
***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

Periodic Table of the Elements

1A 1 H Hydrogen 1.008																	2A 2 He Helium 4.003																		
3 Li Lithium 6.941	4 Be Beryllium 9.012																	10 Ne Neon 20.18																	
11 Na Sodium 22.99	12 Mg Magnesium 24.31																	17 Cl Chlorine 35.45	18 Ar Argon 39.95																
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.58	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80																		
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3																		
55 Cs Cesium 132.9	56 Ba Barium 137.3	57 La* Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.5	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 208.9	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)																		
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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:

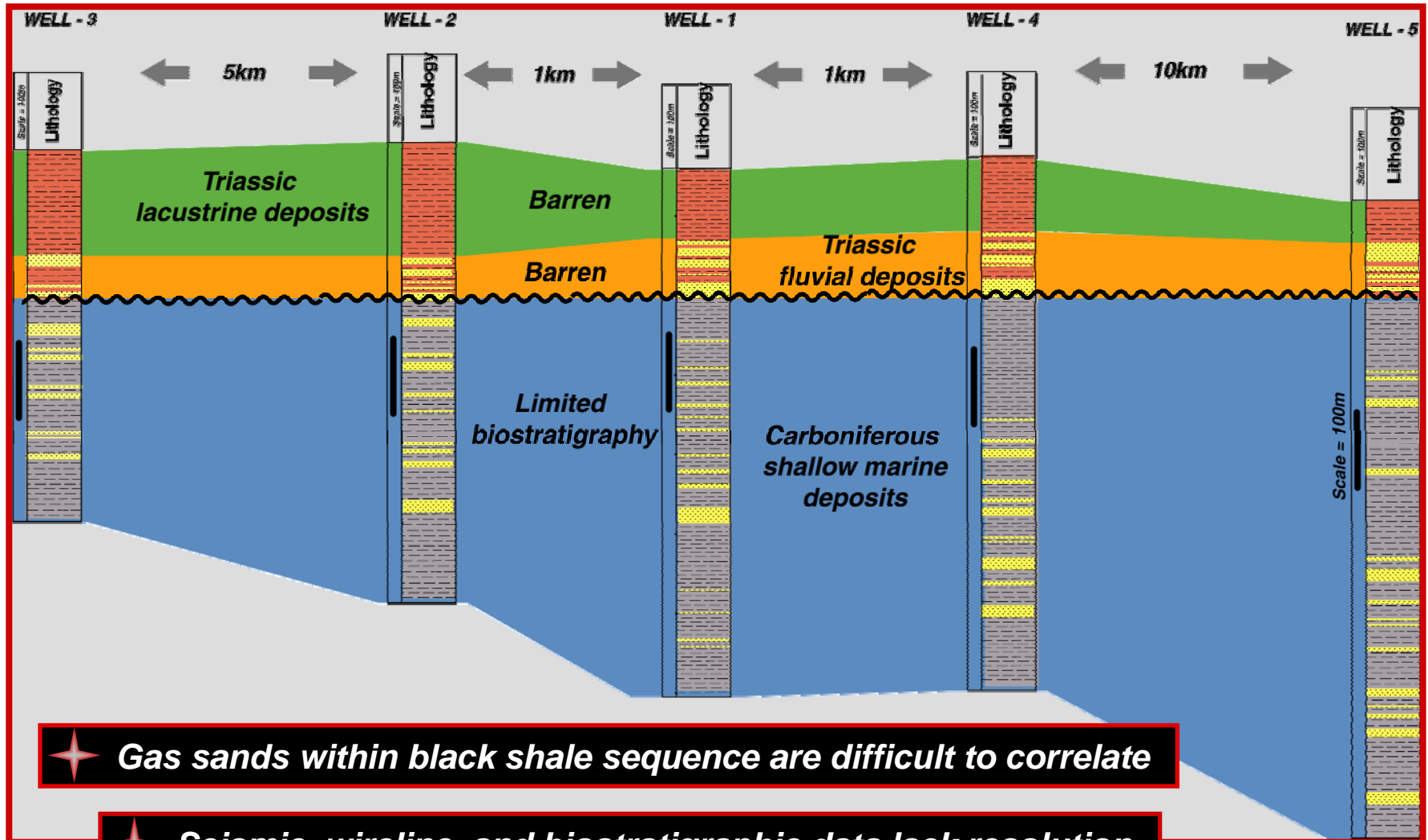
- Fossils are sparse or absent***
- High sedimentation rates reduce biostratigraphic resolution***
- Petrophysical log signatures are ambiguous***



Highly successful for **correlation** on scales ranging from individual reservoirs within a field to thick sequences across a region.

