Evaluation of the Tyler Formation, Williston Basin, Western North Dakota*

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Abstract

The Williston Basin is a large oval-shape intracratonic sedimentary basin in southern Saskatchewan, eastern Montana, and western North and South Dakota. The marginal marine depositional environment of the Tyler Formation (Pennsylvanian age) can be very challenging for petroleum exploration and production, particularly on the barrier islands in the transgressive sequence. Depending on the subsidence rate and sediment supply, these environments can range from very thick sand deposits with uniform strike orientation to very thin discontinuous sand bodies with small reservoirs displayed in any number of orientations, which are correspondingly high risk reservoirs. The Tyler Formation represents the later type of deposition and hence the importance of evaluating all aspects and making detail maps of the source and reservoir formation. The rare earth elements (REE's) and trace elements are excellent indicators of depositional environments. Determination of REE's chemical composition, coupled with total organic content and biomarkers, show petroleum migration pathways from source to reservoir rocks within the Tyler Formation.

The Tyler Formation, which has produced 84 million Bbls oil over the past 50 years, out of an estimated 1.5 billion Bbls reserve, represents its own hydrocarbon source and reservoir. This study used cores and oil samples from the Tyler Formation within the Williston Basin of western North Dakota. Samples were examined for geochemical composition, primarily rare earth elements (REE), trace elements, and total organic content, as well as biomarkers, atomic ratios of hydrogen/carbon, oxygen/carbon, and maturity by using pyrolysis, inductively-coupled plasma - mass spectrometry (ICP-MS), and gas chromatography-mass spectrometry (GC-MS). The geochemical data has been mapped and analyzed using Arc GIS with RockWare geochemical software. Thin sections from the cores were examined for micro-sedimentary structures, porosity and permeability. The data from the geochemical analysis, thin sections and the geophysical logs will be used to model potential drilling sites using Schlumberger's Petrel® simulation software.

Utilizing rare earth elements, trace elements and total organic content in innovative and standardized geochemical techniques, coupled with the computer modeling, will enhance our understanding of the depositional environments, source and reservoir rocks, and petroleum migration pathways, which will enable better drilling decision making.

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EVALUATION OF THE TYLER FORMATION, WILLISTON BASIN, WESTERN NORTH DAKOTA

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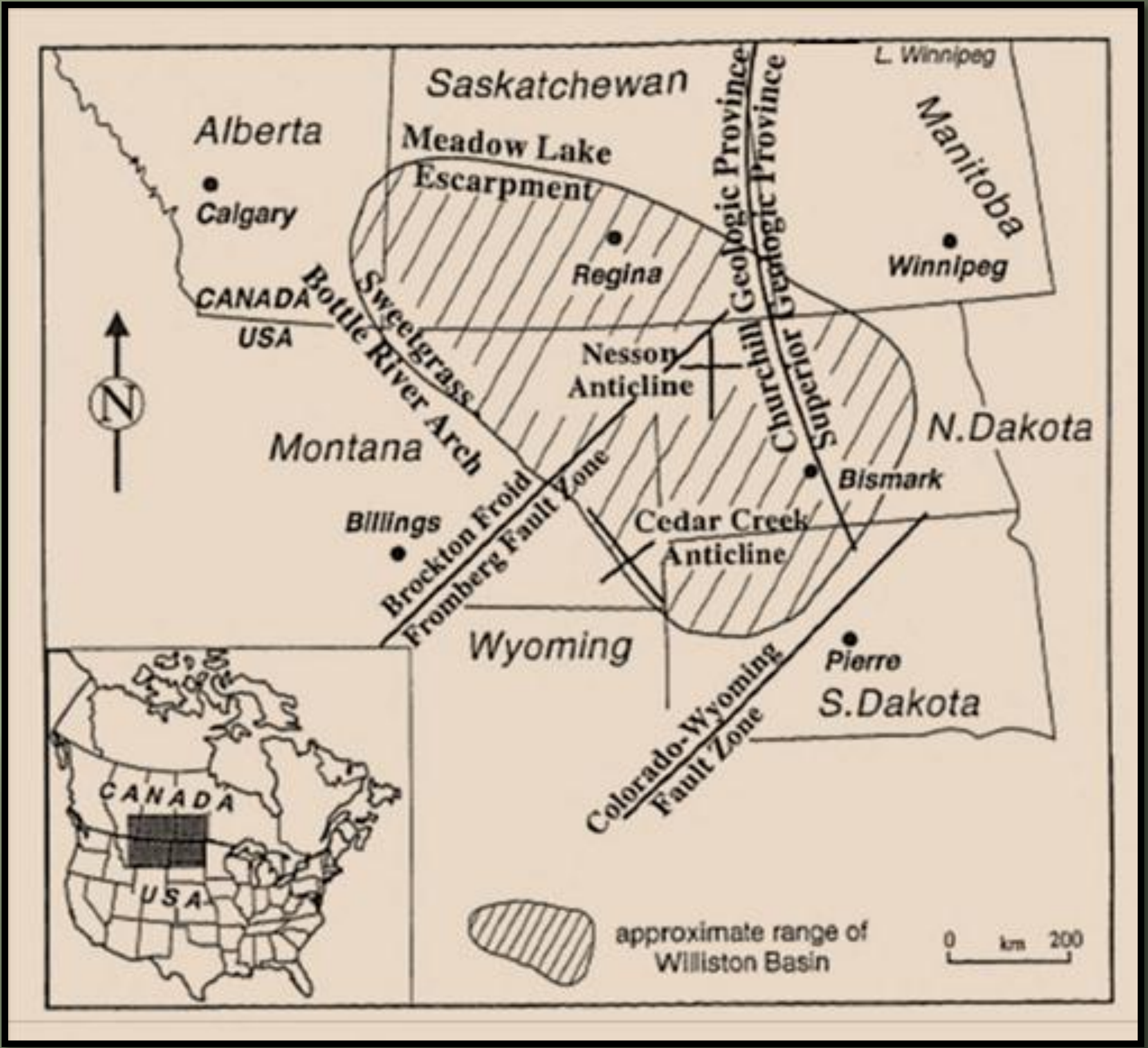
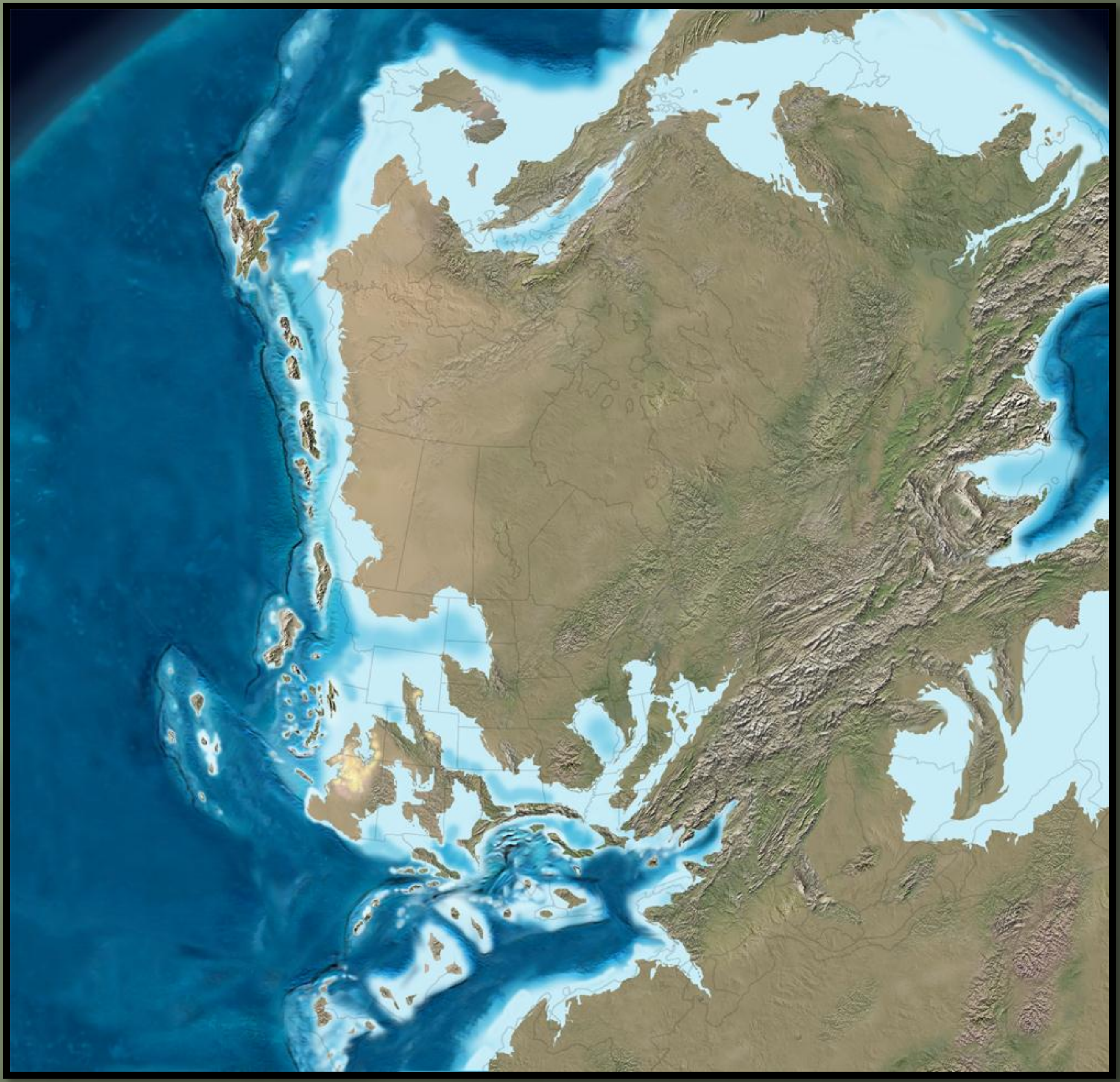
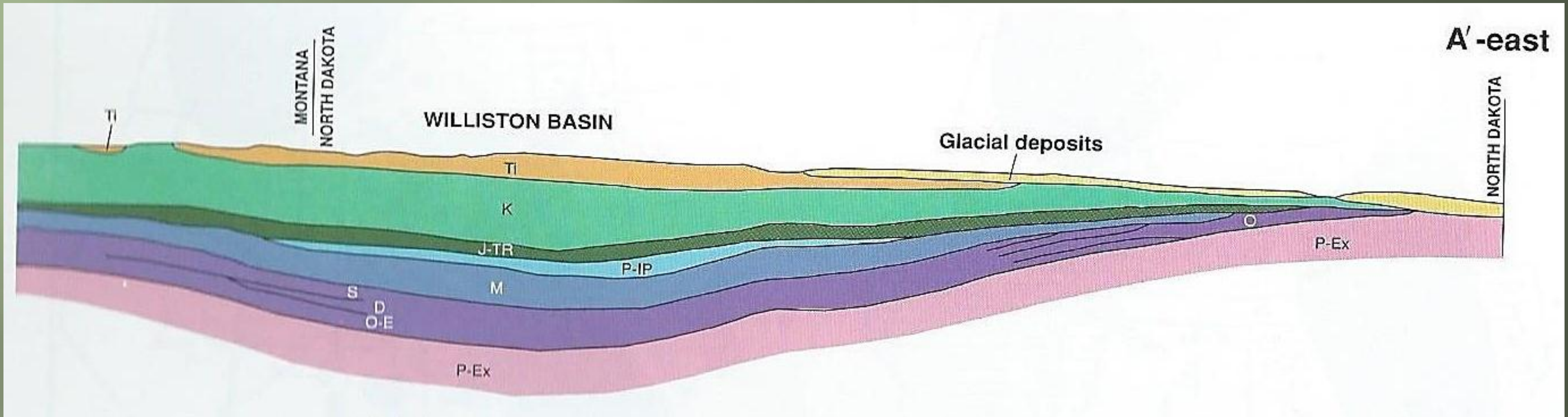


