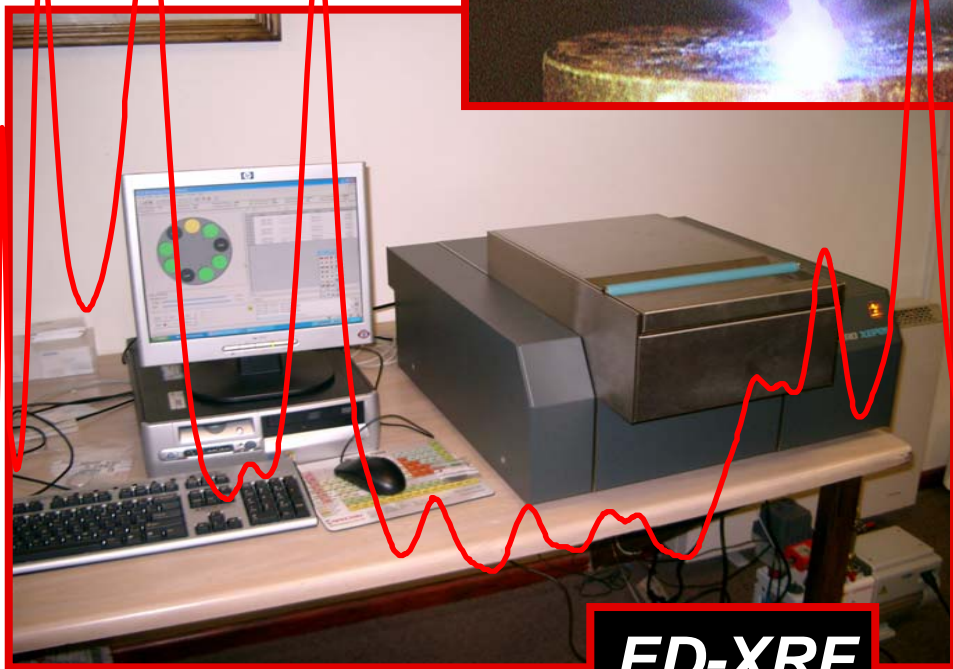# Solution: Greatly Improved Correlation Utilizing Chemostratigraphy

11 chemostratigraphic units give better correlation of reservoir sands

Correlation is valid for almost 700 meters of section over a distance of 17 kilometers
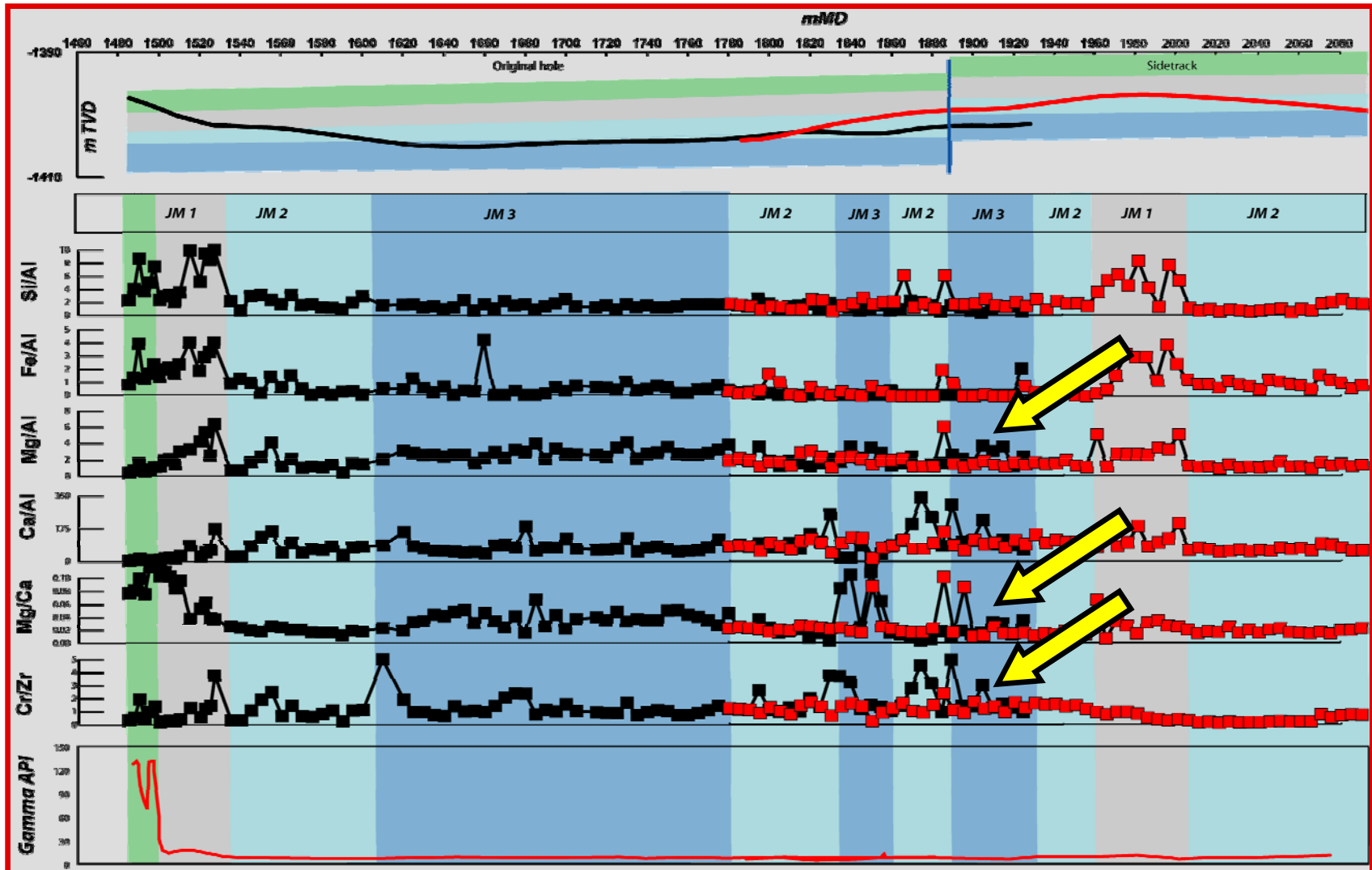
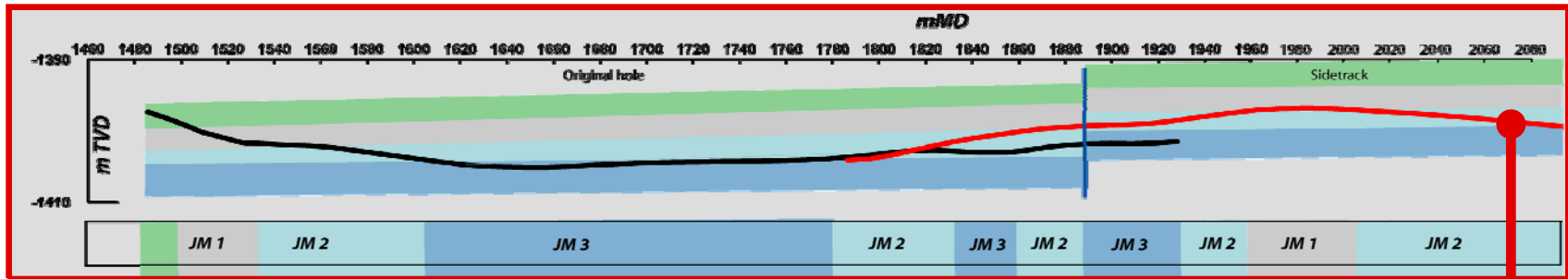# Wellsite Analytical Instrumentation