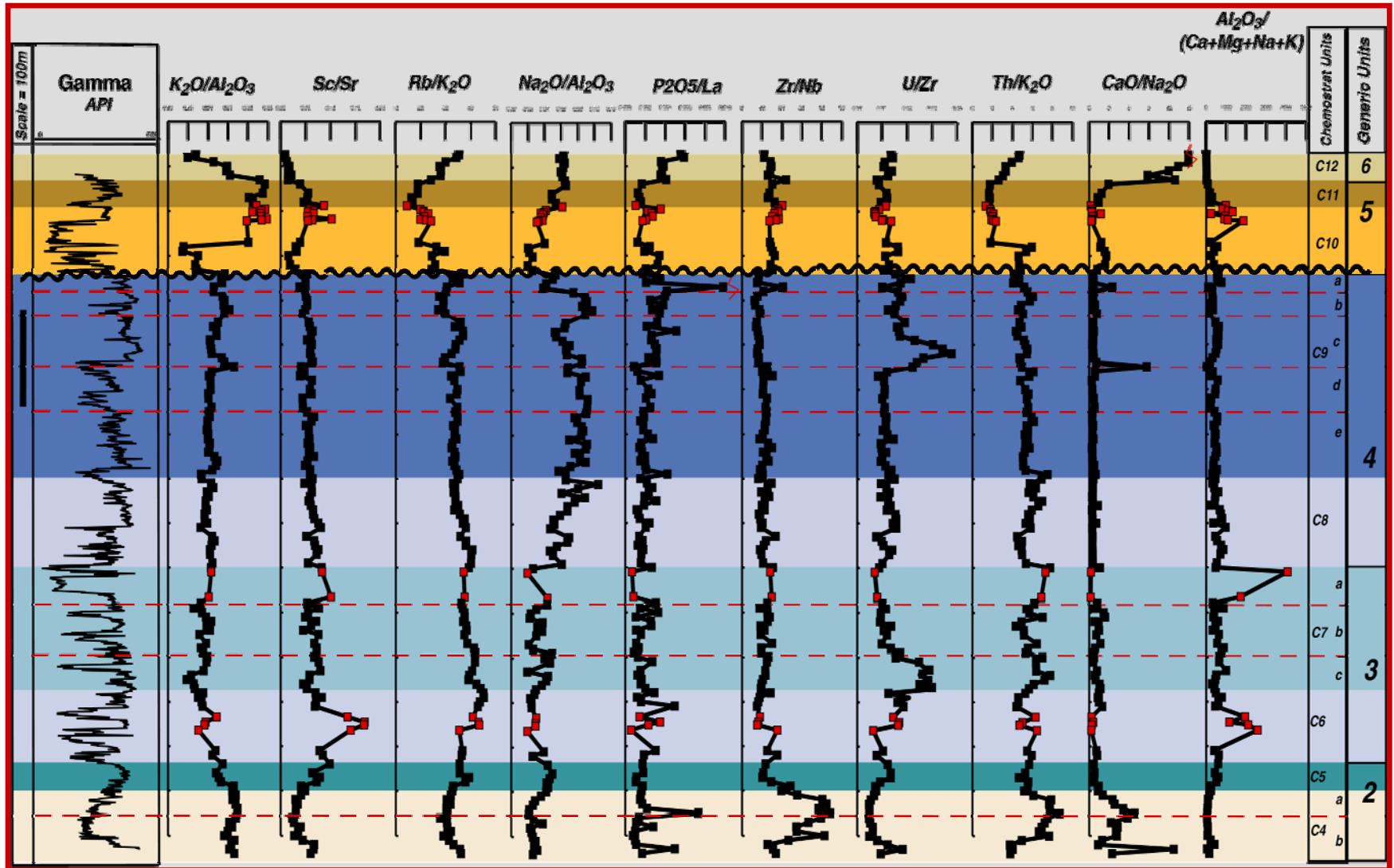
Problem: Poor Field-Scale Correlation

Carboniferous Shallow-Marine Gas Sands in Algeria

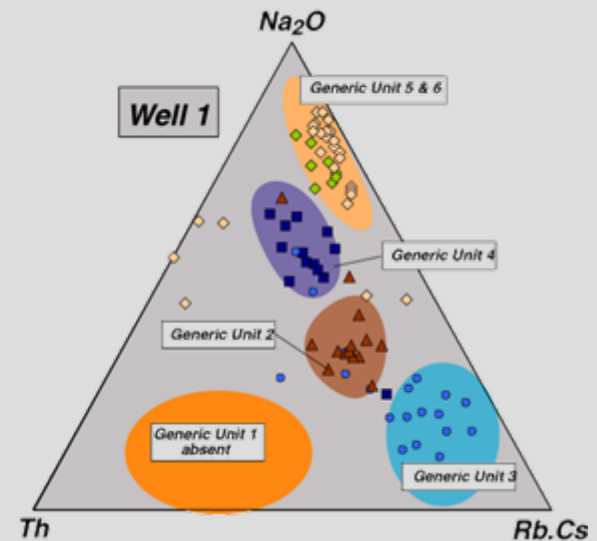
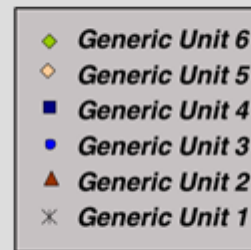
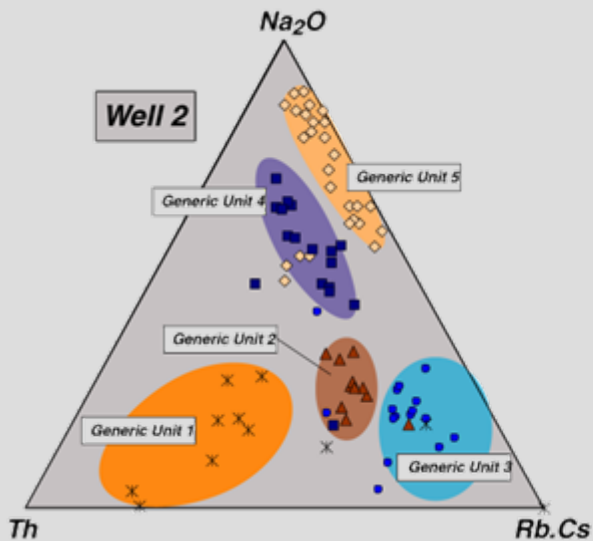
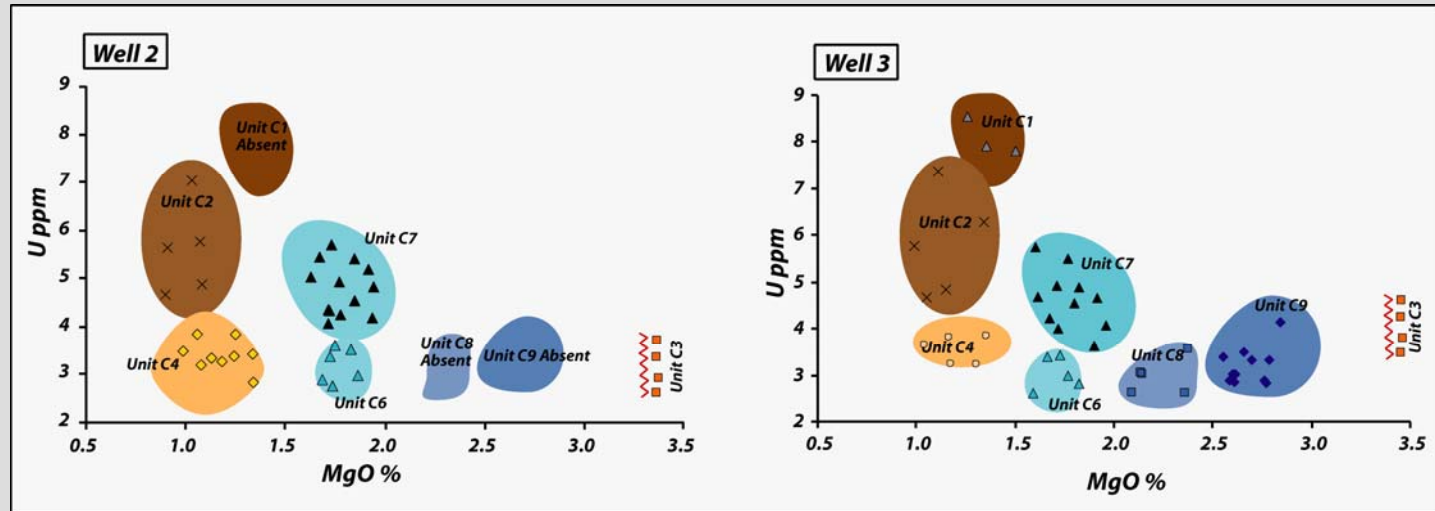