Index map showing location and main structural elements of the Williston Basin (from Obermajer et al., 2000)



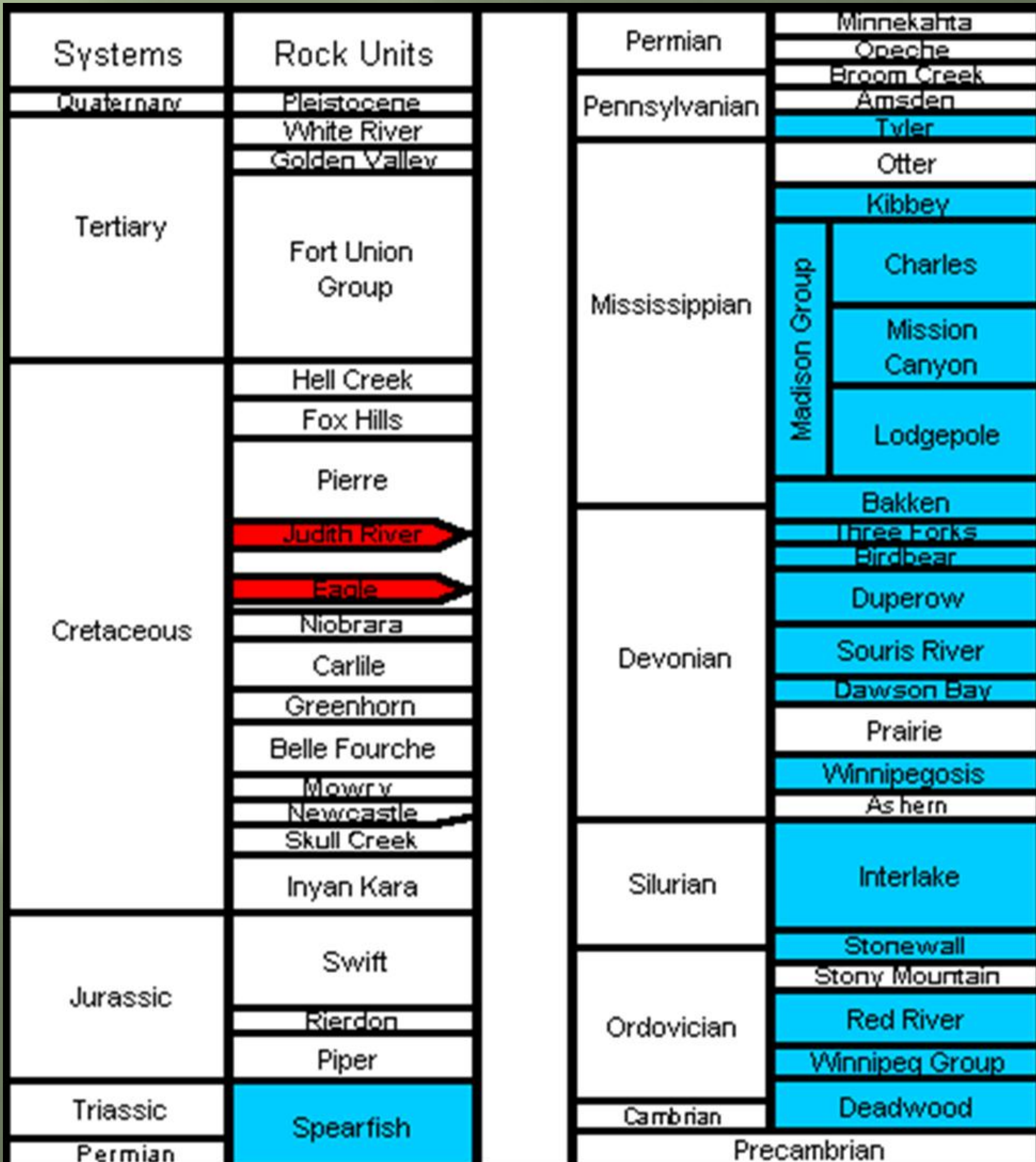
Dr. Ron Blakey,
http://www2.nau.edu/rcb7/nam.html