Data in
20-30 minutes
from cuttings

ED-XRF

LIBS

Improved Geosteering Results
Devonian Limestone Reservoir in Canada

Improved Geosteering Results
Devonian Limestone Reservoir in Canada


- Only one extra day of rig time required in a time-critical situation

- 200 meters of additional wellbore exposure to the reservoir was achieved

- Gas flow was doubled from 1.2 to 2.5 MMCFD

Shales Contain Highest Amount of Chemostratigraphic Information!
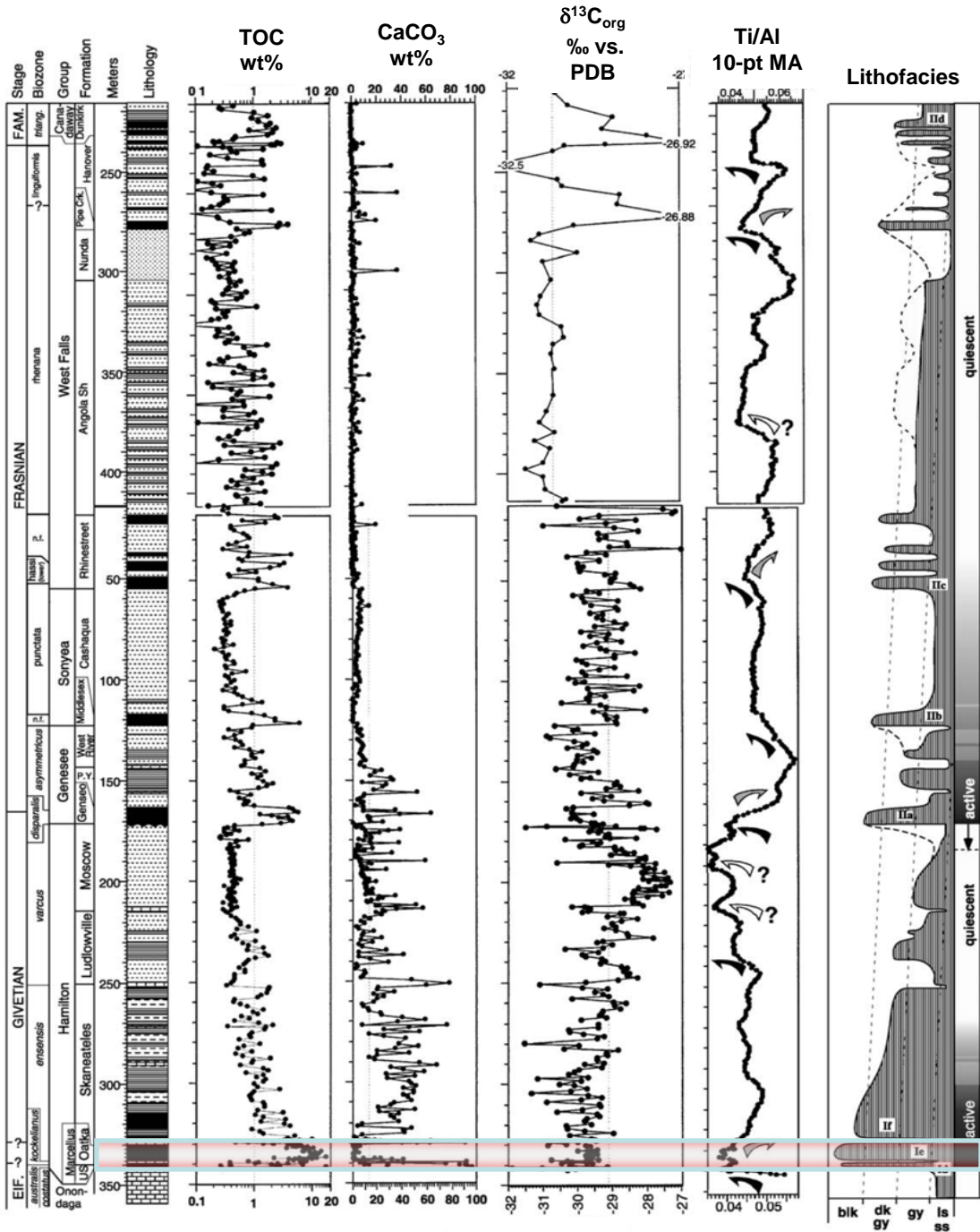
From Jürgen Schieber Website

Devonian Shale Study in Western New York
Core Locations & Stratigraphic Intervals

From Sagemon et al. 2003
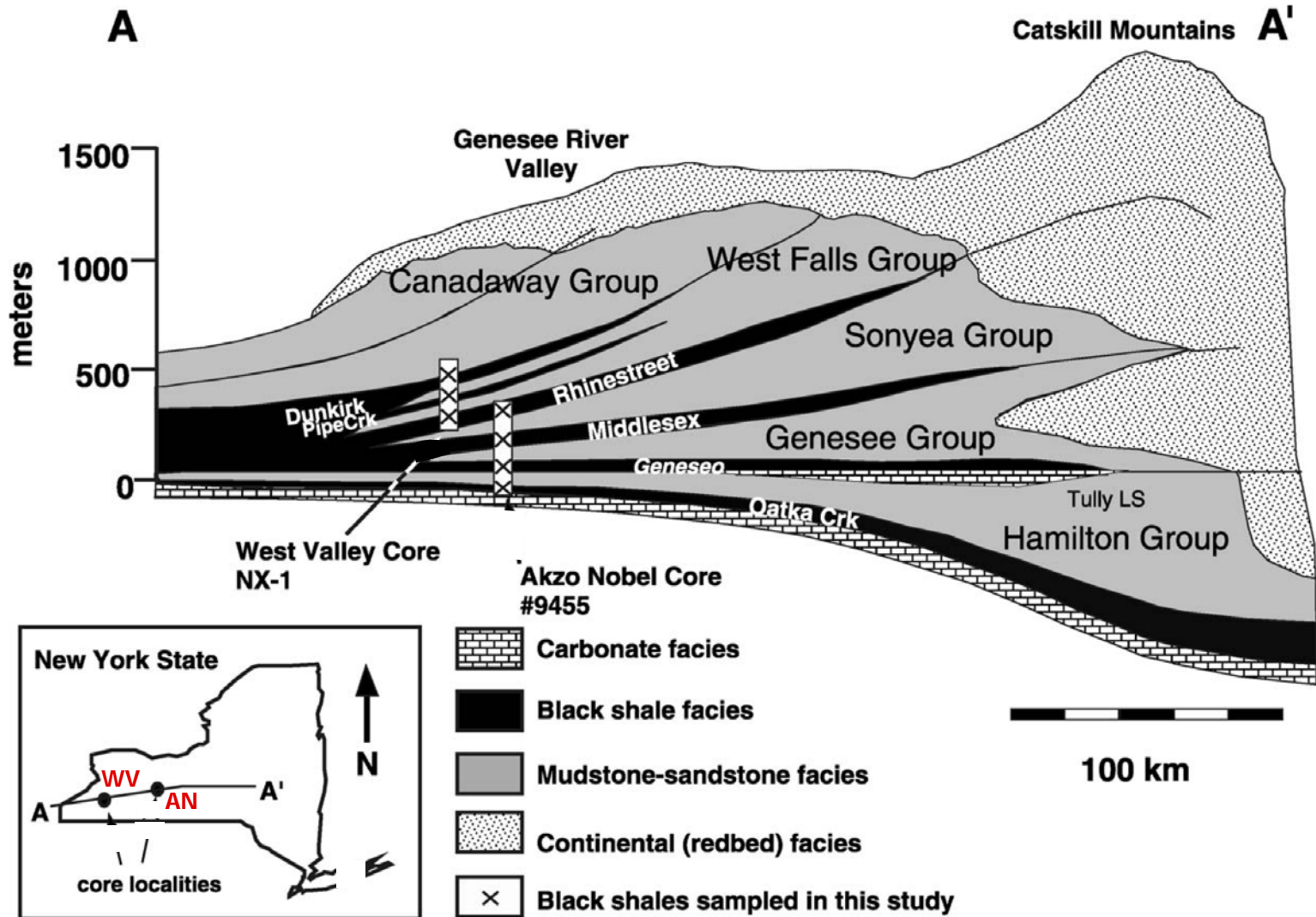
Sageman et al. (2003)