Key Elemental Ratio Profiles

Chemostratigraphic Zonation Based on Shales

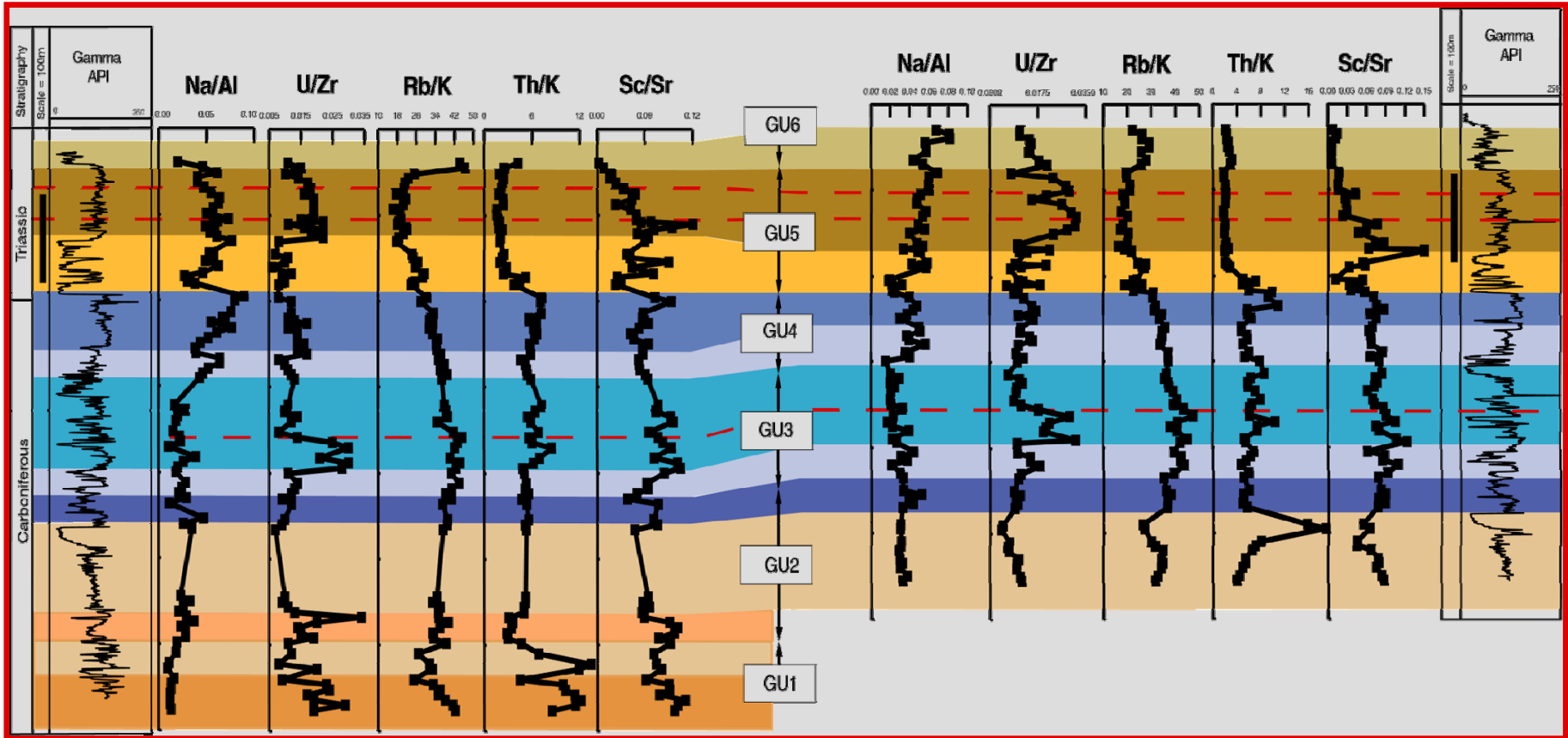


Binary & Ternary Plots Allow Discrimination of Chemostratigraphic Units

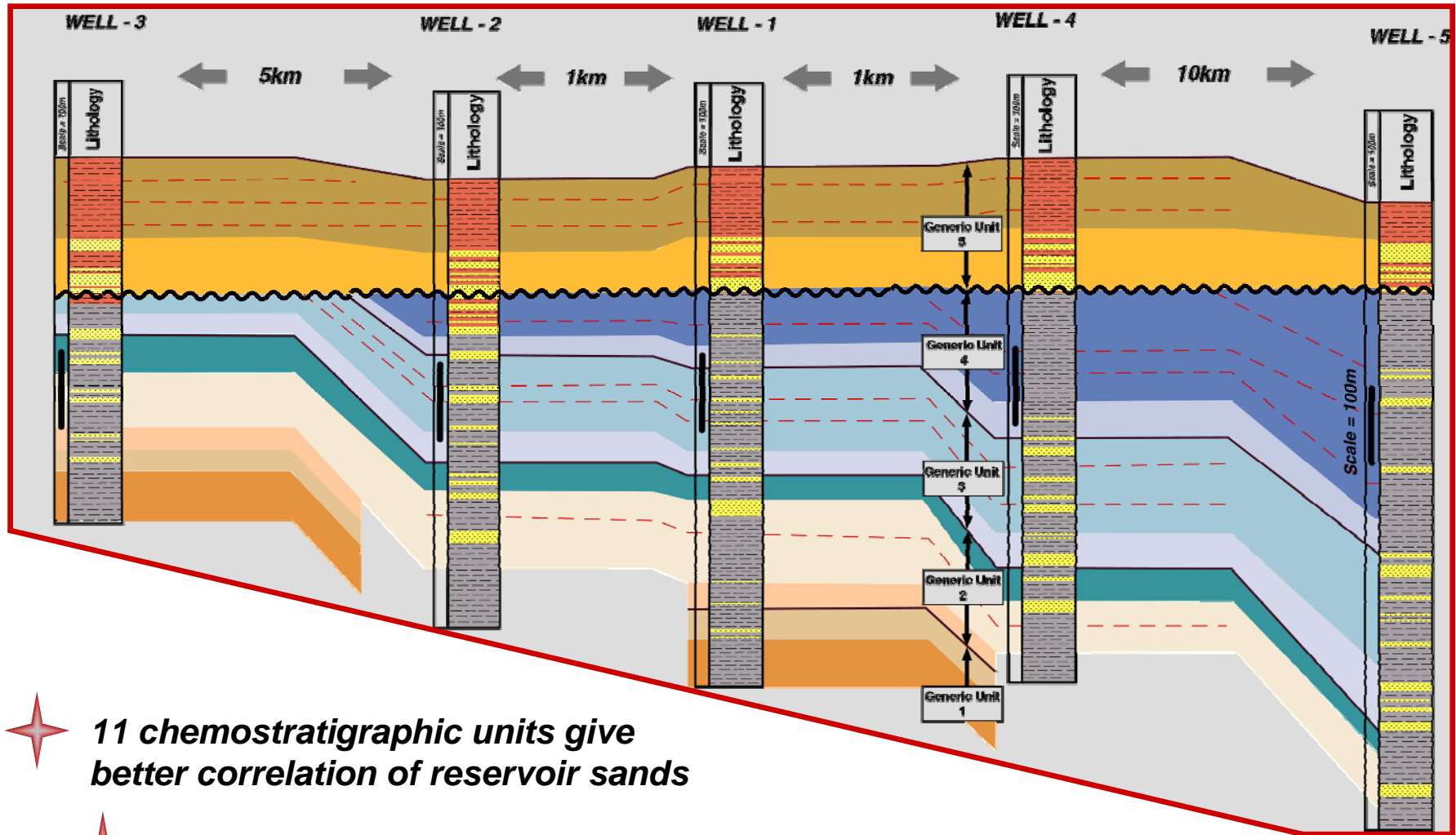


Two-Well Correlation

Chemostratigraphic Zonation Based on Shales



Solution: Greatly Improved Correlation Utilizing Chemostratigraphy

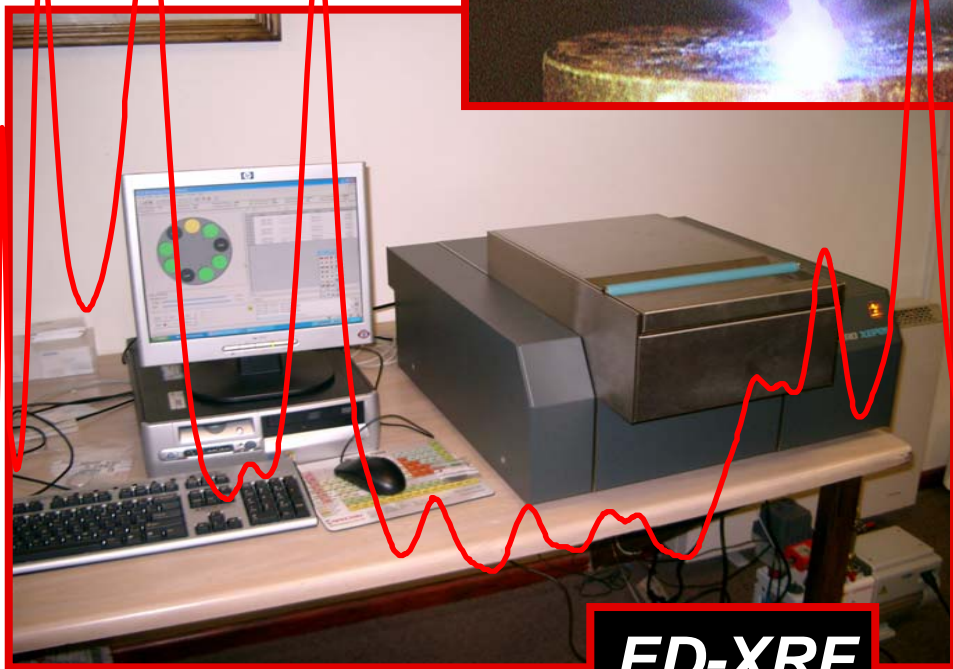


✦ 11 chemostratigraphic units give better correlation of reservoir sands

✦ Correlation is valid for almost 700 meters of section over a distance of 17 kilometers

