

# **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.

### References Cited

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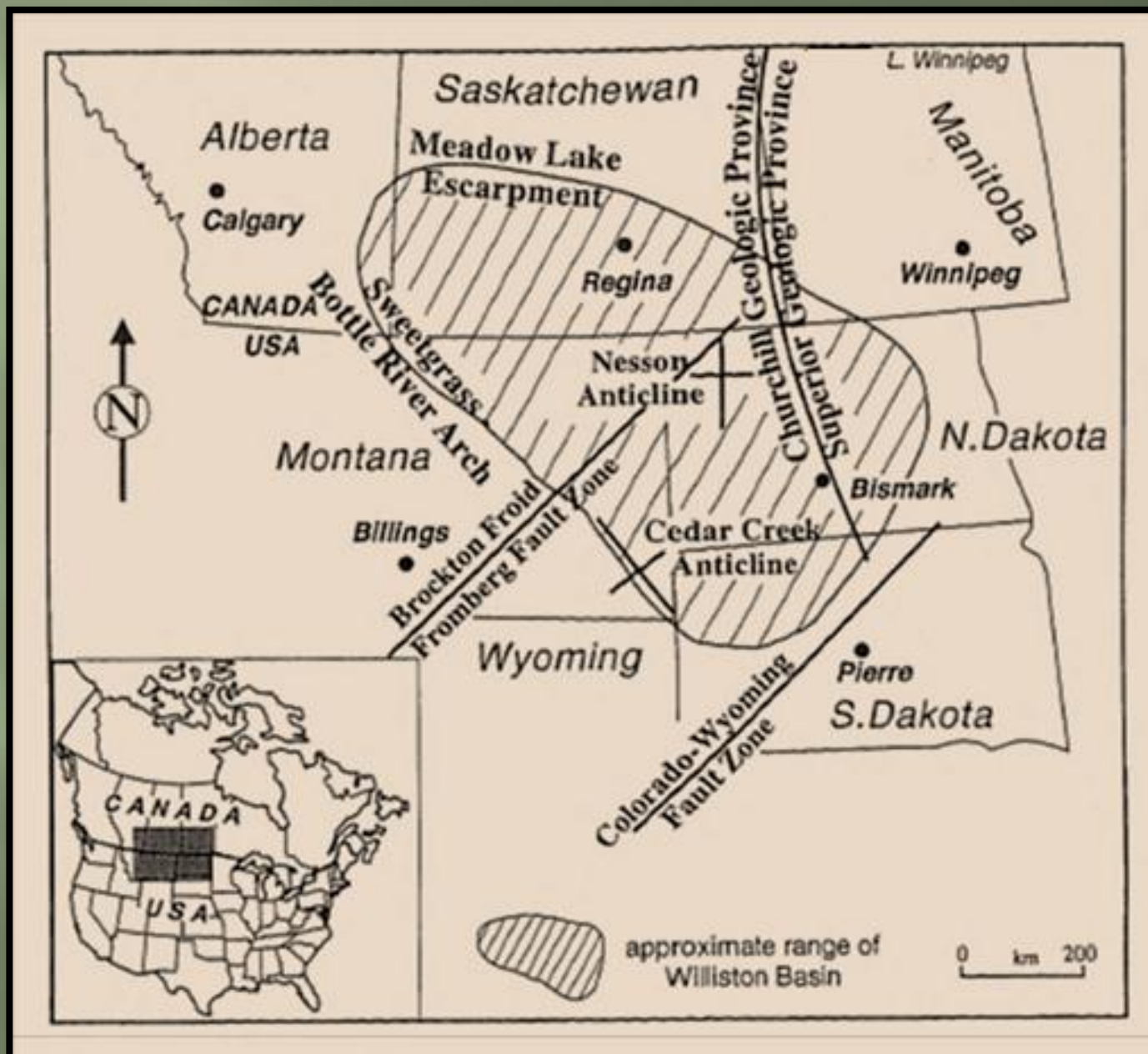
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Sturm, S.D., 1987, Depositional history and cyclicity in the Tyler Formation (Pennsylvanian), southwestern North Dakota, *in* J.A. Peterson, D.M. Kent, S.B. Anderson, R.H. Pilatzke, and M.W. Longman, eds., Williston Basin; anatomy of a cratonic oil province: RMAG, p. 209-222.