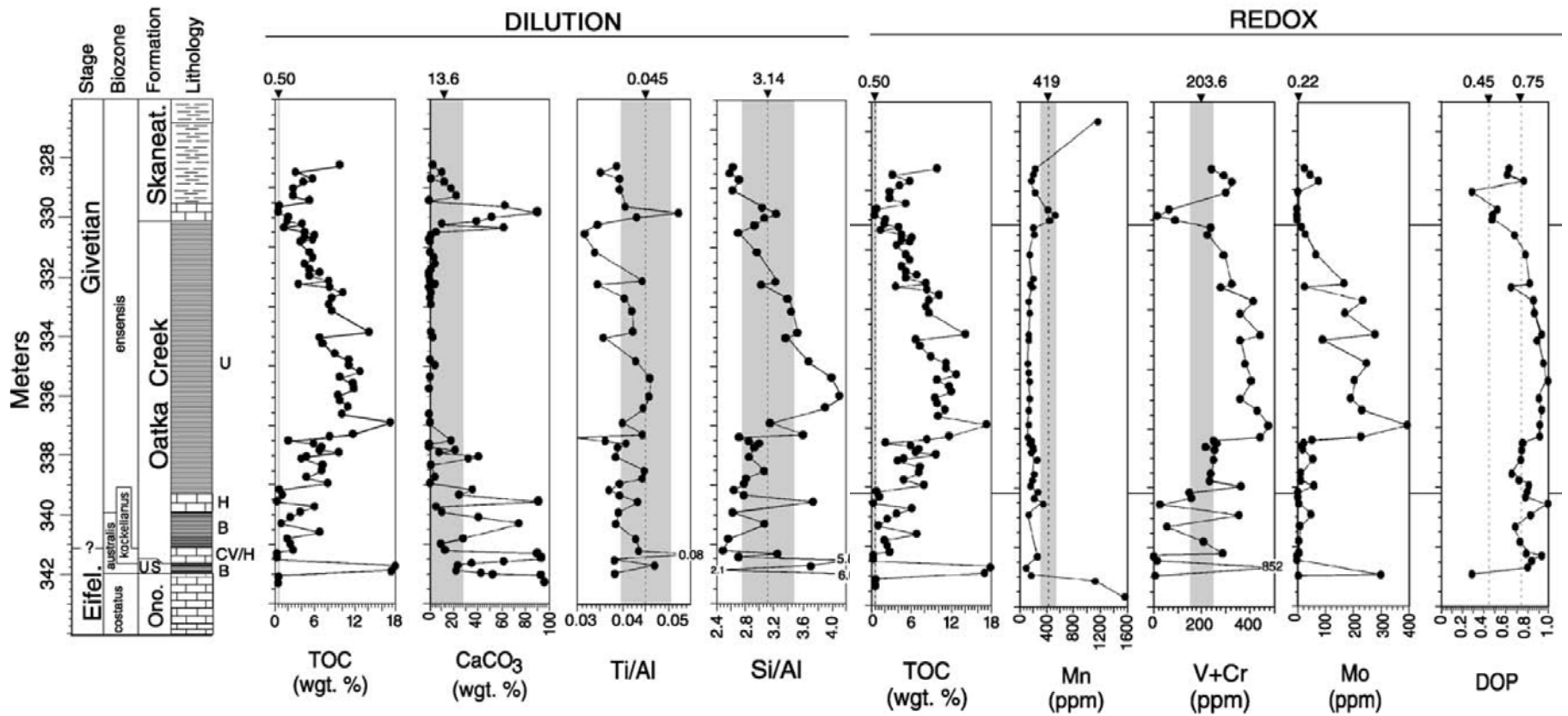- 9 elements
- TOC
- CaCO₃

Standard Chemostratigraphic Study on Shale

- 50-55 elements