Wellsite Analytical Instrumentation

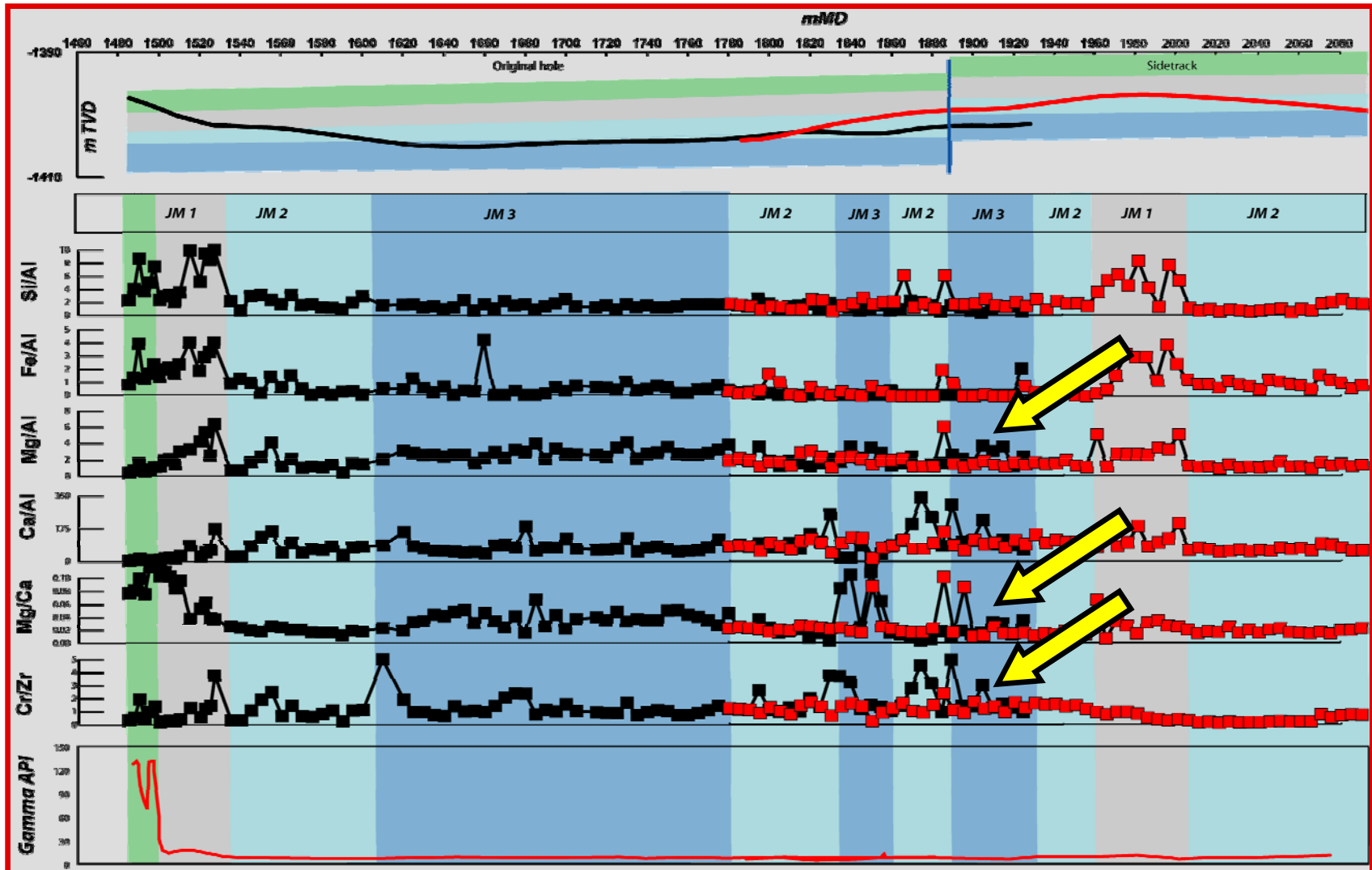
*Data in
20-30 minutes
from cuttings*



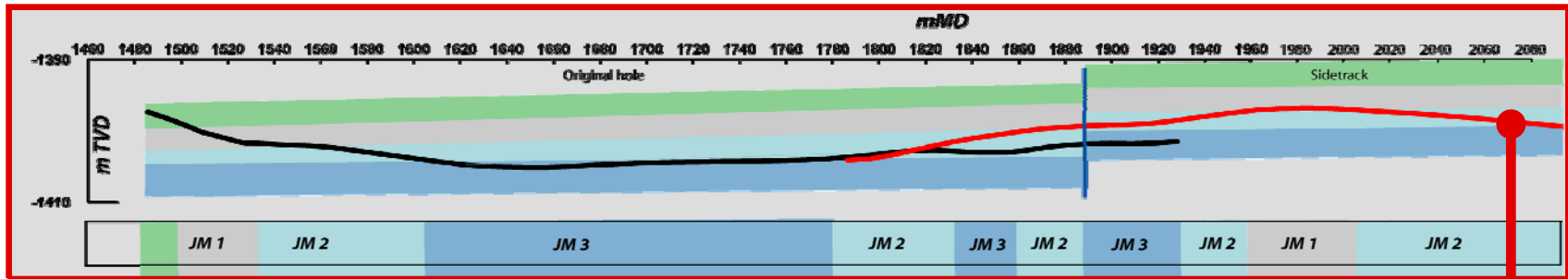
ED-XRF

LIBS

Improved Geosteering Results Devonian Limestone Reservoir in Canada



Improved Geosteering Results Devonian Limestone Reservoir in Canada



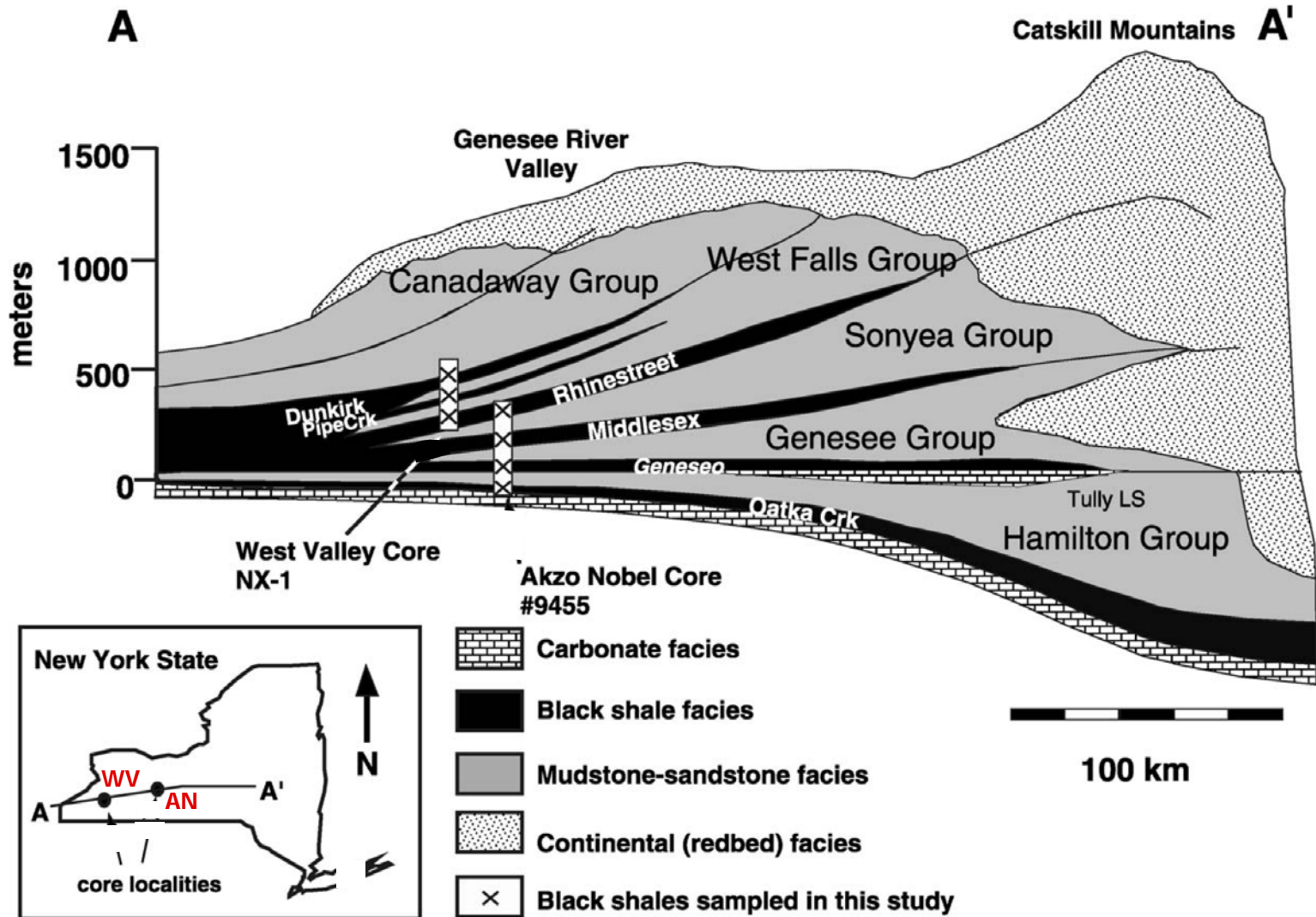
- ✦ ***Only one extra day of rig time required in a time-critical situation***
- ✦ ***200 meters of additional wellbore exposure to the reservoir was achieved***
- ✦ ***Gas flow was doubled from 1.2 to 2.5 MMCFD***

Shales Contain Highest Amount of Chemostratigraphic Information!



From Jürgen Schieber Website

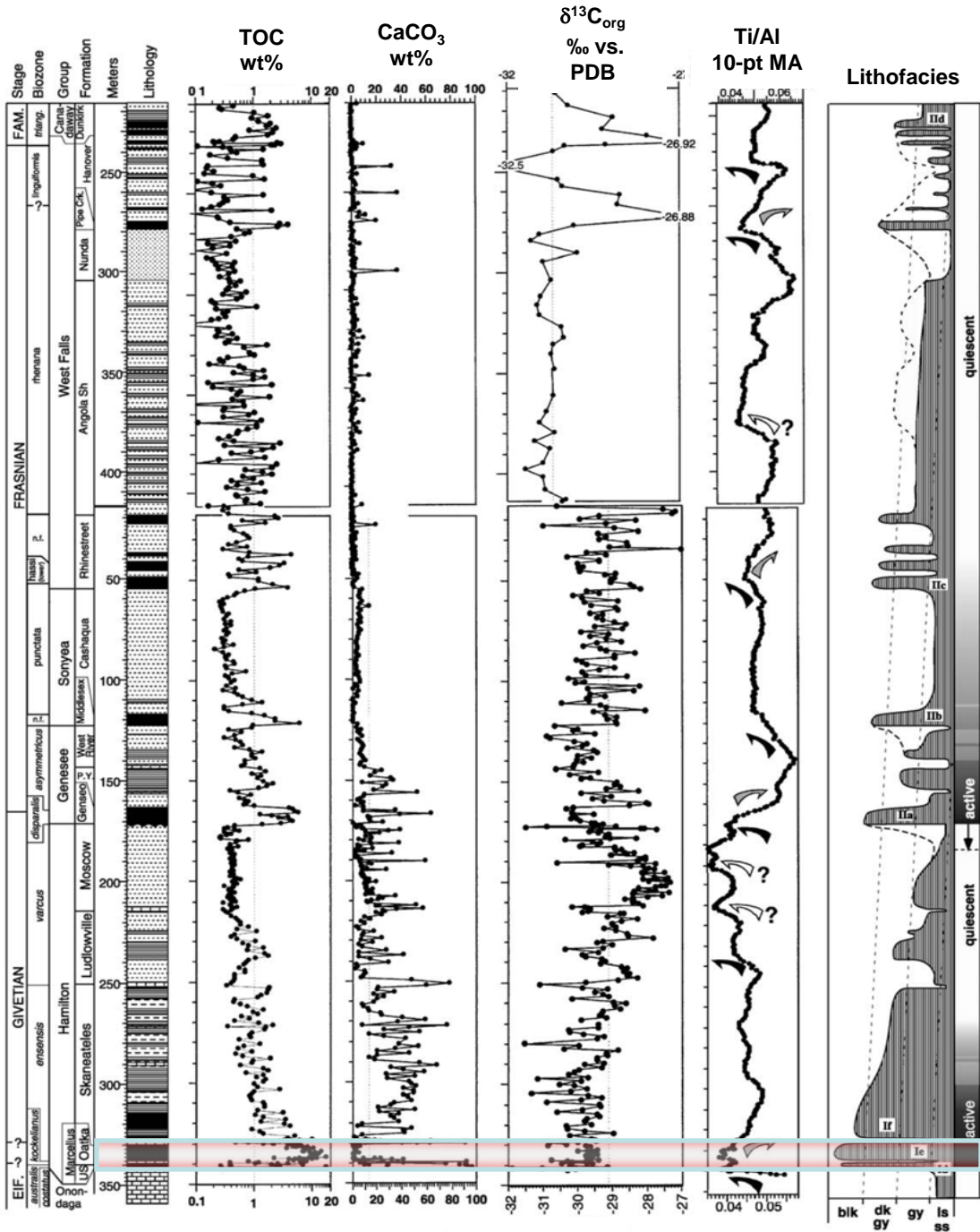
Devonian Shale Study in Western New York Core Locations & Stratigraphic Intervals



A

West Valley Core NX-1

Akzo Core #9455



Sageman et al. (2003)