Cross section through Williston Basin and Montana

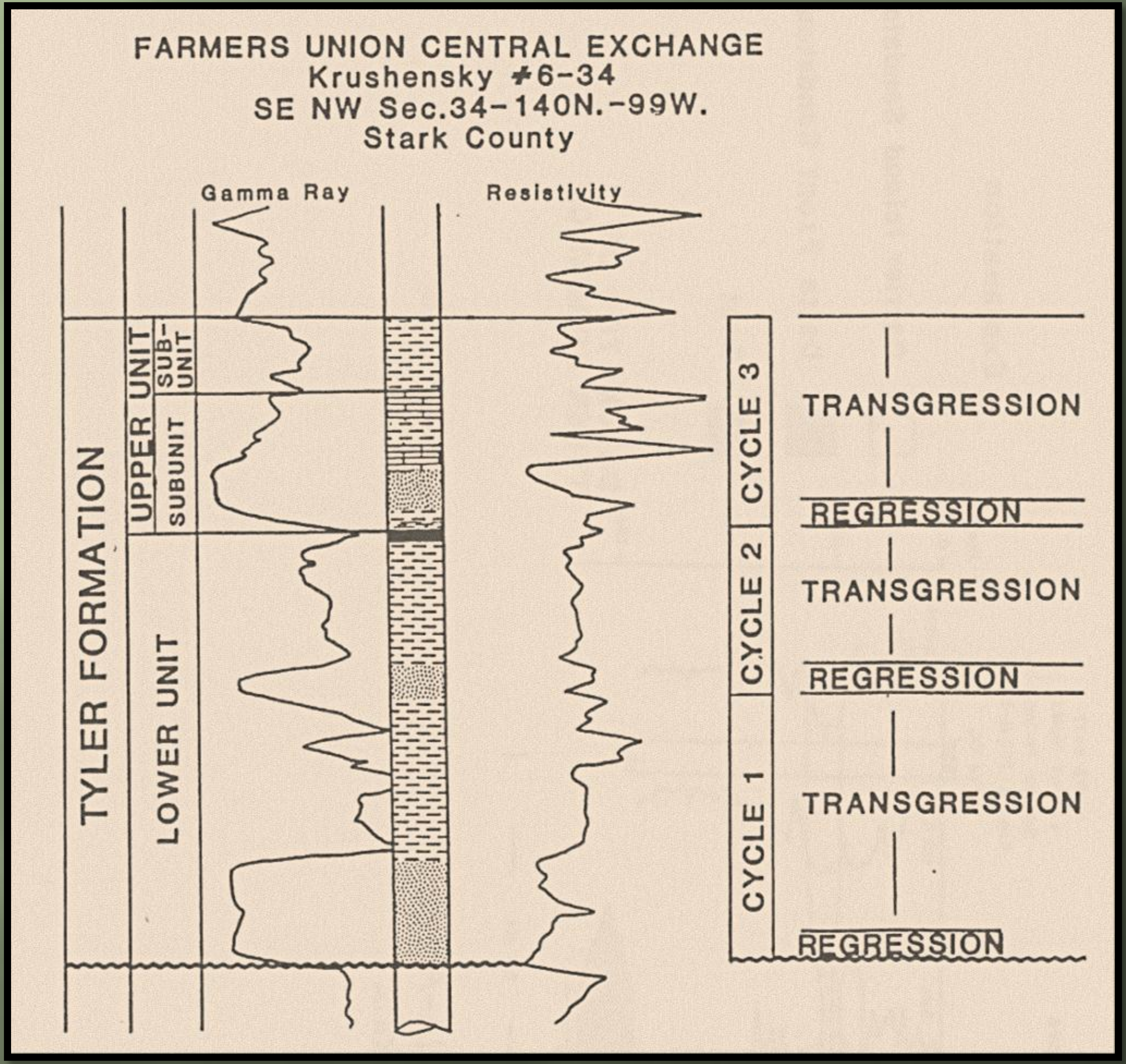


Meissner and Thomasson, 2001

Generalized stratigraphic column of the Williston Basin

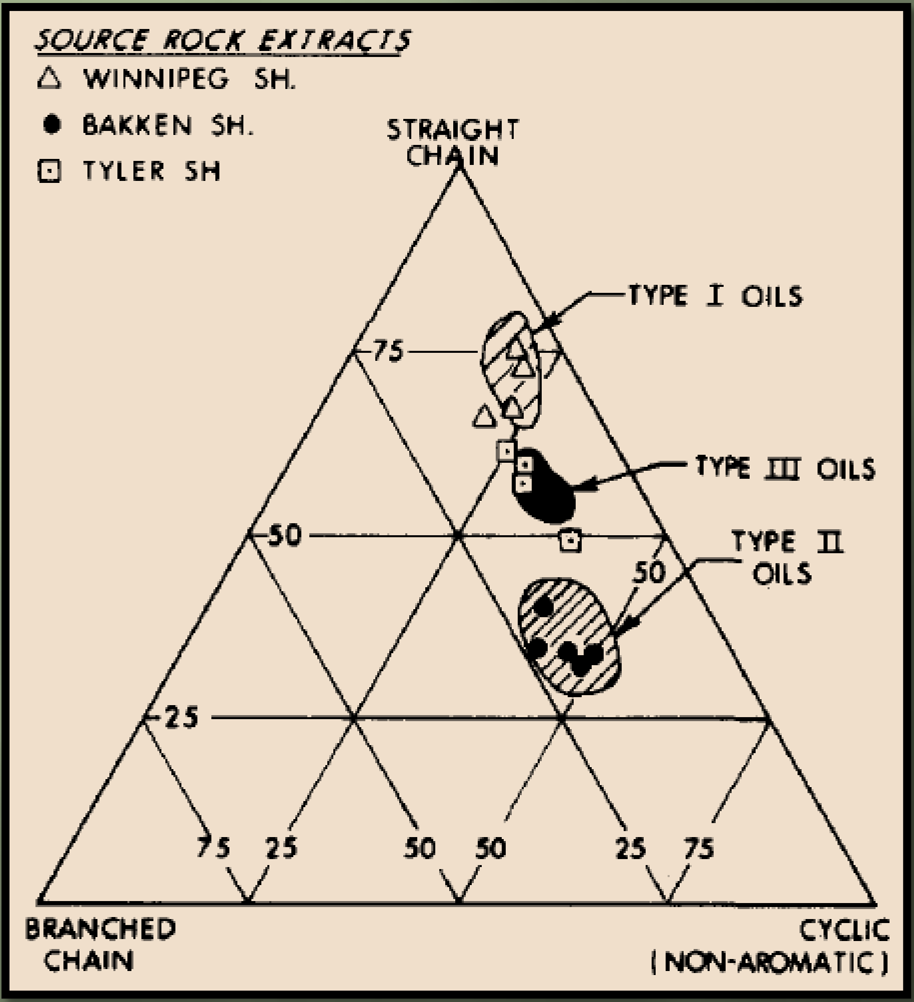


From North Dakota Geological Survey
www.dmr.nd.gov



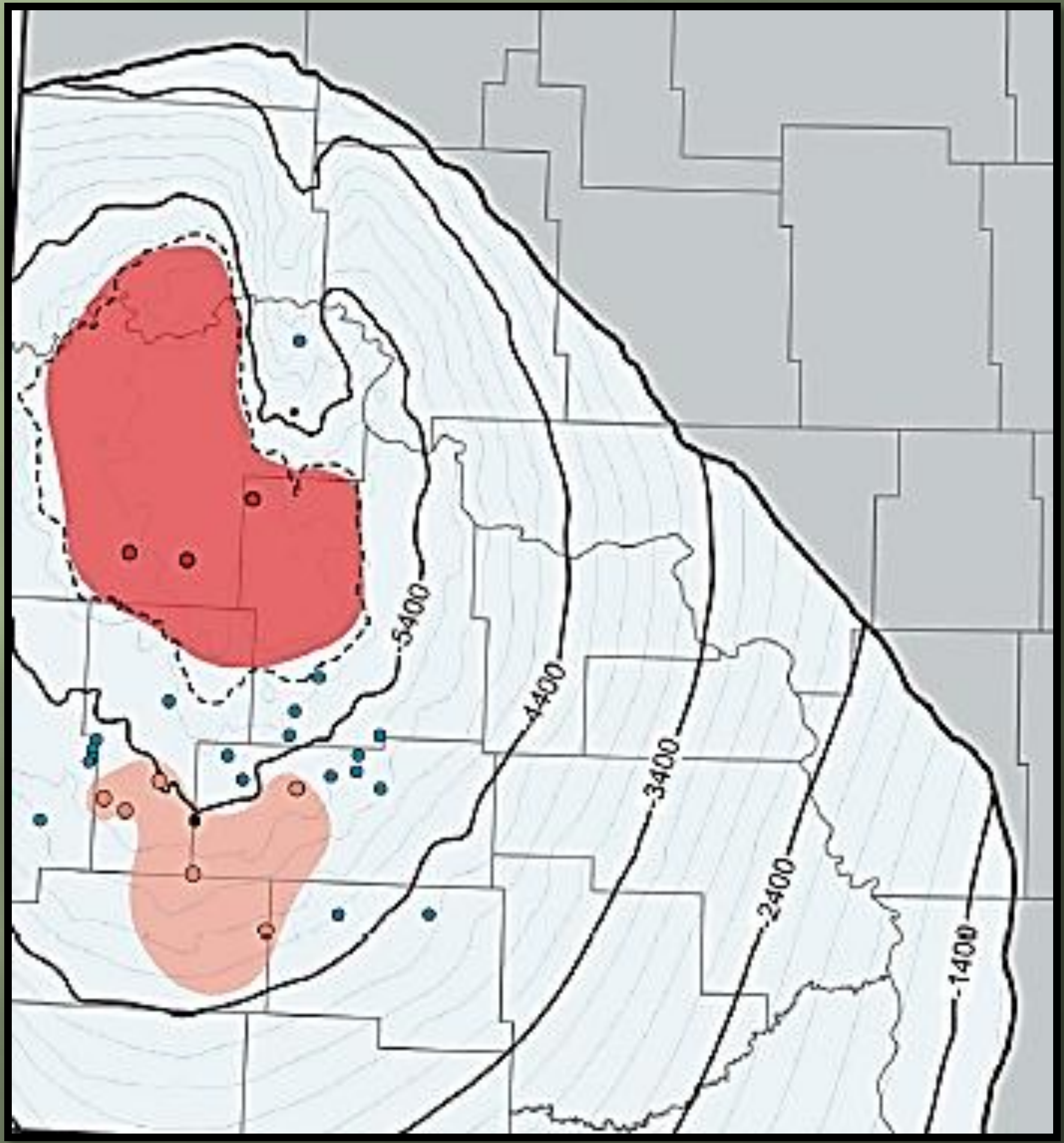
Cyclicity in the Tyler Formation from Sturm, 1987.