- TOC

Marcellus Interval
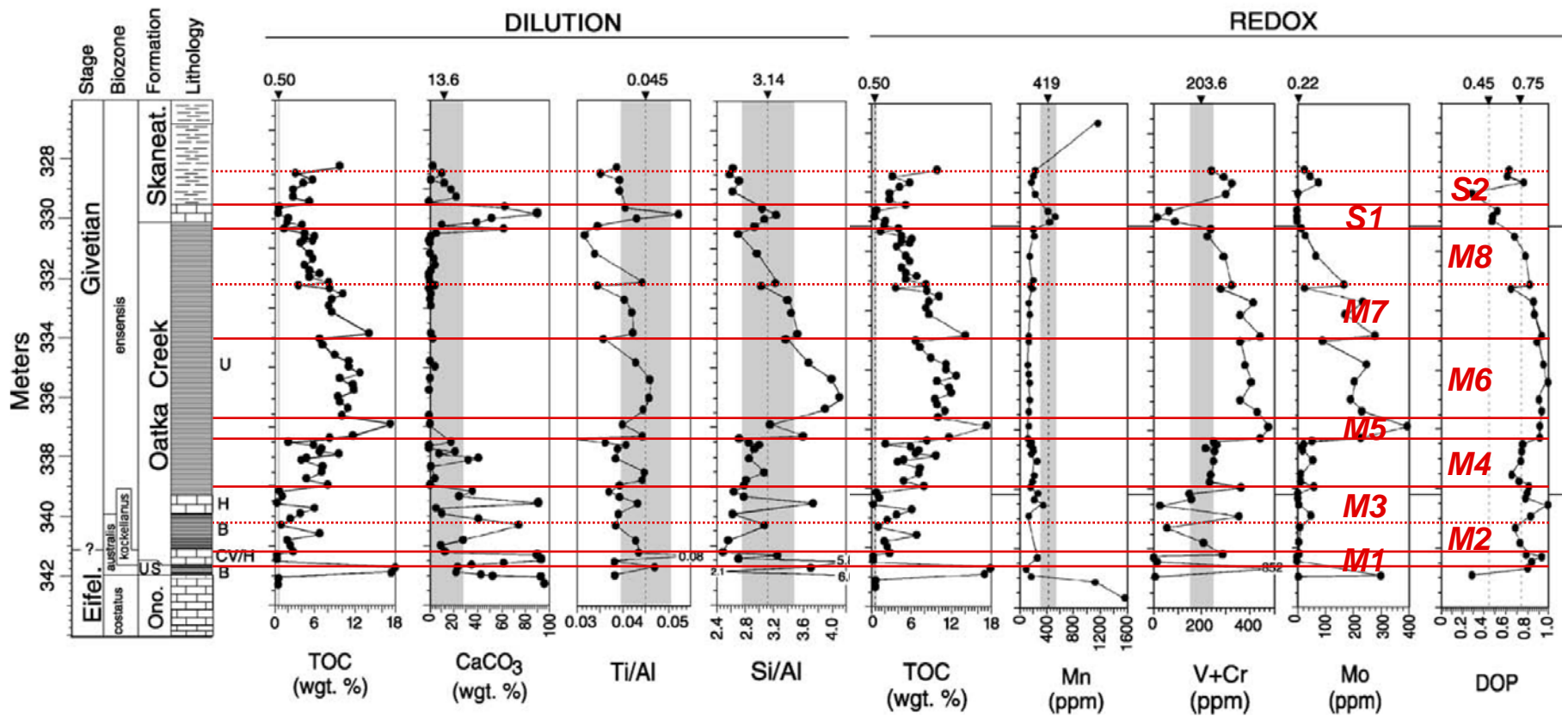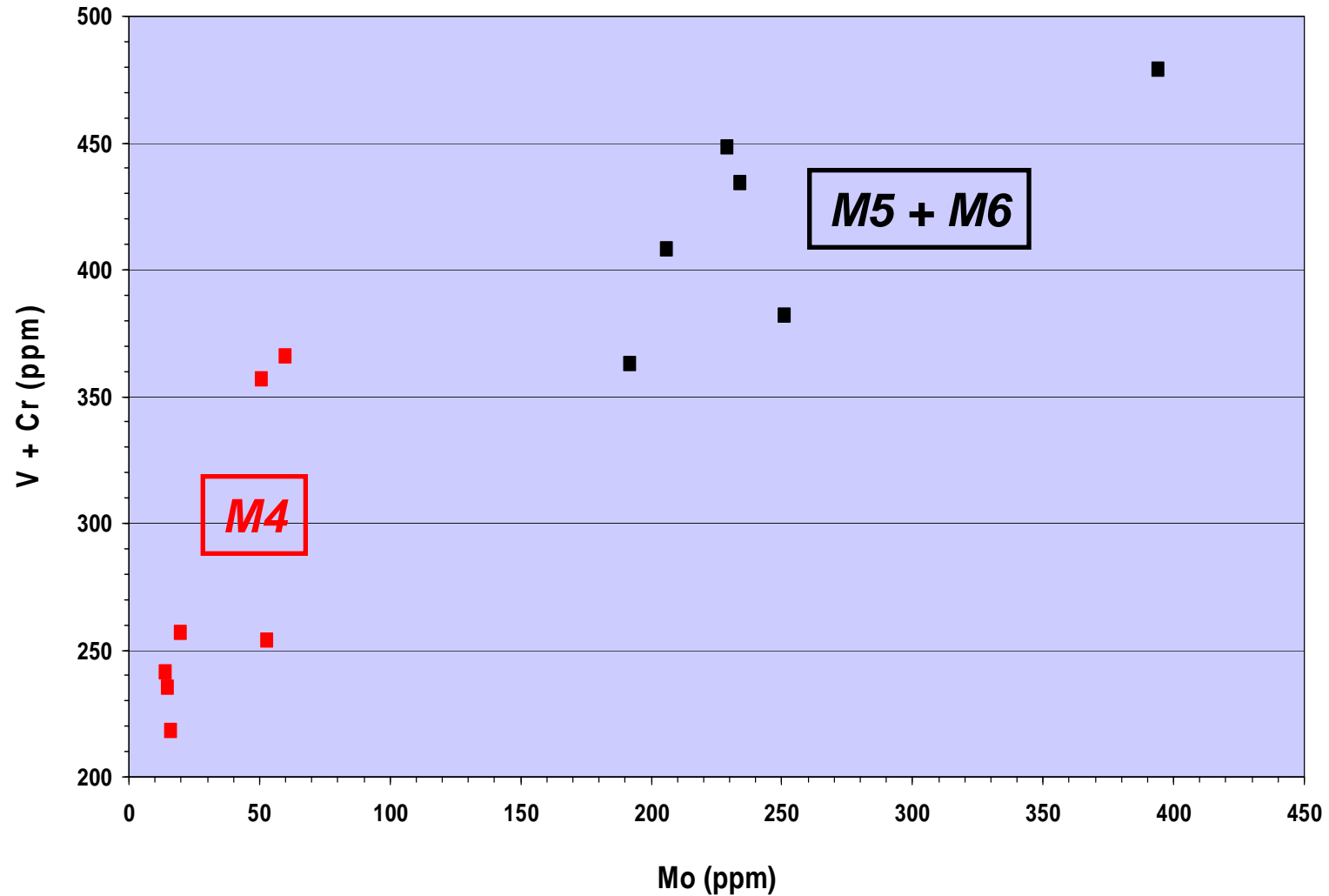12 meters = 39 feet