- 9 elements
- TOC
- CaCO₃

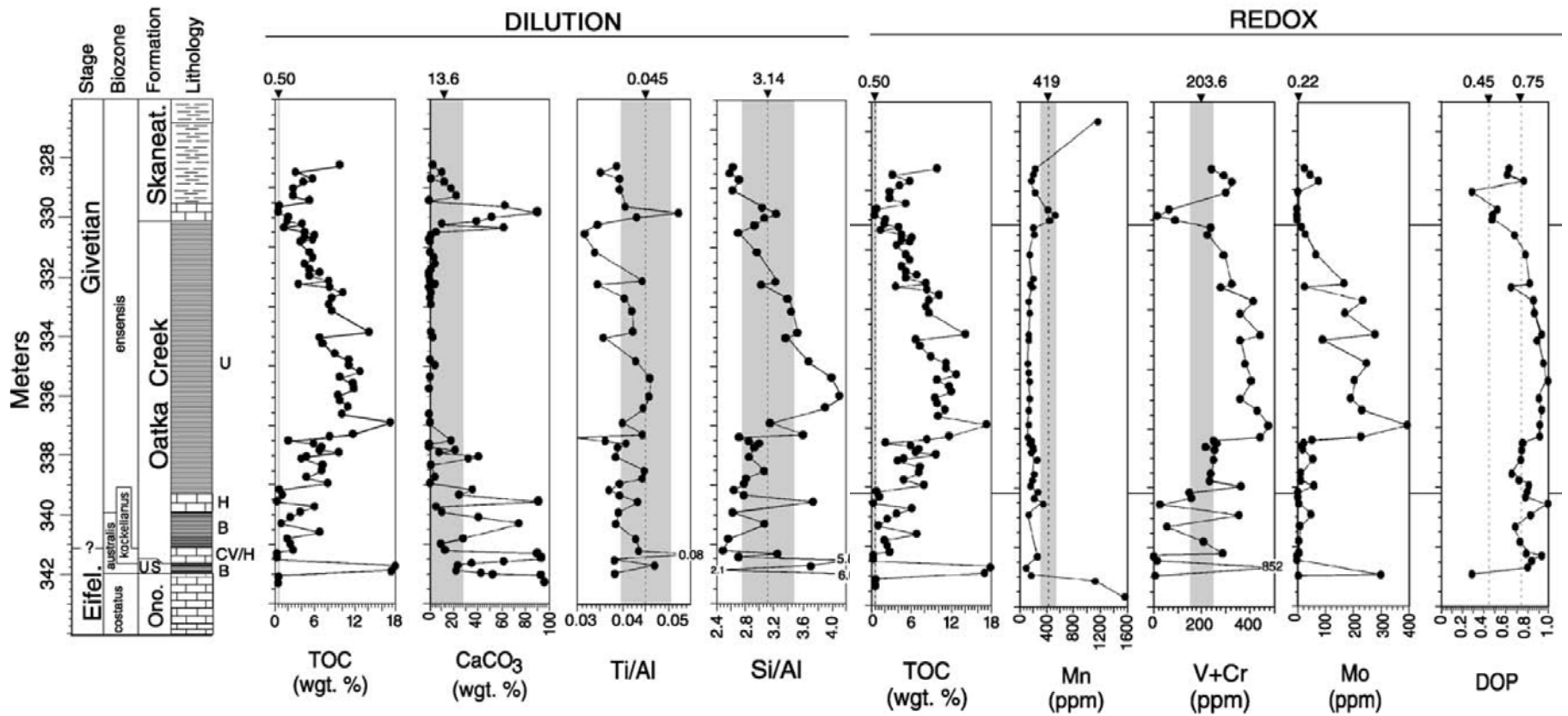
Standard Chemostratigraphic Study on Shale

- 50-55 elements
- TOC

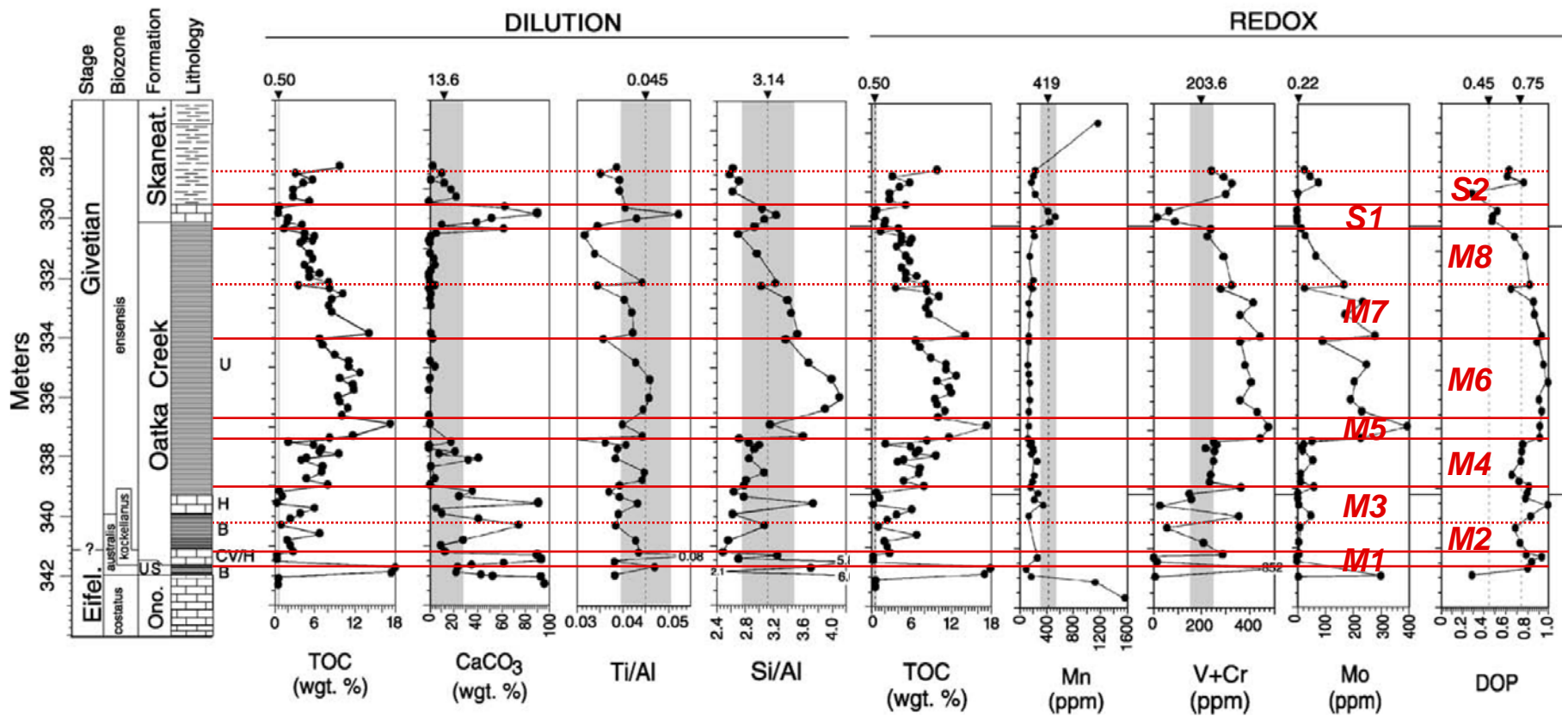
**Marcellus Interval
12 meters = 39 feet**