Geochemistry

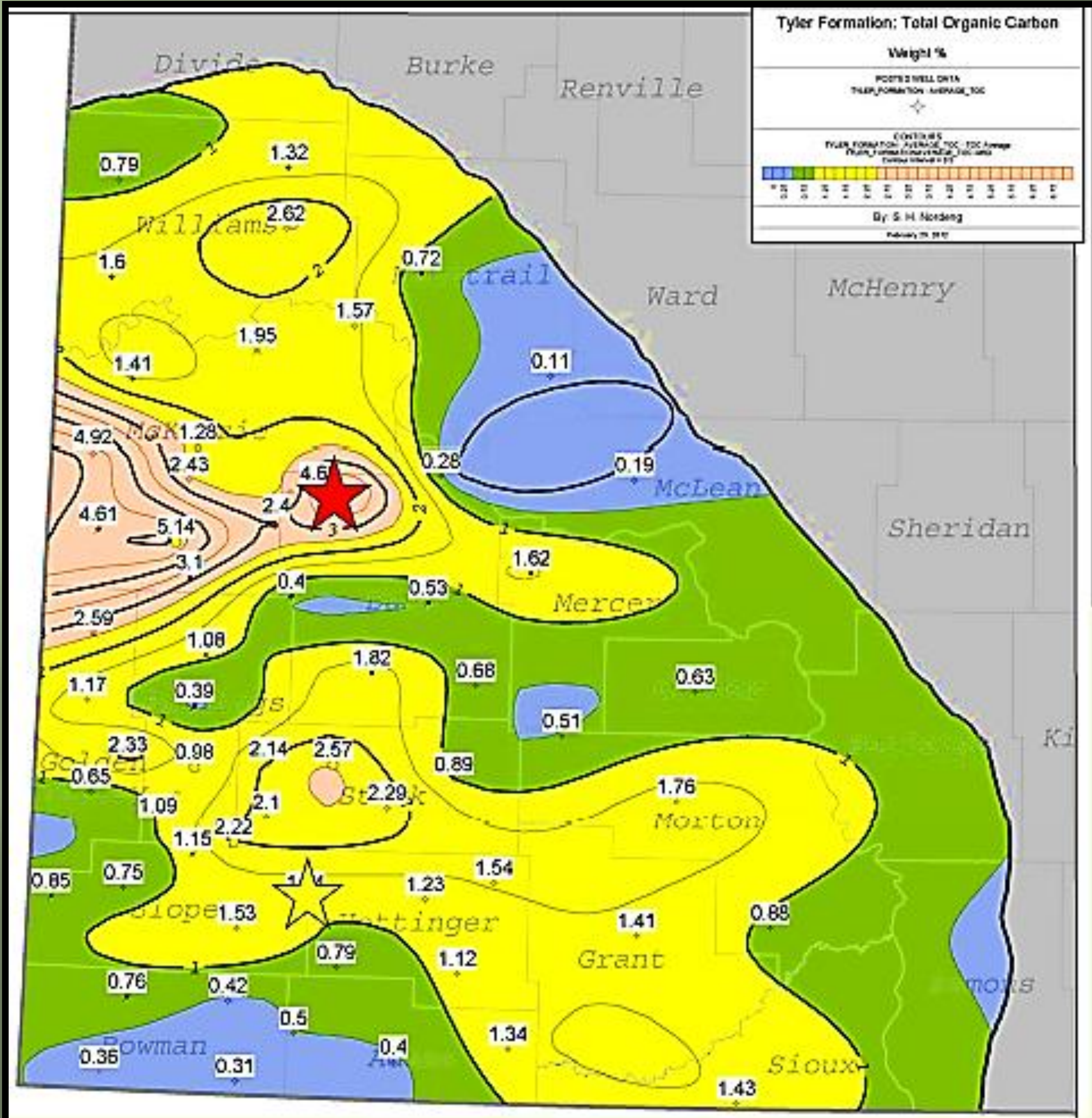


RESERVOIR AGE	TYPE I	TYPE II	TYPE III
TRIASSIC - JURASSIC	—	2	—
PERMIAN	—	—	—
PENNSYLVANIAN	—	—	7
MISSISSIPPIAN	2	69	—
DEVONIAN	3	5	—
SILURIAN	7	—	—
ORDOVICIAN	30	—	—

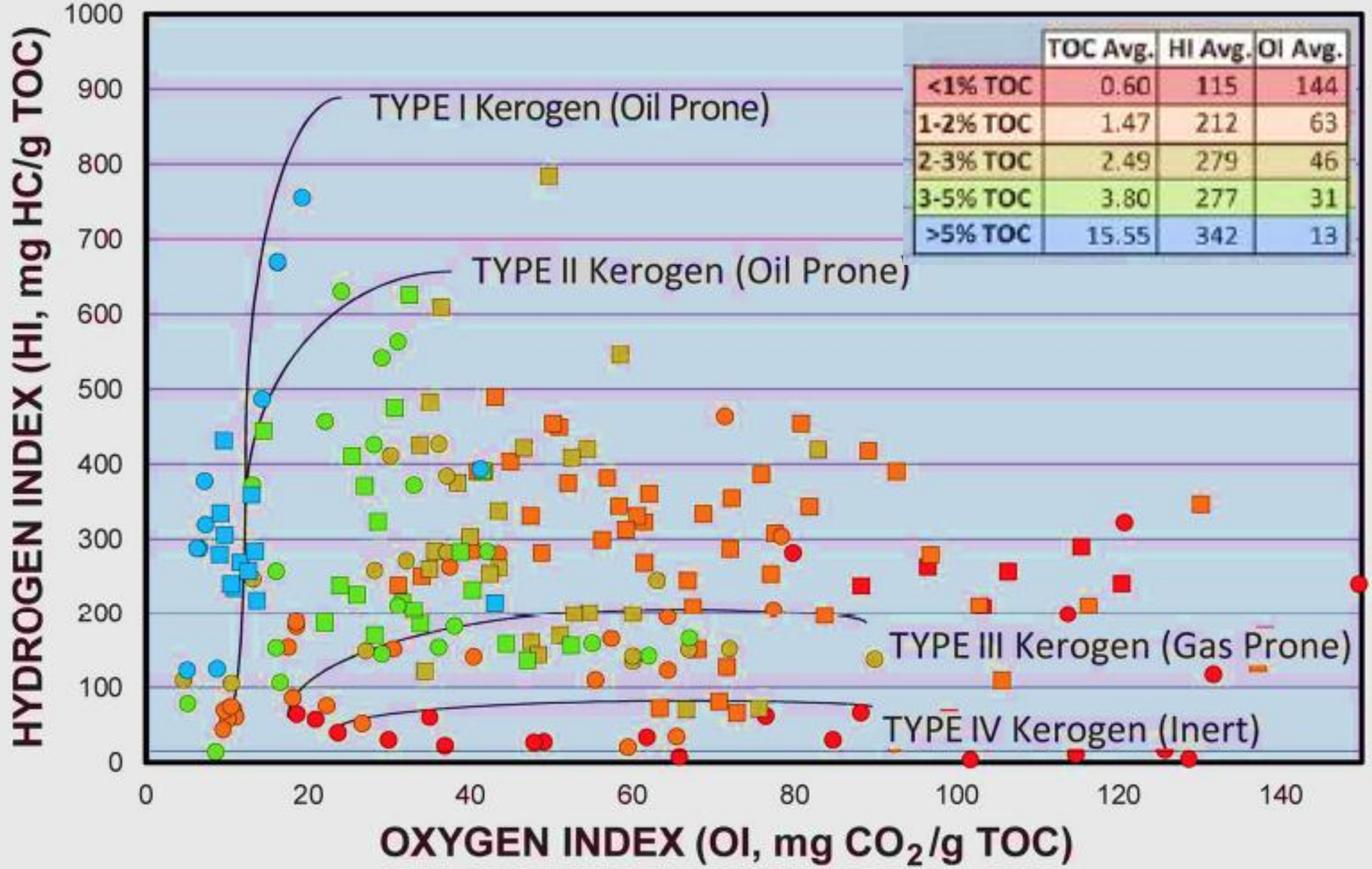
Williams, 1974



Northern and southern fields with abnormally high fluid pressures. Blue dots represent DST with normal fluid pressures, light red dots are pressures in southern field ranging from 3900-4400 psi, and the red dots in northern field range from 4400-4700 psi; from Nesheim and Nordeng, 2011.

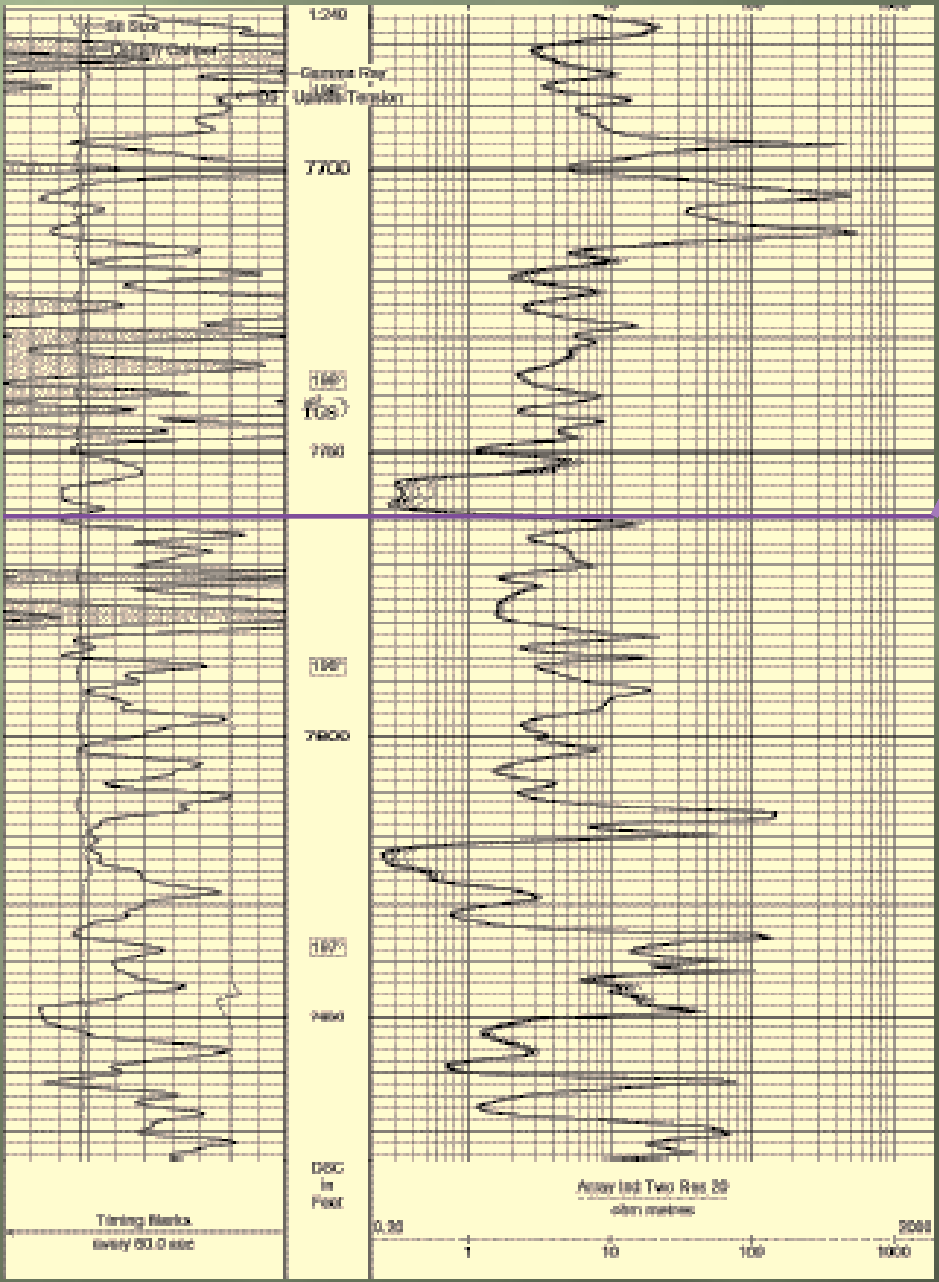


Average total organic carbon content (TOC wt.%) for the entire Tyler section, Nordeng and Nesheim, 2012