Geochemical Profiles
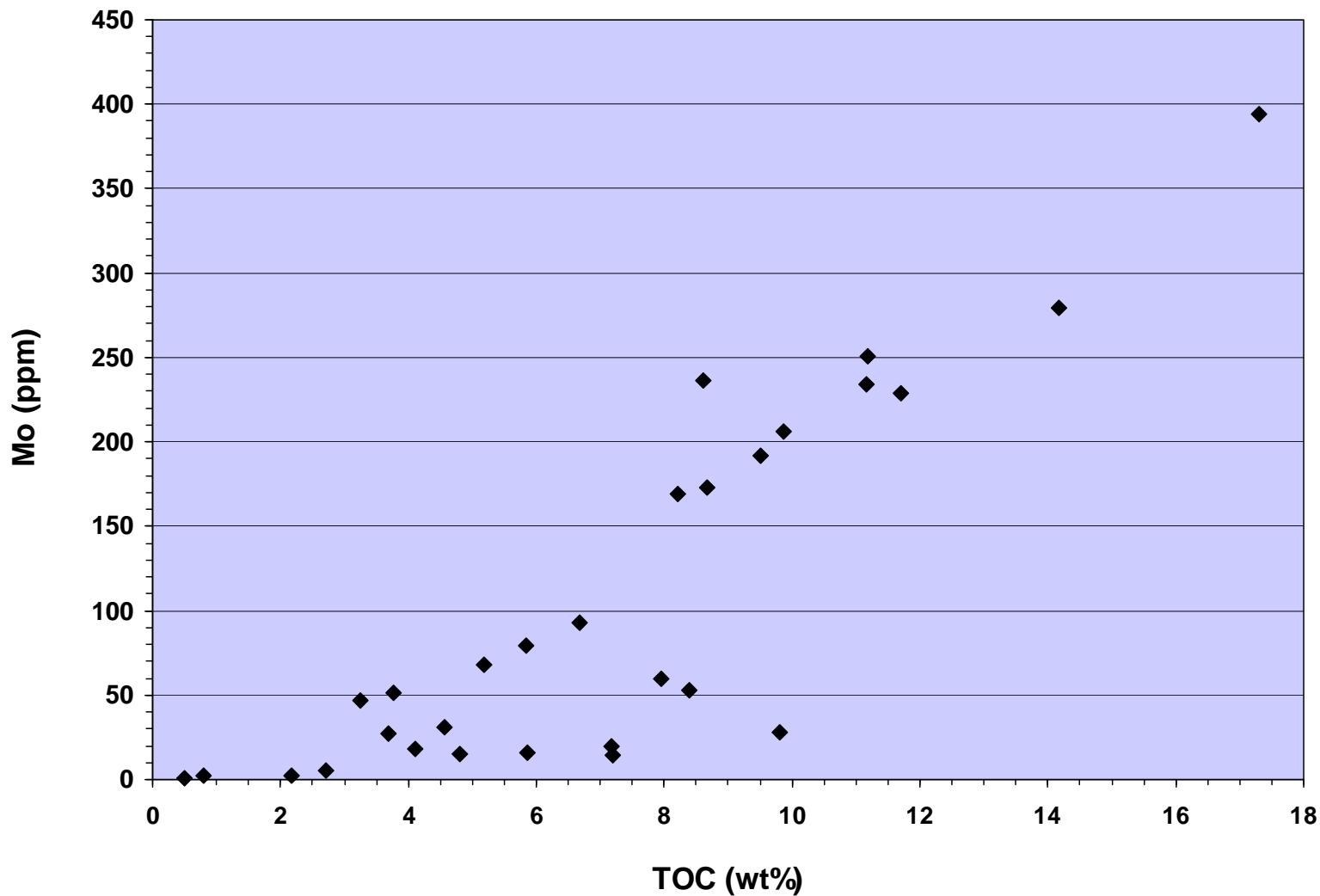## Marcellus Shale in Western New York

From Sagemon et al. 2003

Chemostratigraphic Zonation
Marcellus Shale in Western New York

Modified from Sagemon et al. 2003

Differentiation of Chemostratigraphic Units Marcellus Shale in Western New York

Data from Sagemon et al. 2003

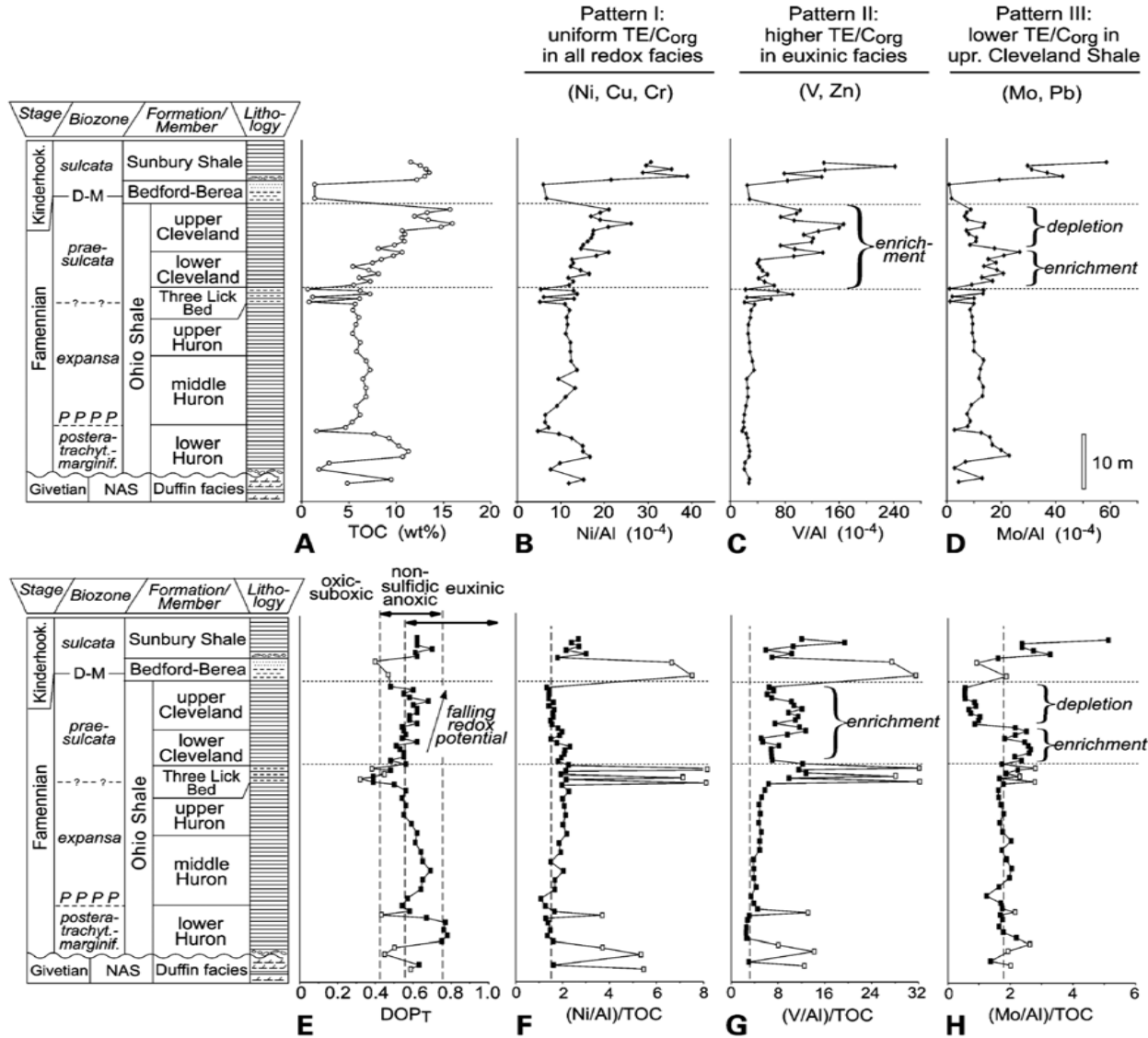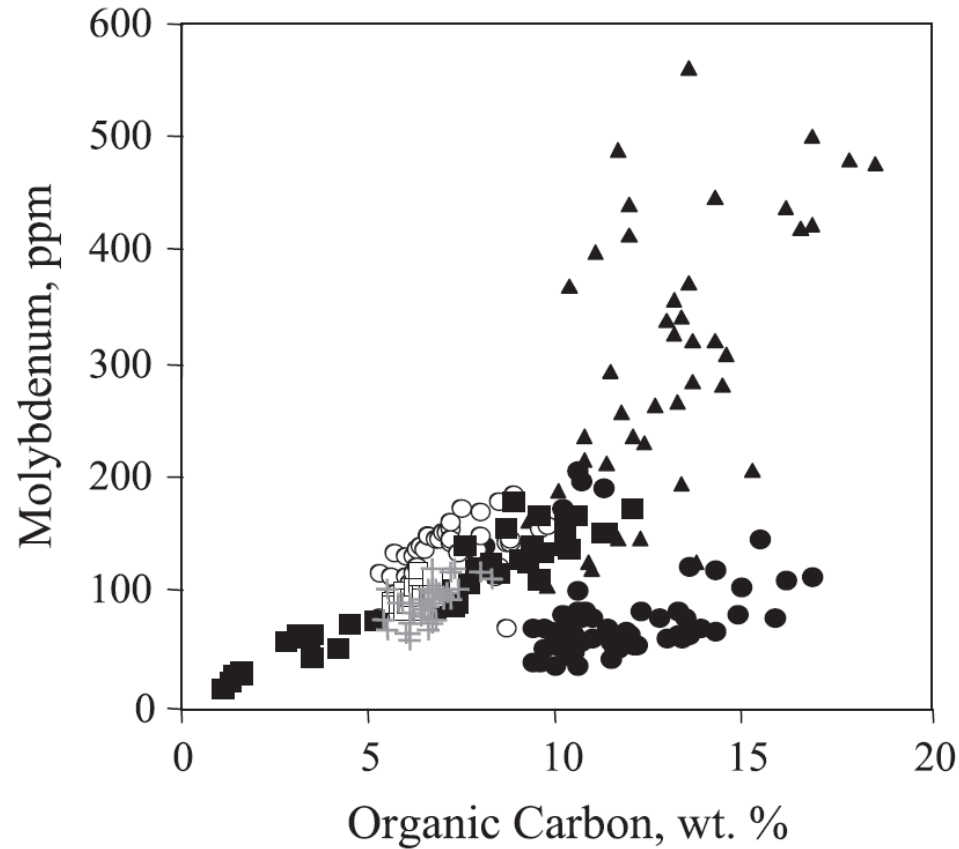# Mo & TOC Relationship
Marcellus Shale in Western New York