Geochemical Profiles

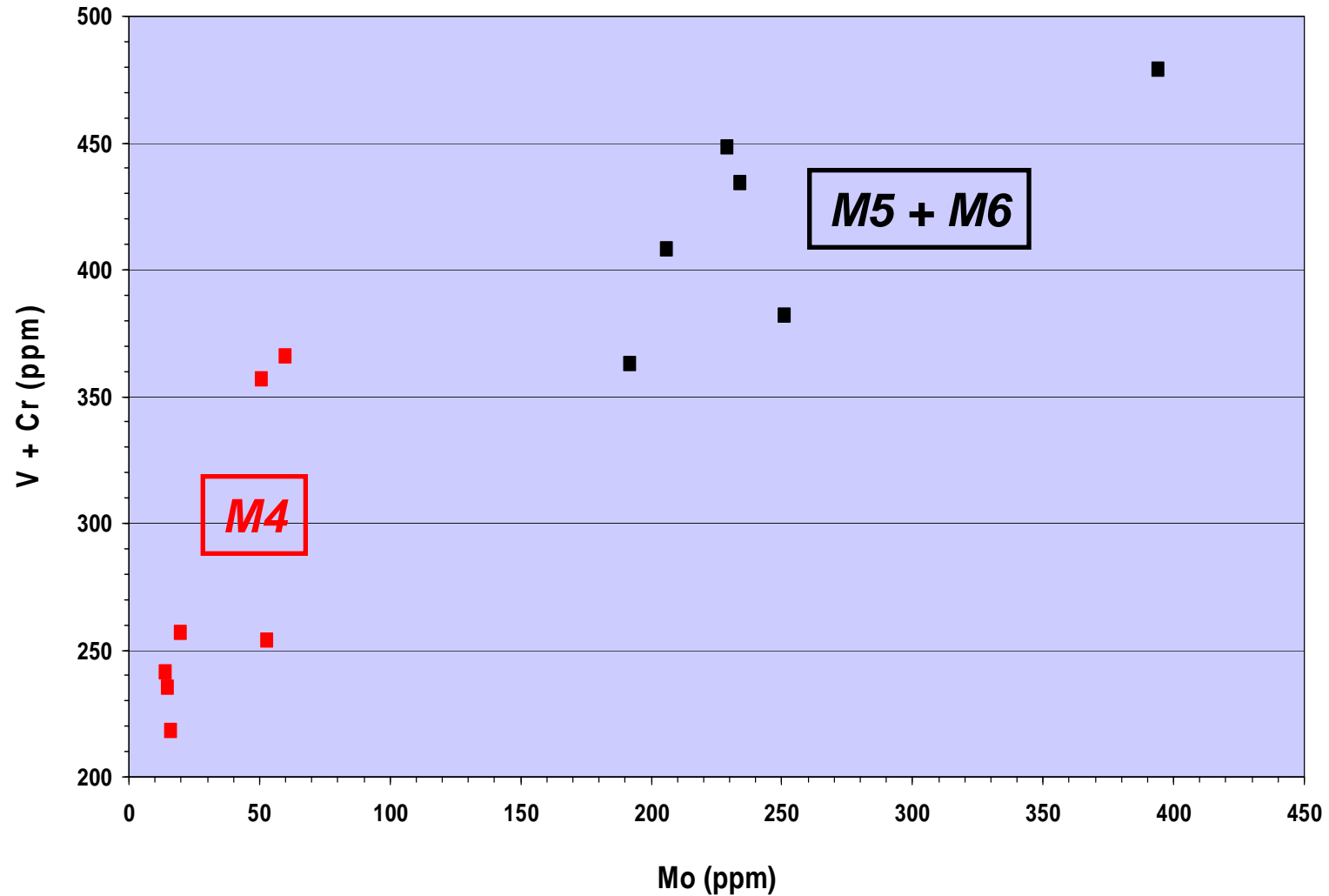
Marcellus Shale in Western New York



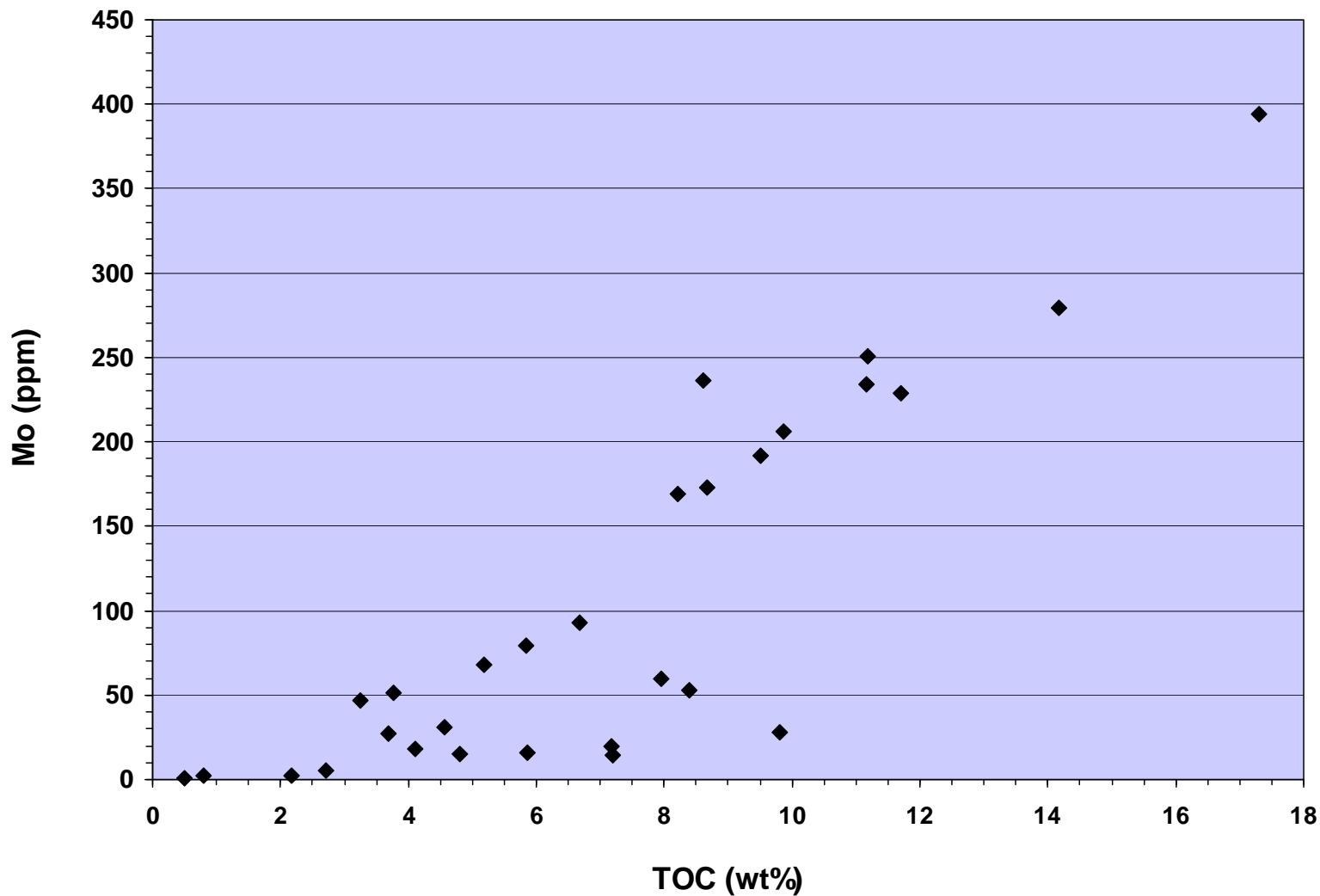
Chemostratigraphic Zonation Marcellus Shale in Western New York



Differentiation of Chemostratigraphic Units Marcellus Shale in Western New York



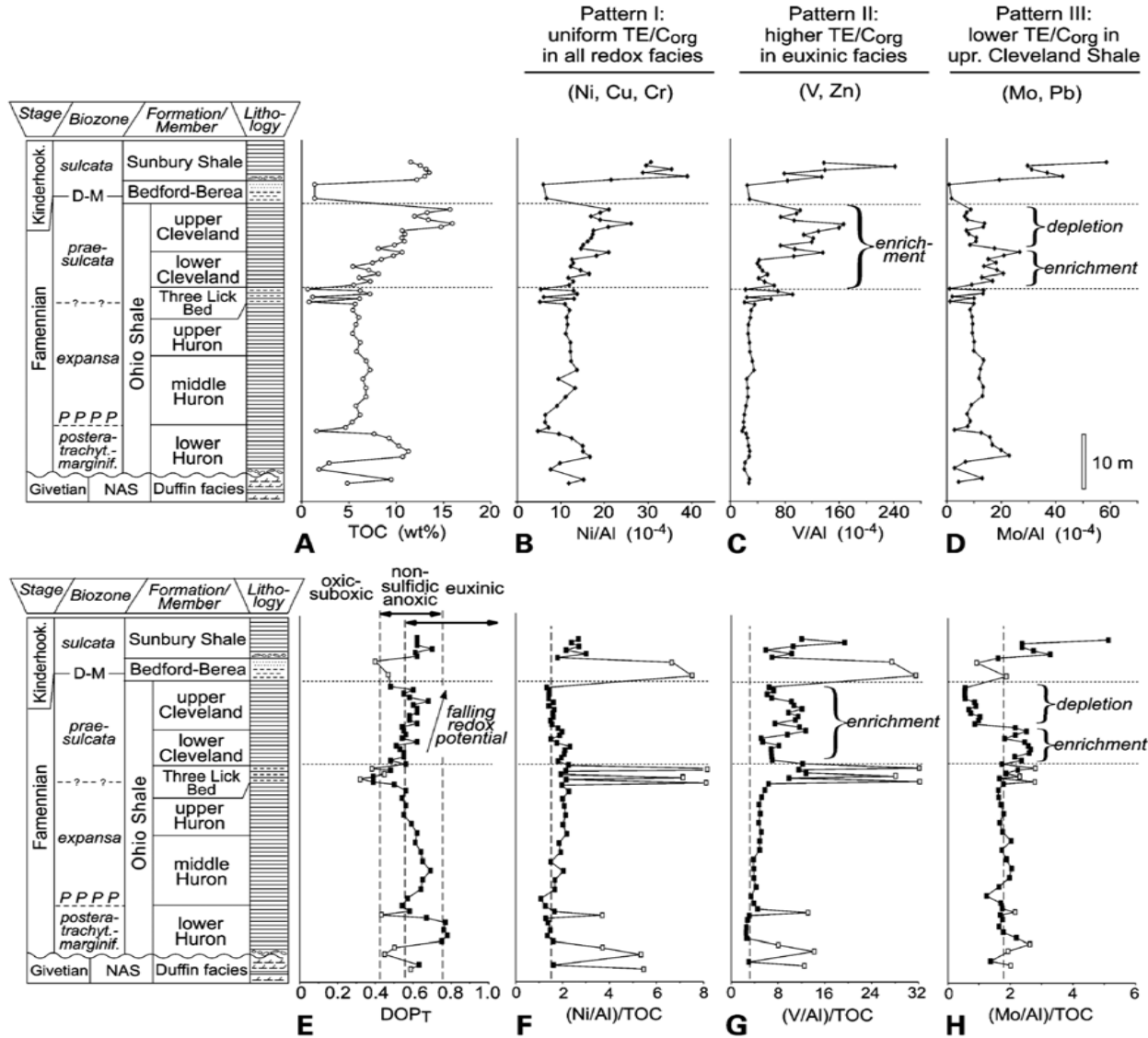
Mo & TOC Relationship Marcellus Shale in Western New York