	TOC Avg.	HI Avg.	OI Avg.
<1% TOC	0.60	115	144
1-2% TOC	1.47	212	63
2-3% TOC	2.49	279	46
3-5% TOC	3.80	277	31
>5% TOC	15.55	342	13

Nordeng and Nesheim, 2012b



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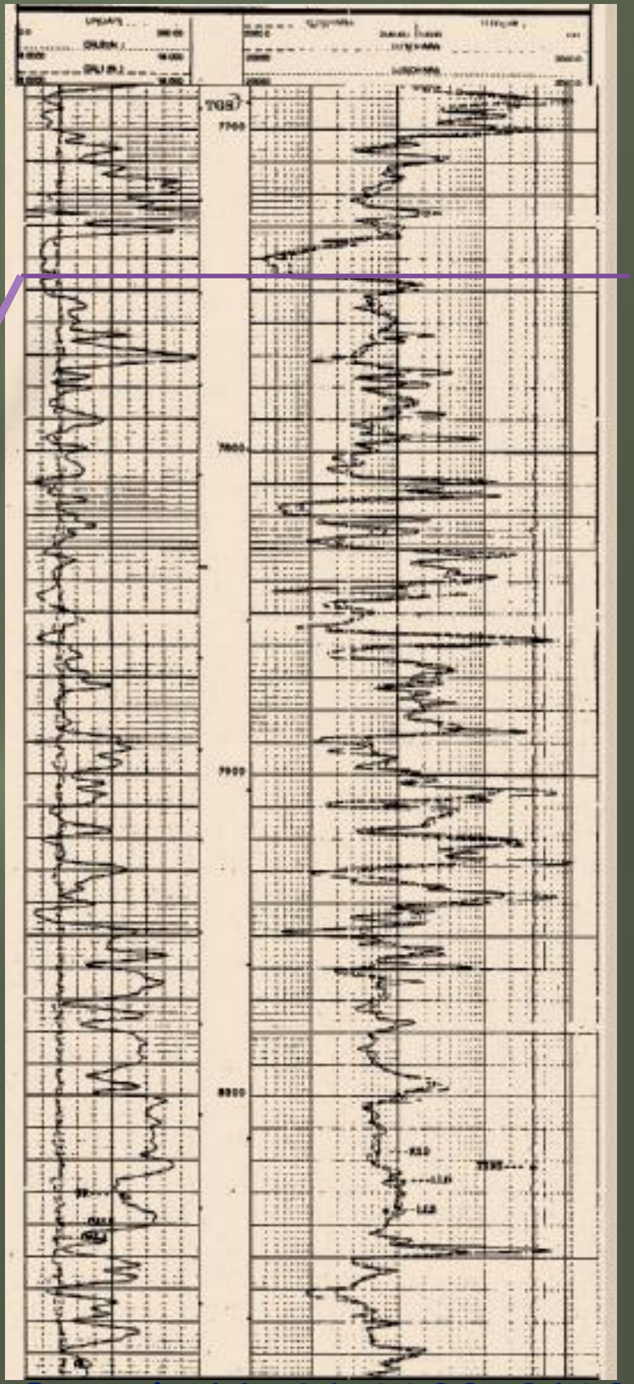

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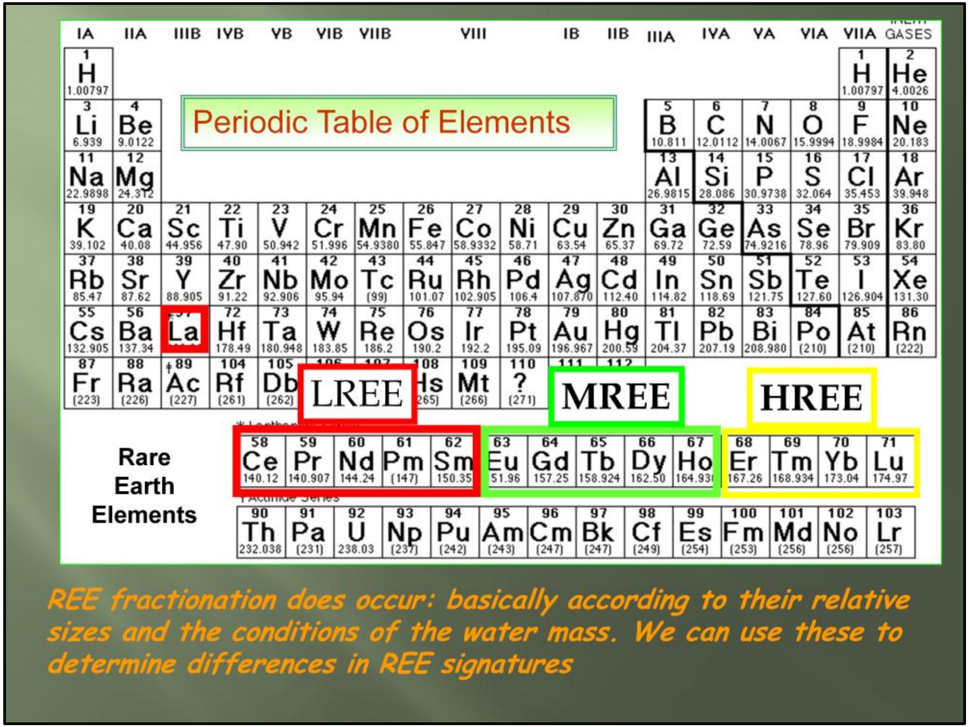


Presenter's notes: Rare Earth Elements are numbered 57-71 on the periodic table. The Lanthanide series includes the elements from La- Lu. They all have similar chemical and physical properties and an oxidation state of +3, with the exception of Ce and Lu which under redox conditions will change their oxidation states. There is an decrease in the ionic radius known as the Lanthanide contraction as we move down the periodic table but generally have similar ionic radii. The significance is here that the REE's have virtually the same ionic radius as Ca.

a) Rare Earths are numbered 57-71 on the periodic table
b) Include La- Lu
c) 3+ Oxidation state:Ce will change its oxidation state in certain oxidizing conditions
d) Although there is a steady decrease in ionic radii all have ~ the same radius as Ca

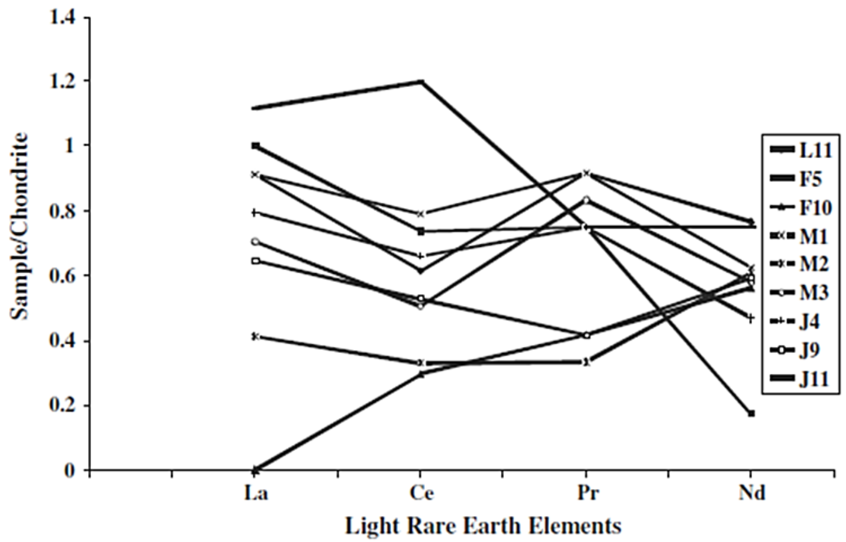


Fig. 3b. Chondrite-normalized LREE patterns for oils offshore fields in the Niger Delta.