Chemostratigraphic Zonation
Ohio Shale in Eastern Kentucky (Algeo 2004)

Mo & TOC Relationships
Ohio Shale in Eastern Kentucky (Rimmer 2004)

Legend:
- ▲ Sunbury
- ● Upper Cleveland
- ○ Lower Cleveland
- □ Upper Huron
- + Middle Huron
- ■ Lower Huron

Construct Predictive Elemental Model
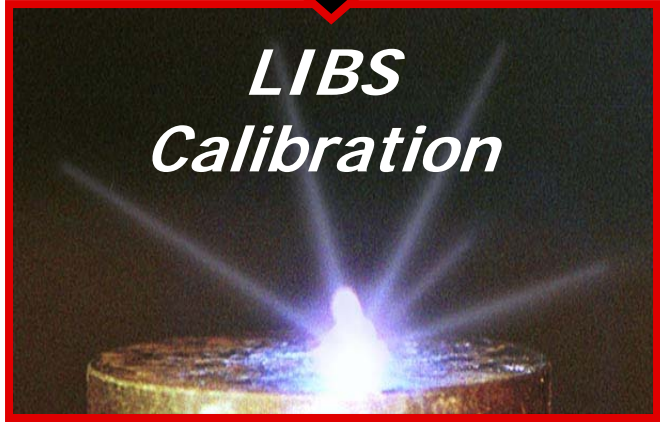# from Comprehensive Gas Shale Data Set
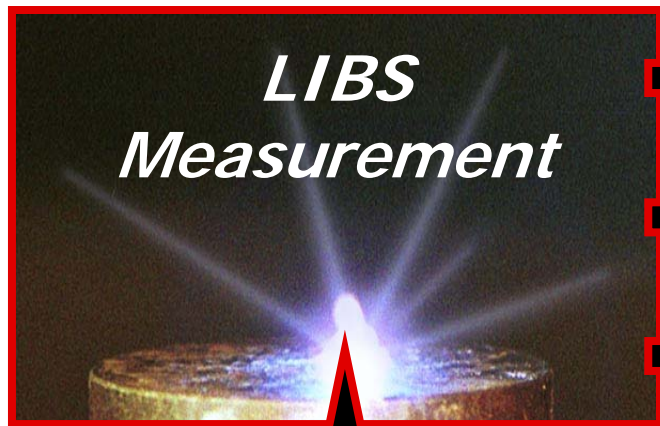
Elemental Composition

Mineralogical Composition

Organic Composition

Flow Properties

Geomechanical Properties

STFM

LPFM

NNEM

LIBS Calibration

Elemental Analysis While Drilling
Immediate Input for Improved Frac Design

LIBS Measurement → *Chemosteering®*

→ *Mineralogy*

→ *Geomechanical Parameters*

Recognition of Carbonate-Filled Fractures in Gas Shales Based on Elemental Data?

✦ *Calibrate against petrographic data based on technique of Laubach (2003)*

✦ *Need large contrast in mineralogy and elemental composition between carbonate fracture-filling and host rock*

✦ *Late carbonate fracture-filling will likely have relatively high Fe_2O_3 + MgO + MnO, and may be recognizable*

✦ *Quartzose tight gas sandstones have very high SiO_2, very low CaO + MgO + MnO – good chance for Travis Peak*

✦ *Most black shales have high Al_2O_3 and TOC, low CaO + MgO + MnO – good chance?*

Microfractures and remnant pores in quartzose sandstone are sealed by late ankerite cement.