Data from Sagemon et al. 2003

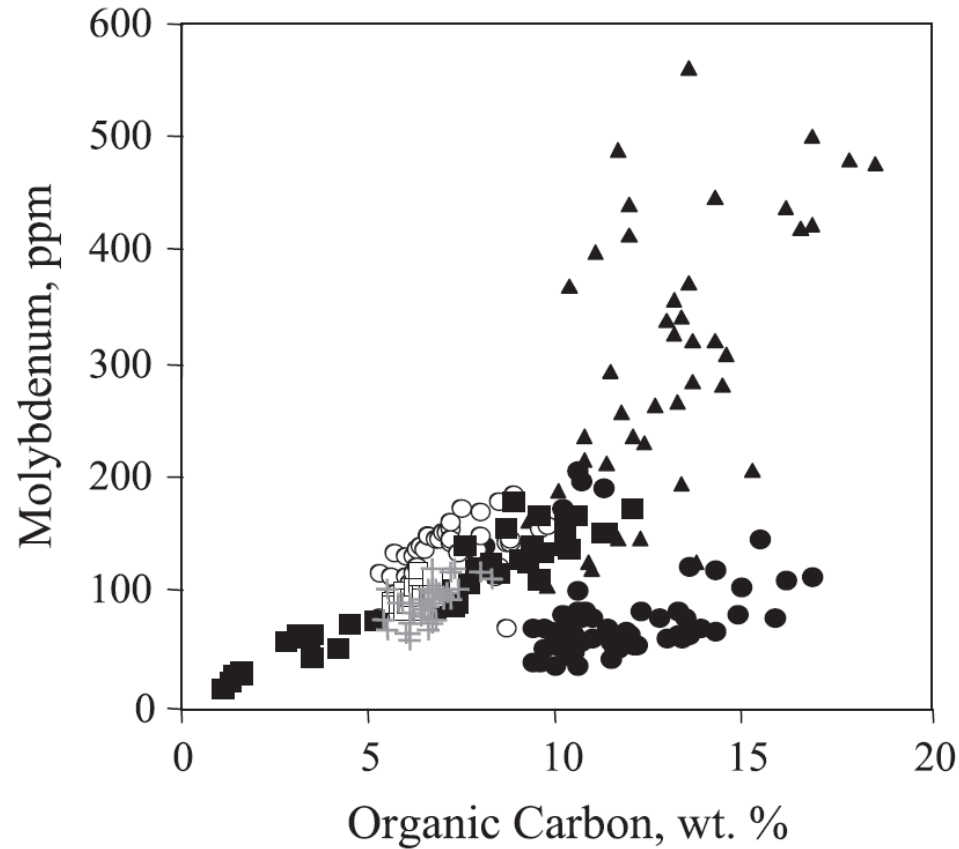
Chemostratigraphic Zonation

Ohio Shale in Eastern Kentucky (Algeo 2004)



Mo & TOC Relationships

Ohio Shale in Eastern Kentucky (Rimmer 2004)



- ▲ Sunbury
- Upper Cleveland
- Lower Cleveland
- Upper Huron
- + Middle Huron
- Lower Huron

Construct Predictive Elemental Model from Comprehensive Gas Shale Data Set

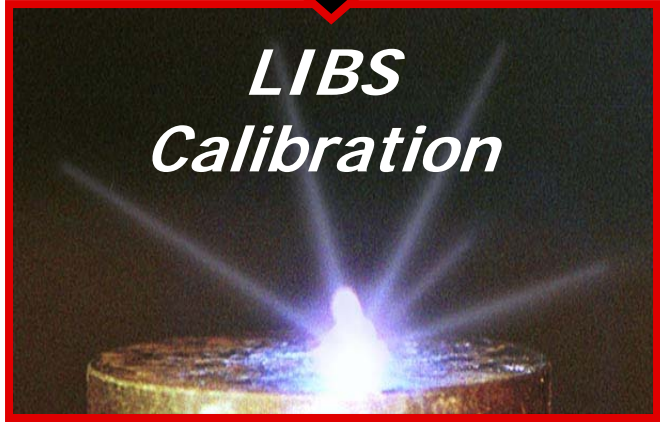
Elemental Composition

Mineralogical Composition

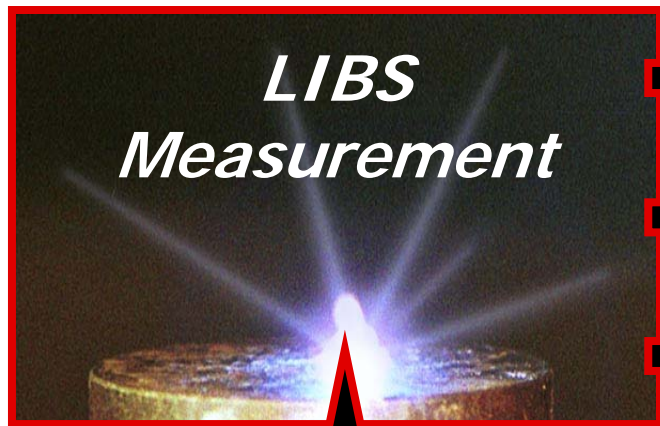
Organic Composition

Flow Properties

Geomechanical Properties



Elemental Analysis While Drilling Immediate Input for Improved Frac Design



Chemosteering[®]








Mineralogy



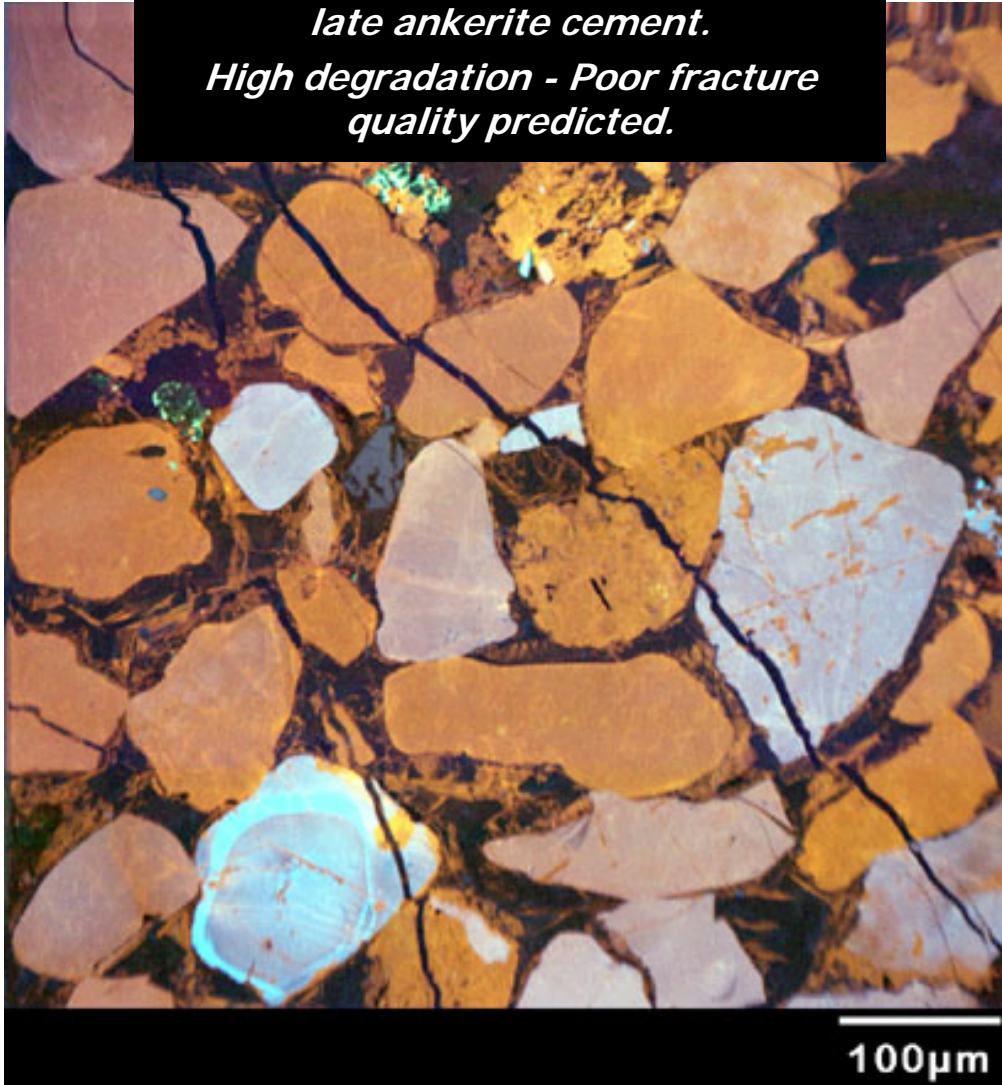
Geomechanical Parameters



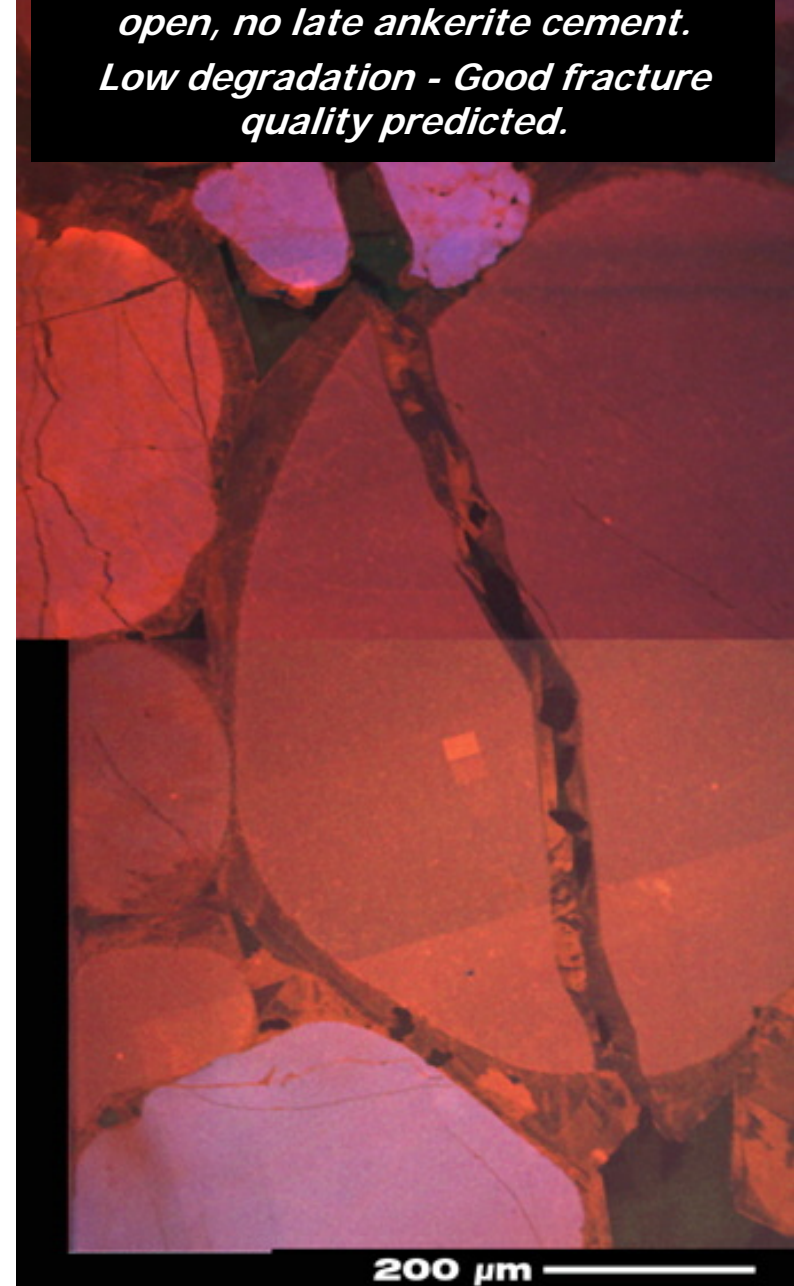
Recognition of Carbonate-Filled Fractures in Gas Shales Based on Elemental Data?