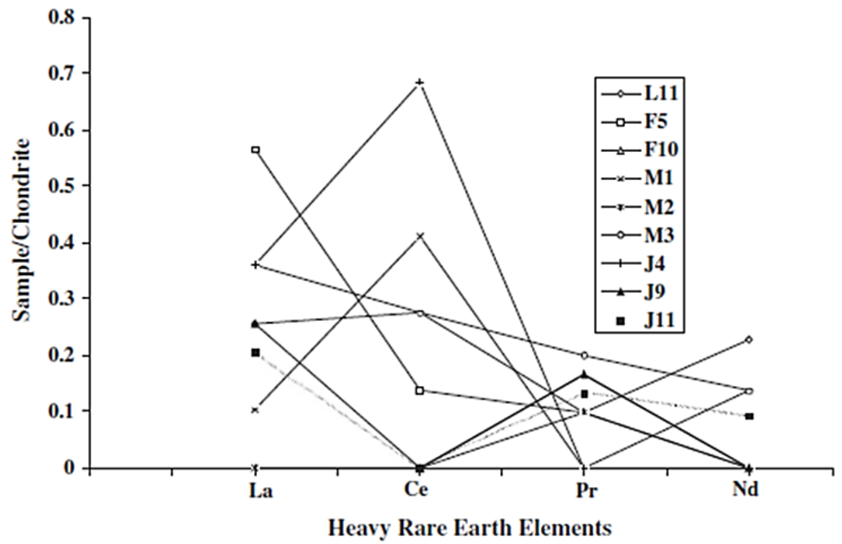
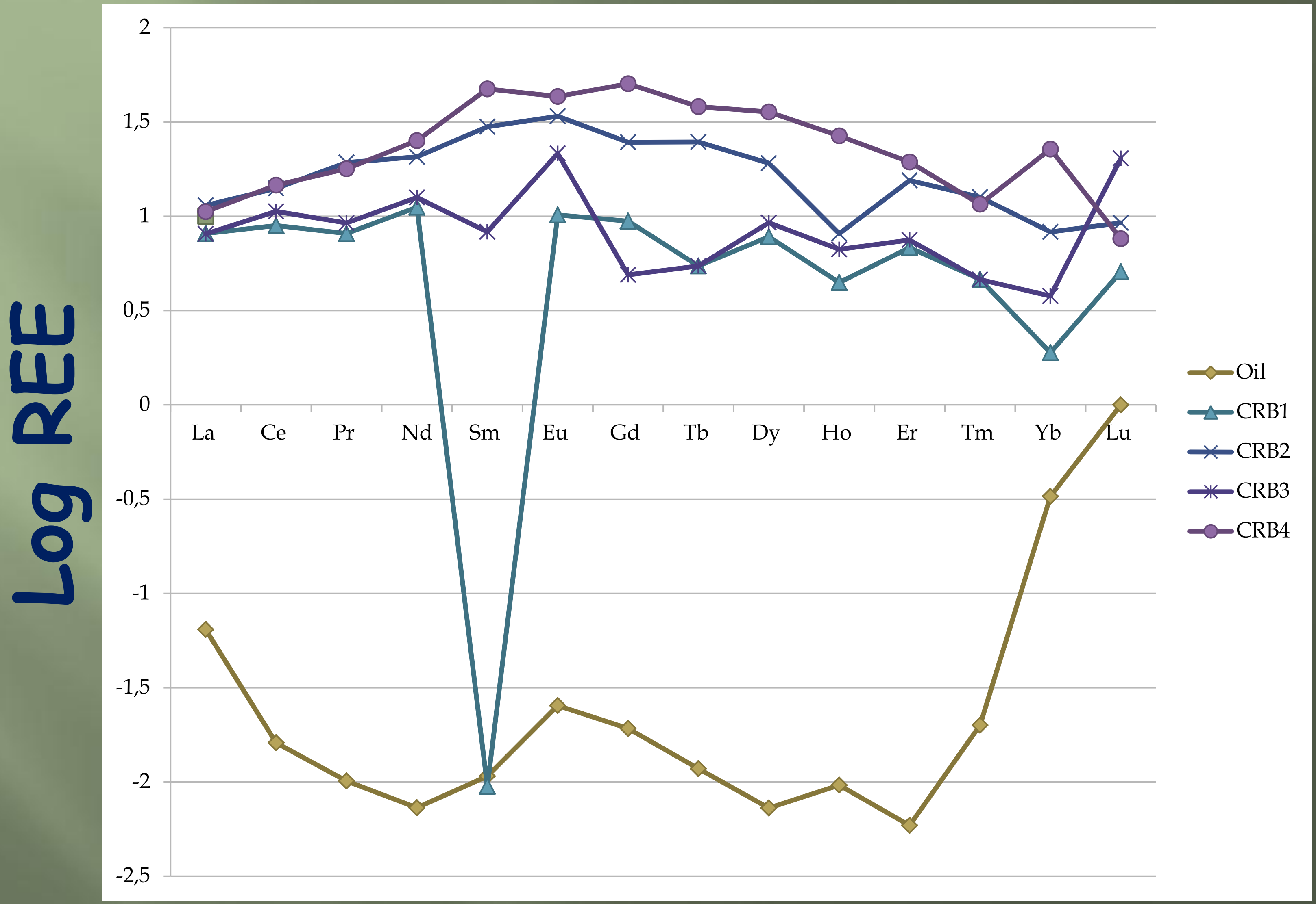


Fig. 4. Chondrite-normalized HREE pattern for oils from offshore fields in the Niger Delta.

Each oil reservoir REE signatures reflect the original depositional environment and are unique to each deposit.