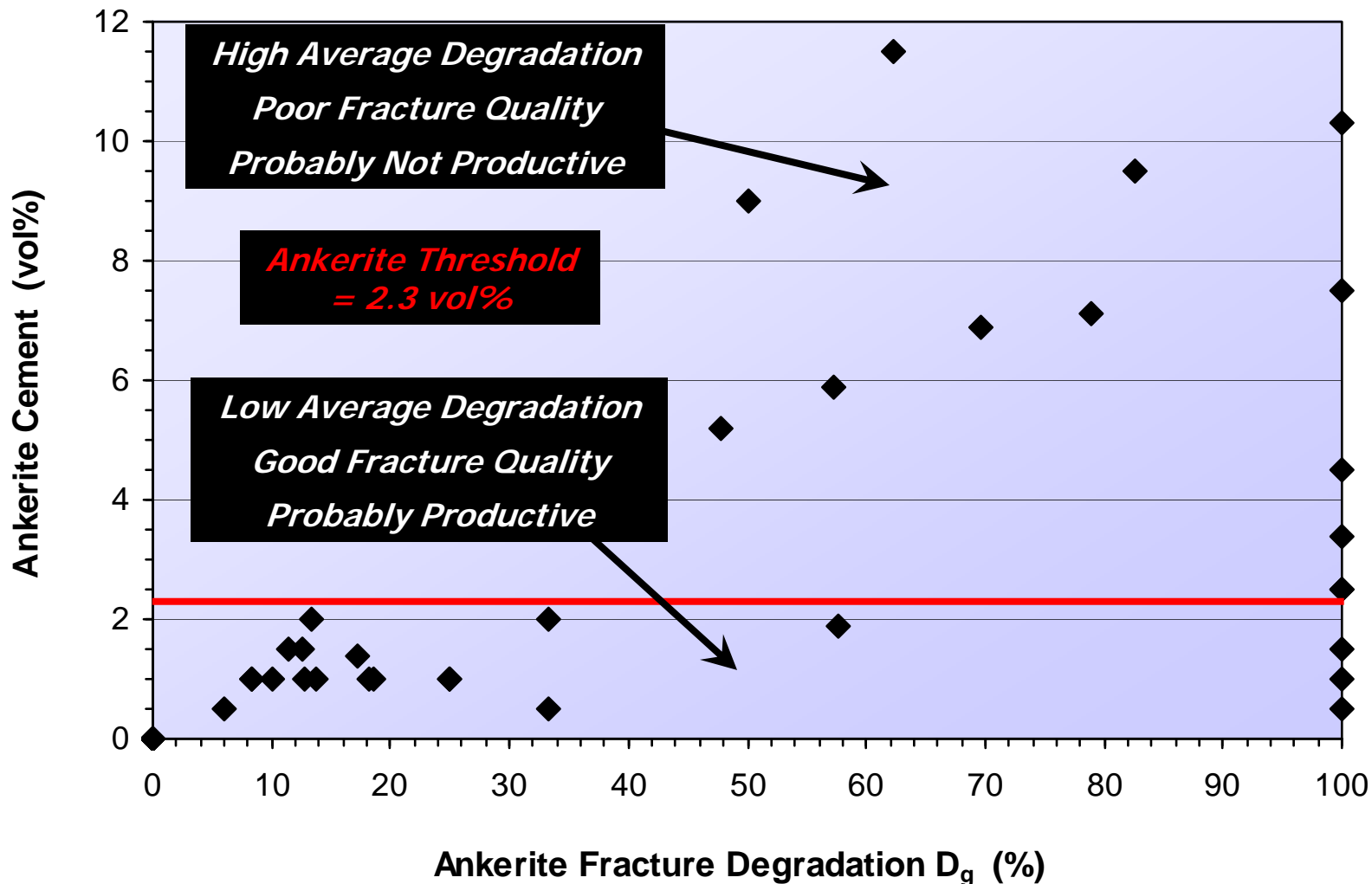High degradation - Poor fracture quality predicted.
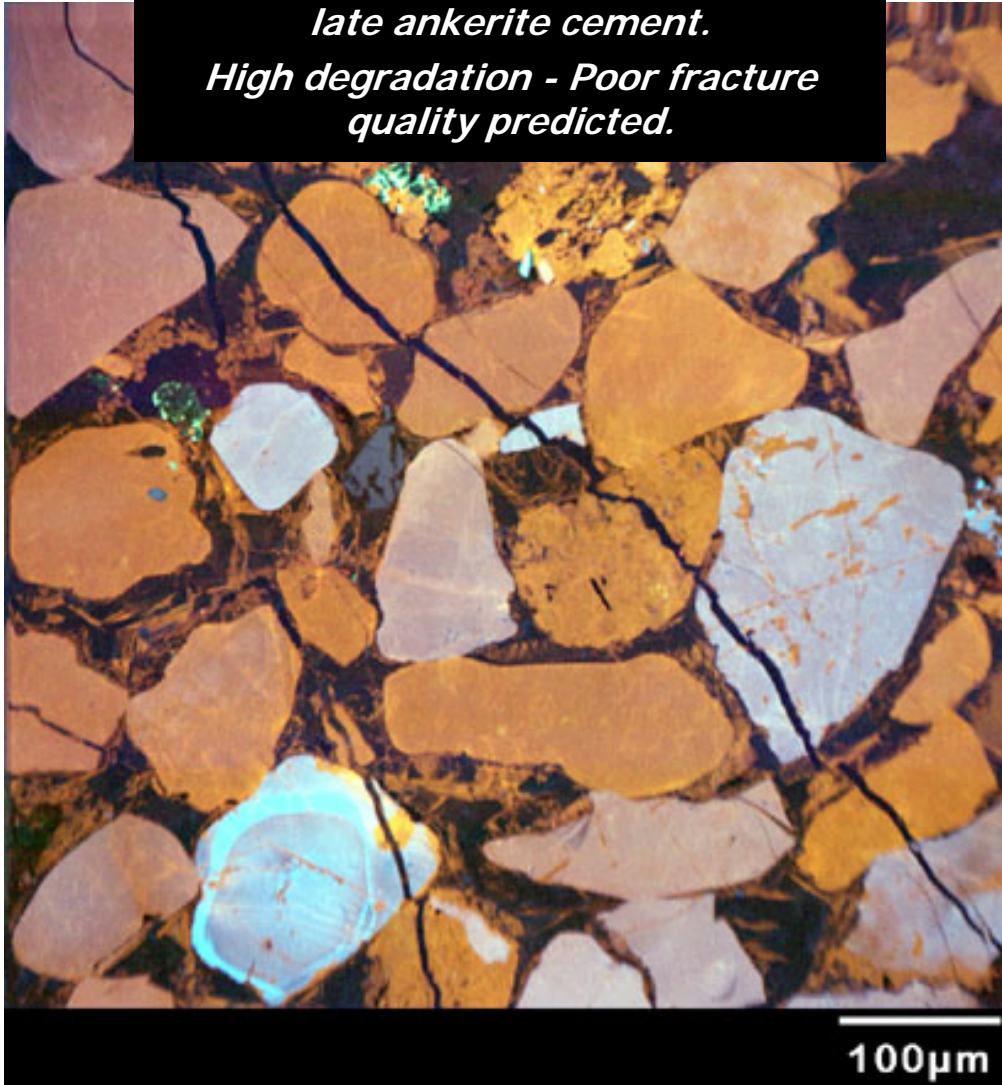
Microfractures and remnant pores in quartzose sandstone are partially open, no late ankerite cement.