-  ***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.

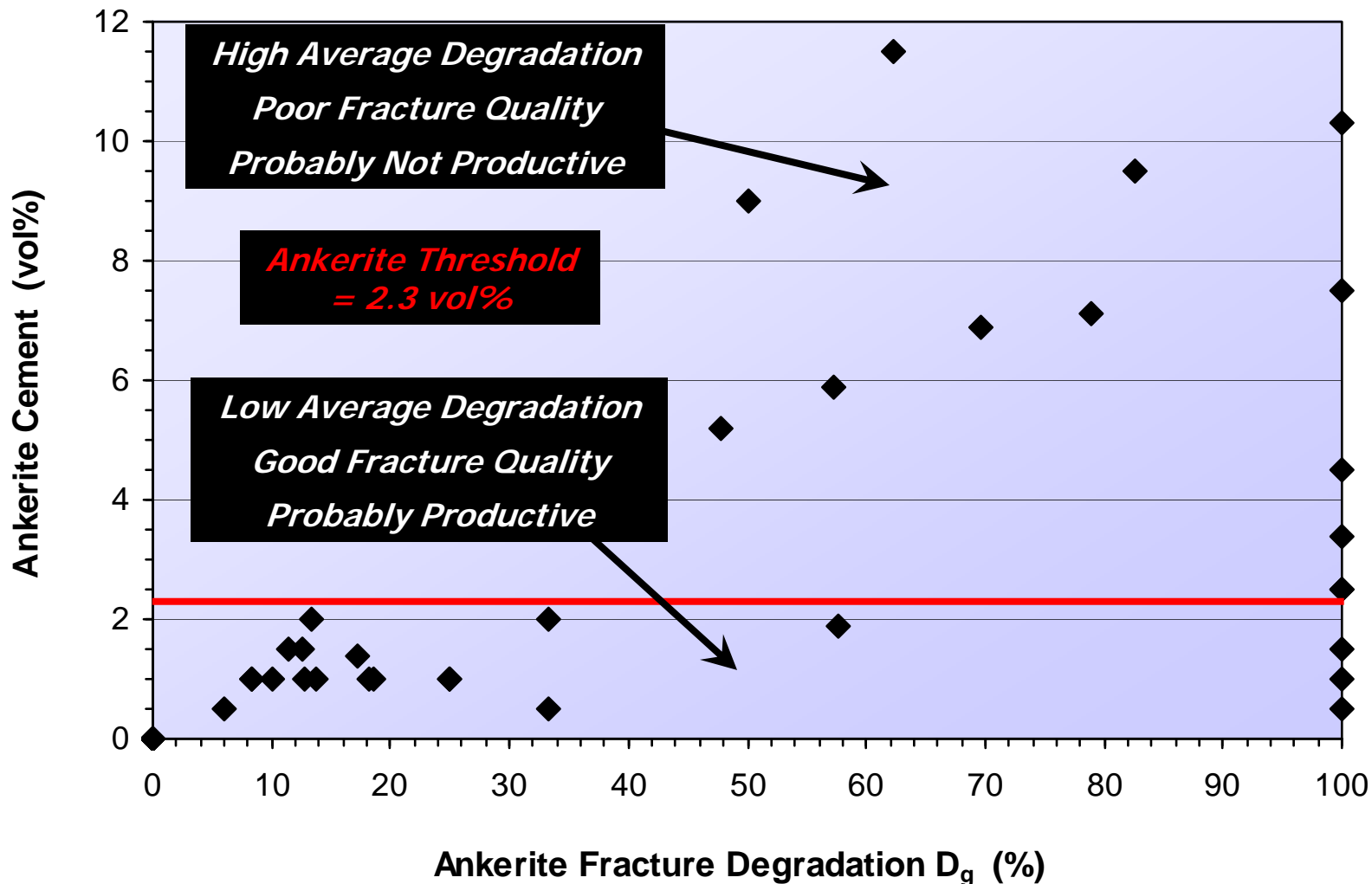


Microfractures and remnant pores in quartzose sandstone are partially open, no late ankerite cement. Low degradation - Good fracture quality predicted.

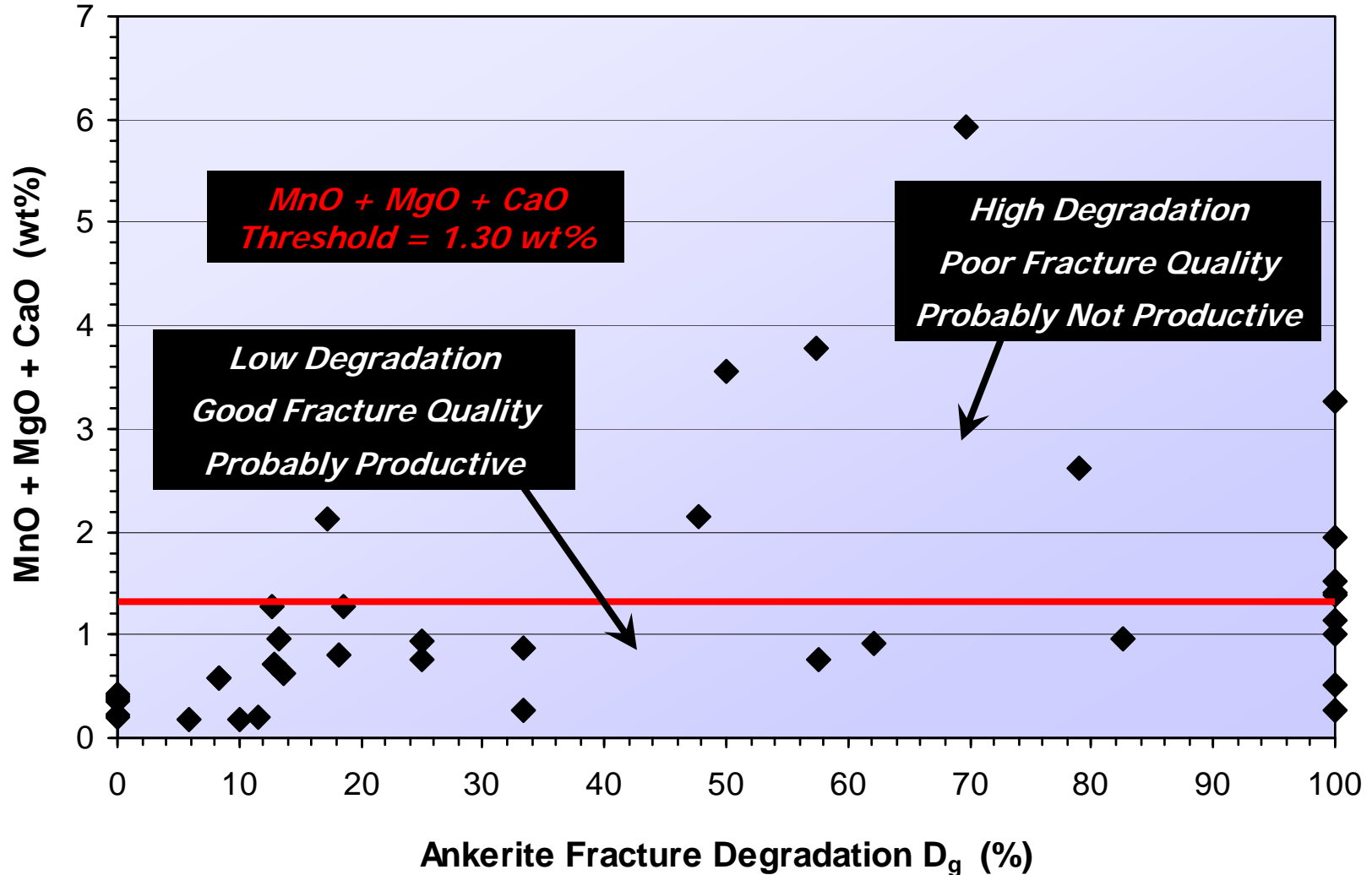


Scanned Cathodoluminescence (CL) Images
From Rob Reed's CL Web Site
Bureau of Economic Geology
Austin, Texas, United States

Petrographic Fracture Degradation Data Cretaceous Travis Peak Sandstone in Texas



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



Elemental Applications for E&P



Wellbore Placement

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Formation Evaluation