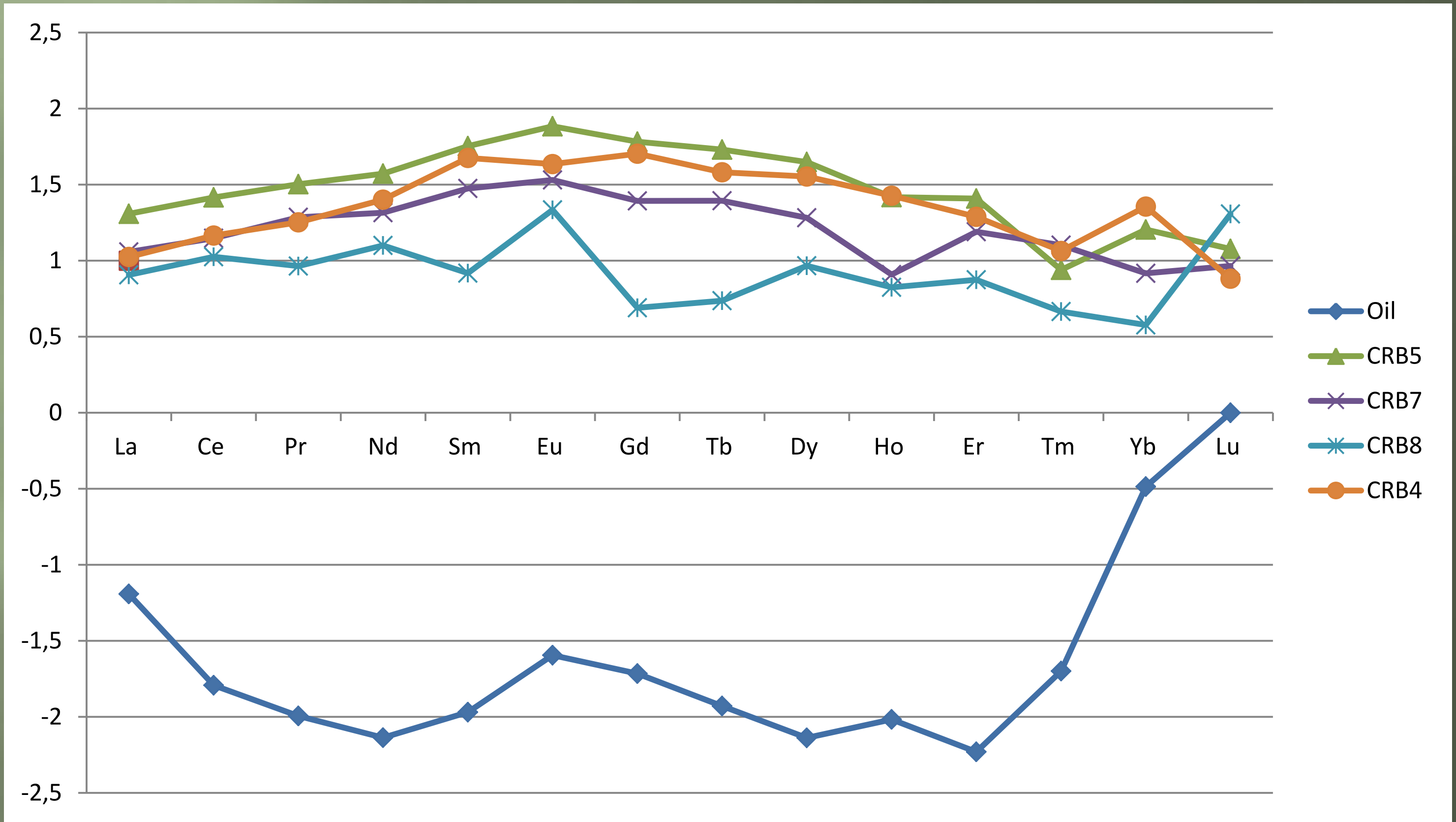
Oil vs CRB 1-4



CRB3 (cryptocrystalline limestone) trend is most similar

Oil vs CRB 5-8

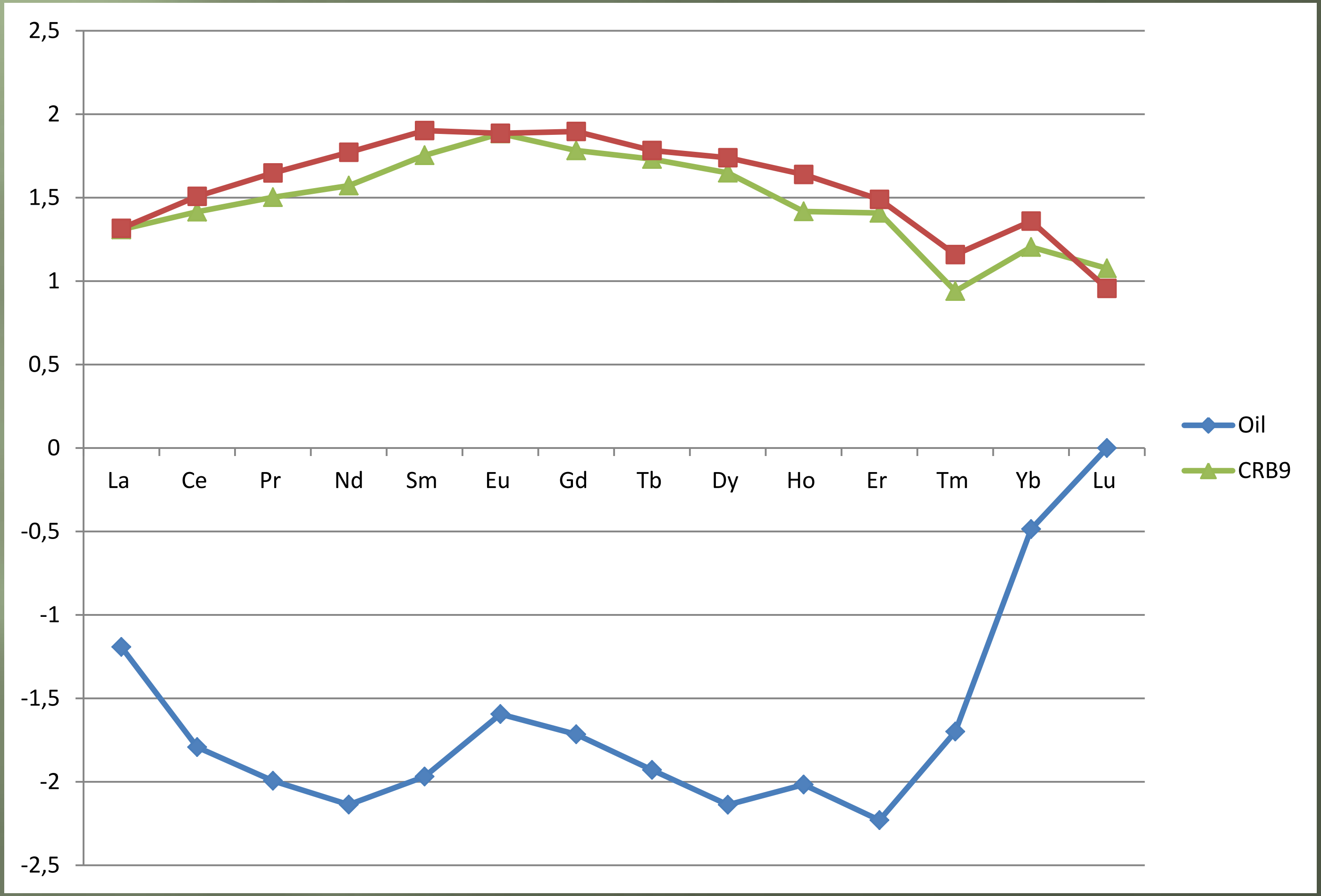
Log REE



CRB8 (sh/ls/ss) trend is most similar

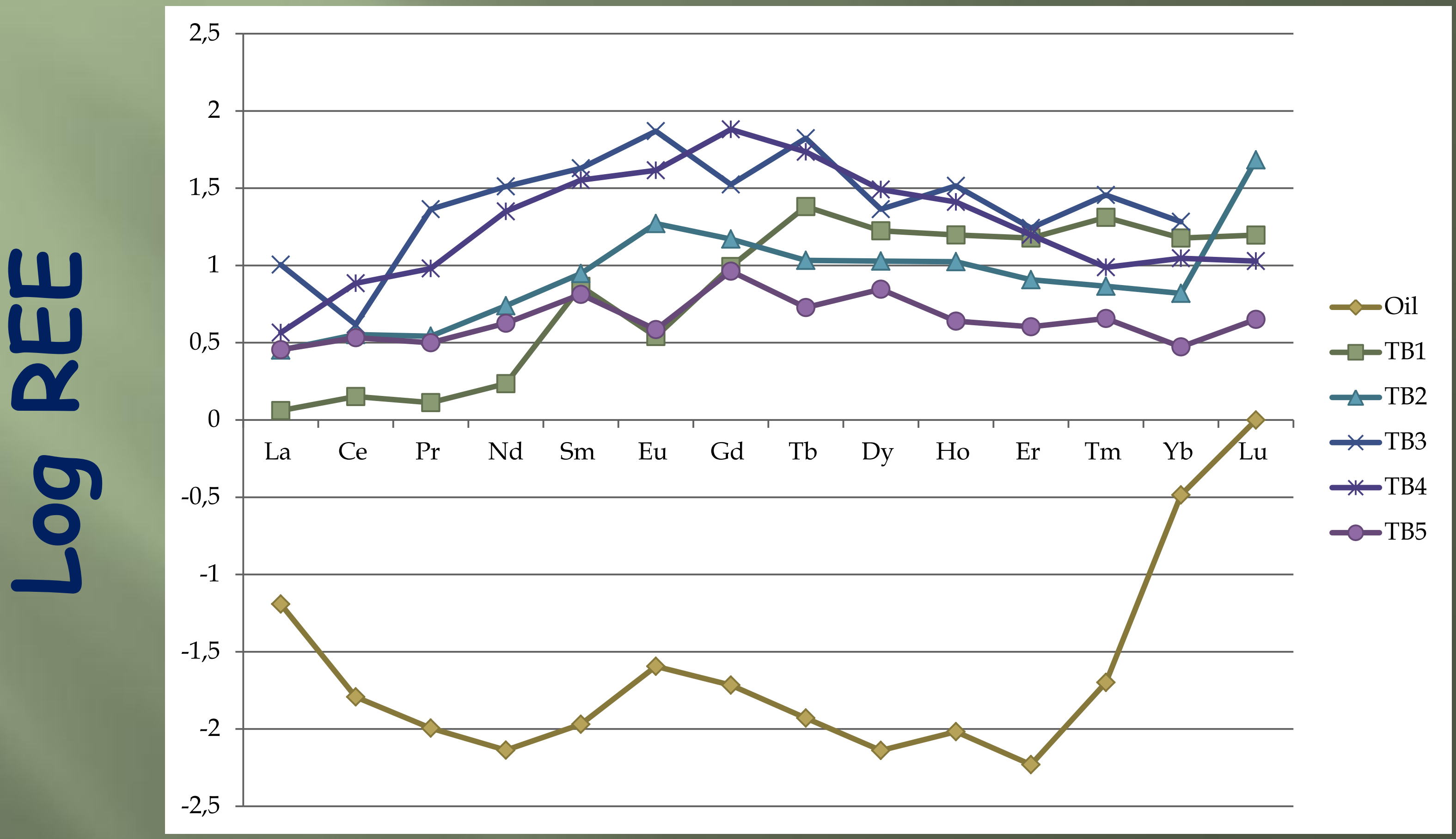
Oil vs CRB 9-10

Log REE



No noticeable similarity

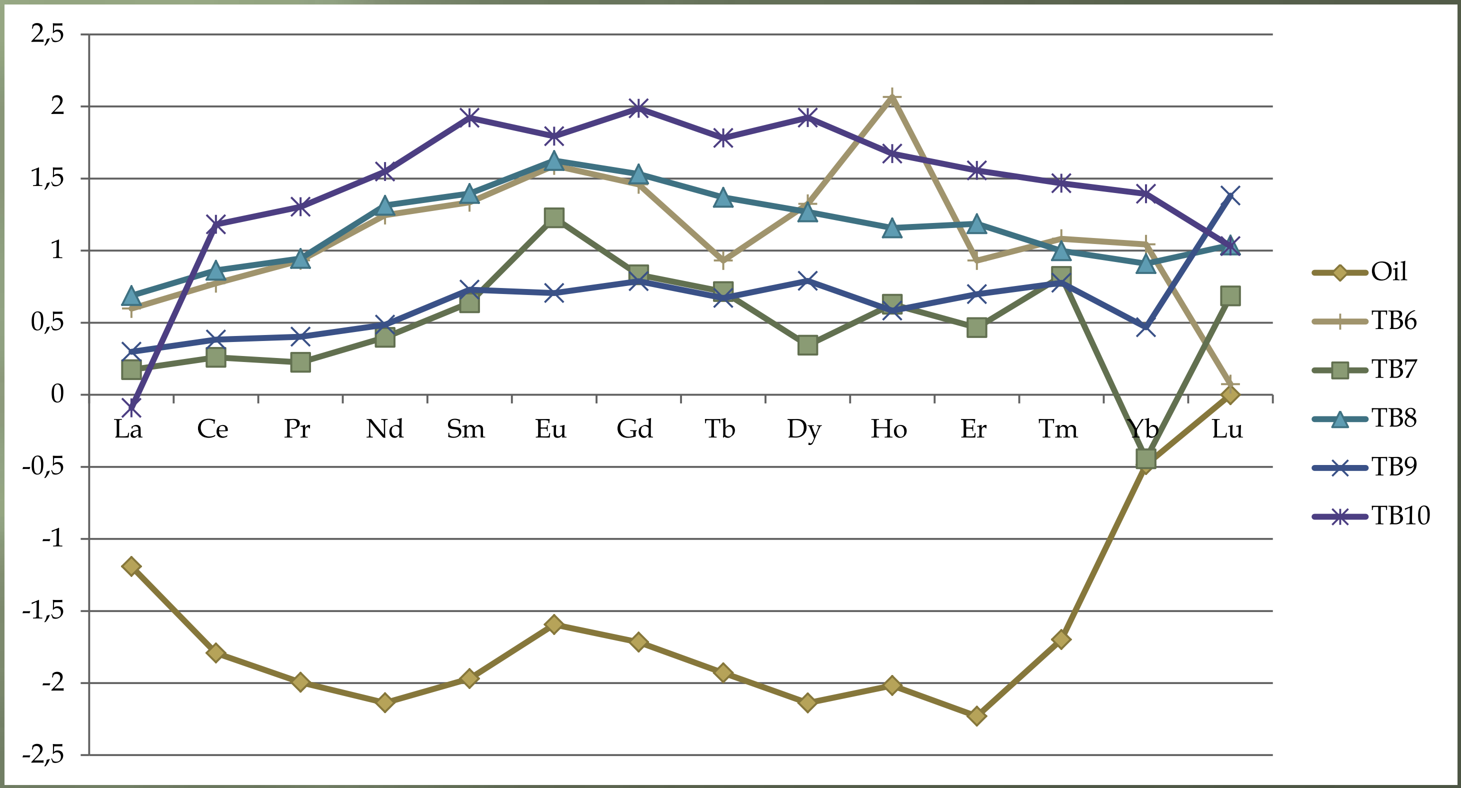
Oil vs TB 1-5



TB2 trend is most similar

Oil vs TB 6-10

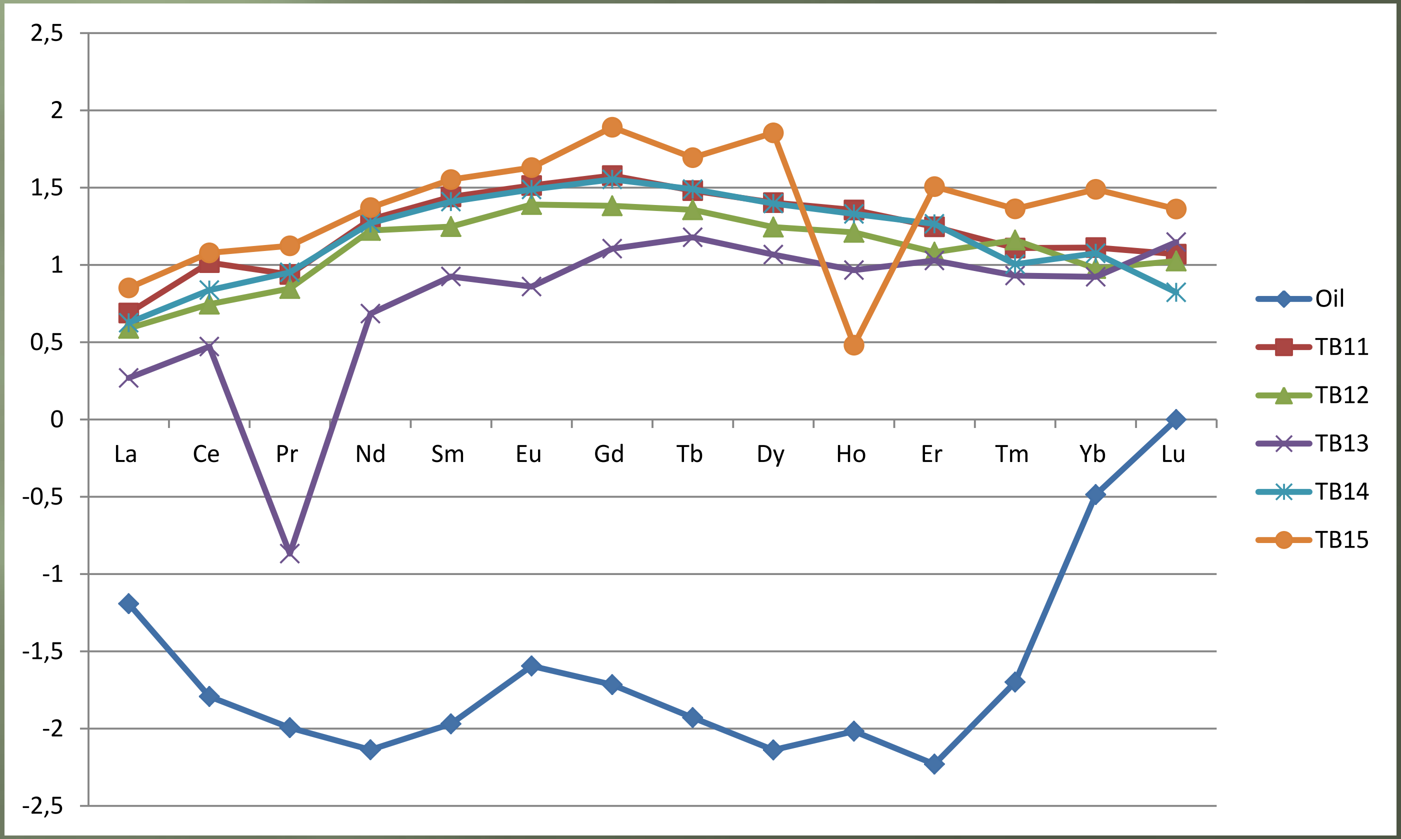
Log REE



TB7 trend is most similar

Oil vs TB 11-15