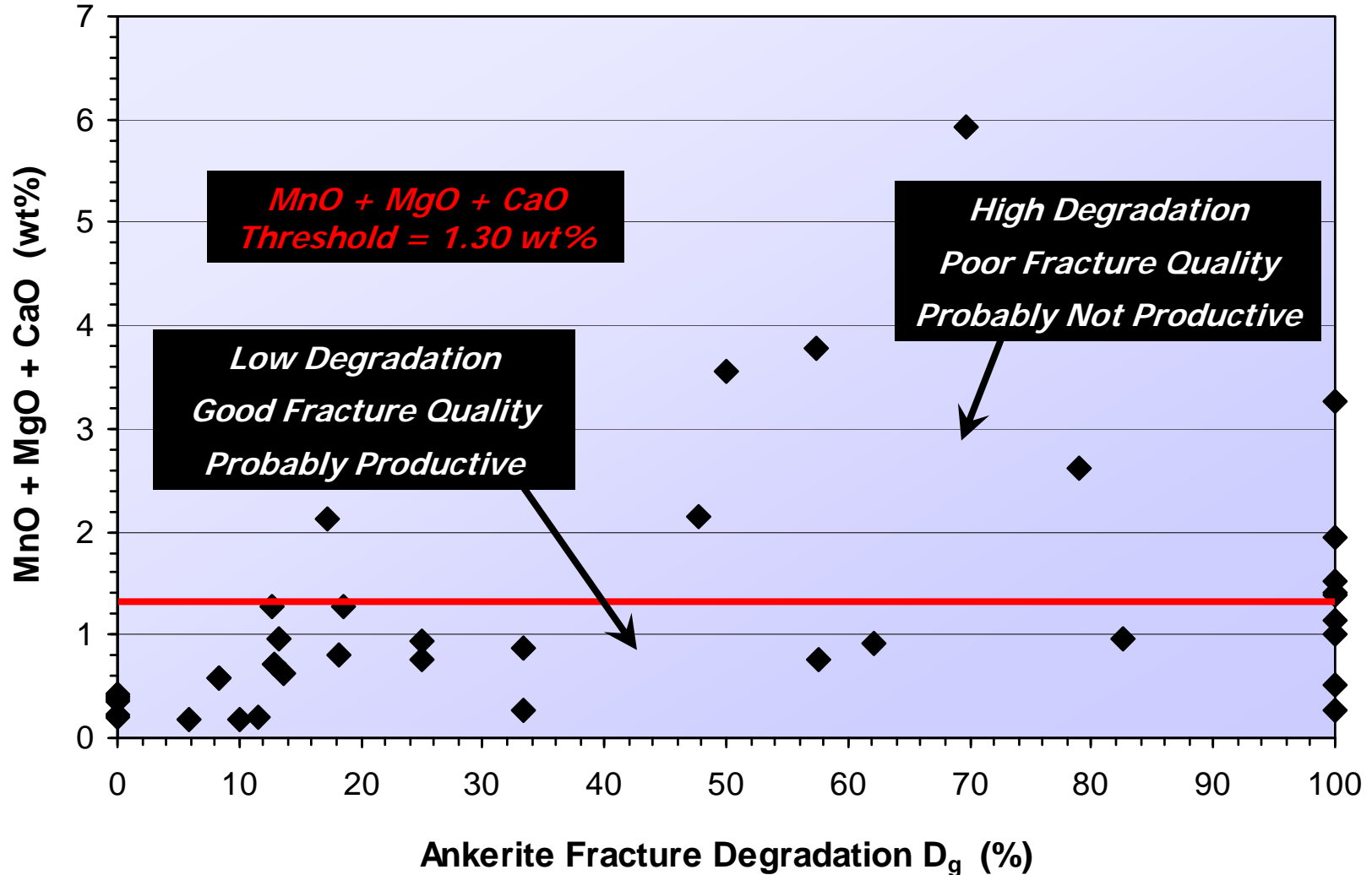Low degradation - Good fracture quality predicted.
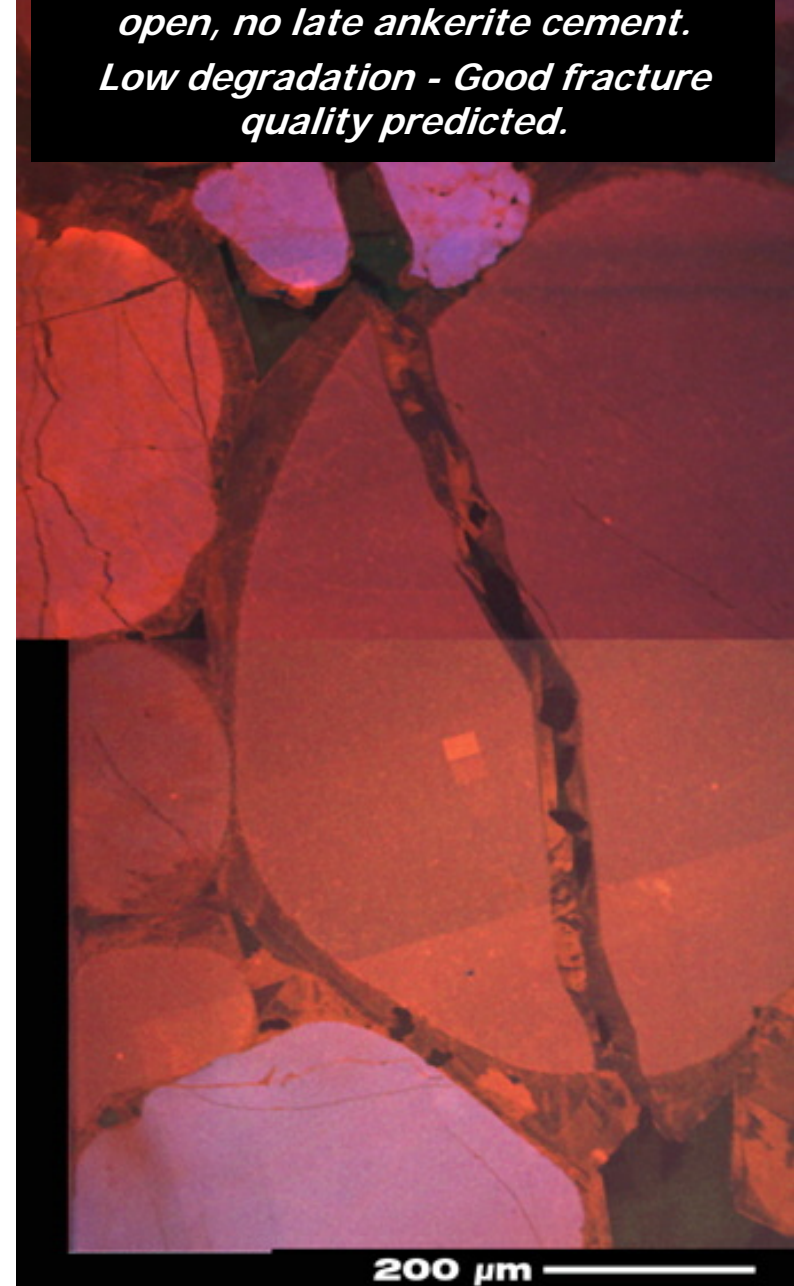
**Scanned Cathodoluminescence (CL) Images
From Rob Reed's CL Web Site
Bureau of Economic Geology
Austin, Texas, United States**

100µm

200 µm

Petrographic Fracture Degradation Data Cretaceous Travis Peak Sandstone in Texas

High Average Degradation
Poor Fracture Quality
Probably Not Productive

Ankerite Threshold
= 2.3 vol%

Low Average Degradation
Good Fracture Quality
Probably Productive

Ankerite Cement (vol%)

Ankerite Fracture Degradation D_g (%)

Petrographic data courtesy of Steve Laubach & Julia Gale

Calibrated Elemental Data for Fracture Prediction Cretaceous Travis Peak Sandstone in Texas

MnO + MgO + CaO (wt%)

MnO + MgO + CaO Threshold = 1.30 wt%

High Degradation
Poor Fracture Quality
Probably Not Productive

Low Degradation
Good Fracture Quality
Probably Productive

Ankerite Fracture Degradation D_g (%)

Petrographic data courtesy of Steve Laubach & Julia Gale

Elemental Applications for E&P

Wellbore Placement

Formation Evaluation

Rare Earth Elements