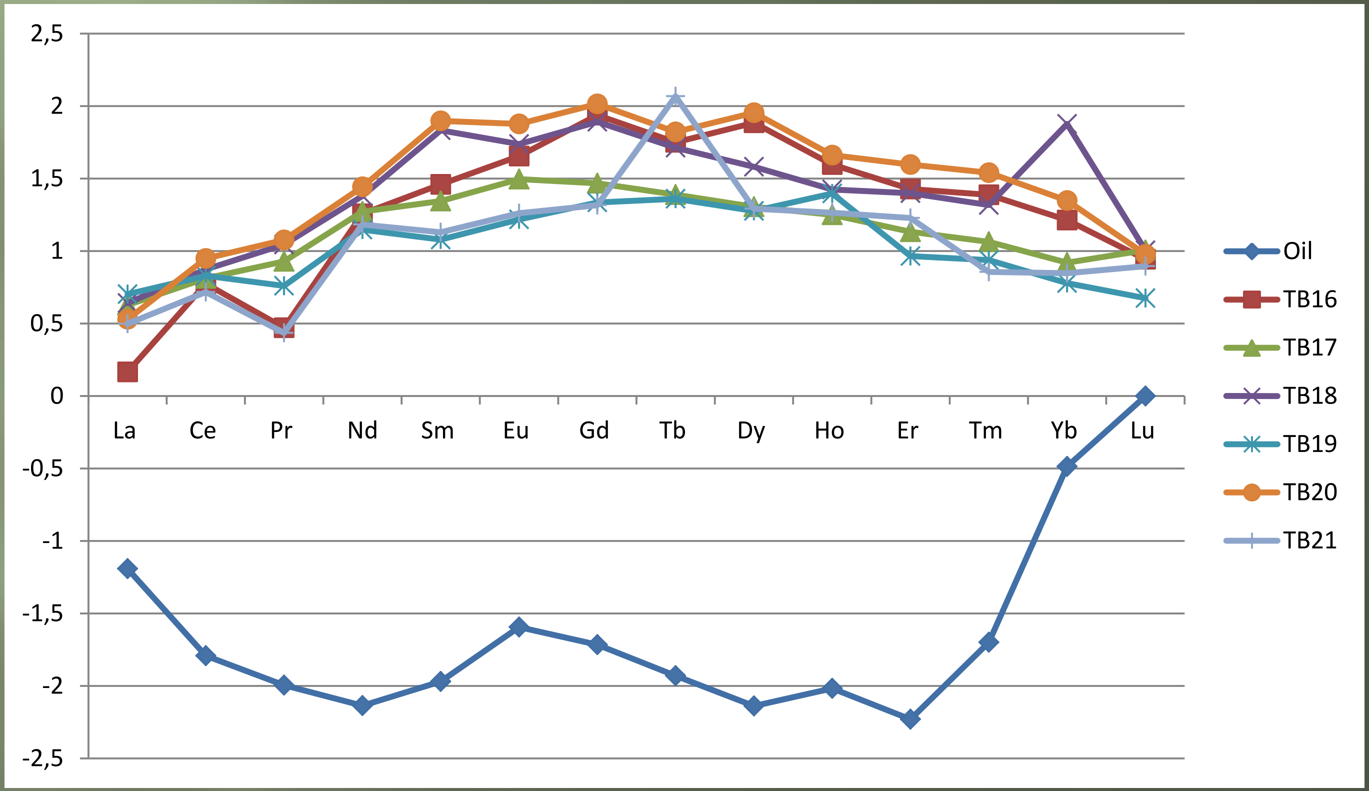
Log REE



No noticeable similarity

Oil vs TB 16-21

Log REE



No noticeable similarity

Further work will entail:

1. Comparison between the oils
2. Oil and core from the same well
3. Discriminant analysis to determine further comparisons of clustering or grouping of data
4. Sequential extraction of the sediments vs the bulk analysis for finer resolution
5. Further graphical analysis looking closer at the paleonenvironments that the REE signatures infer.