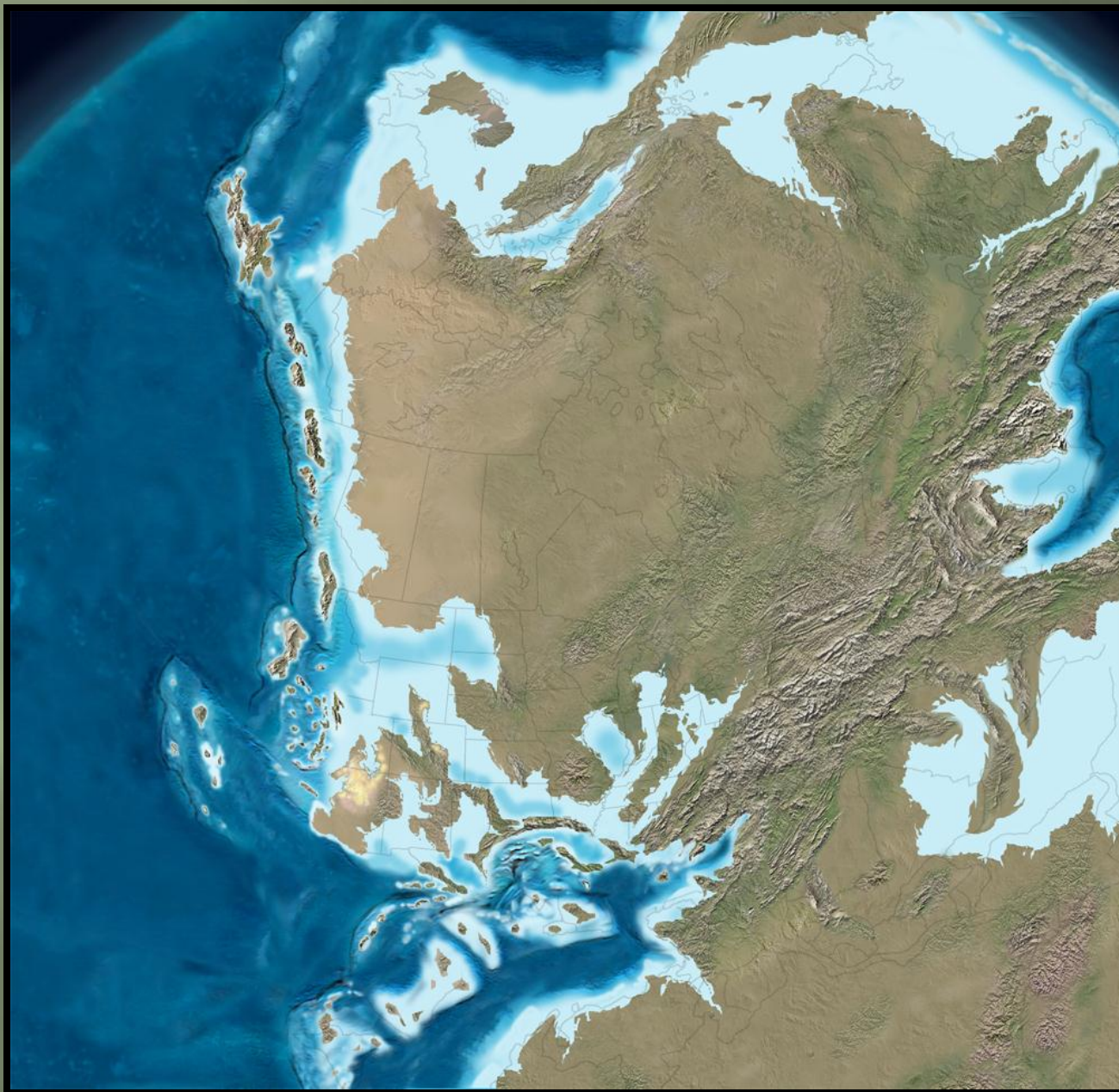
# EVALUATION OF THE TYLER FORMATION, WILLISTON BASIN, WESTERN NORTH DAKOTA

Ivana (Vanja) M. Stevanović



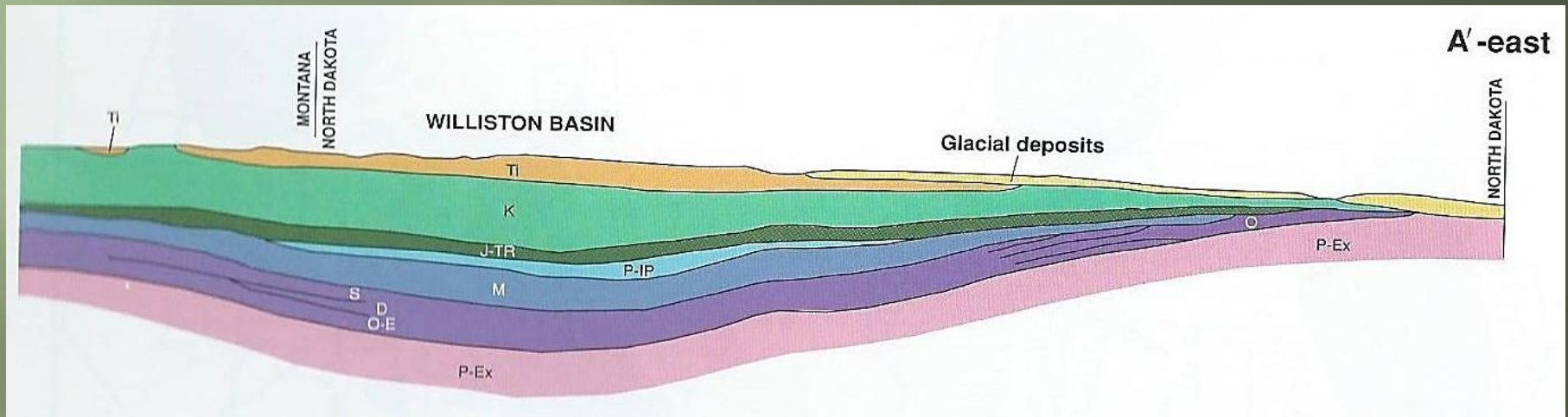
Index map showing location and main structural elements of the Williston Basin (from Obermajer et al., 2000)





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

# Cross section through Williston Basin and Montana



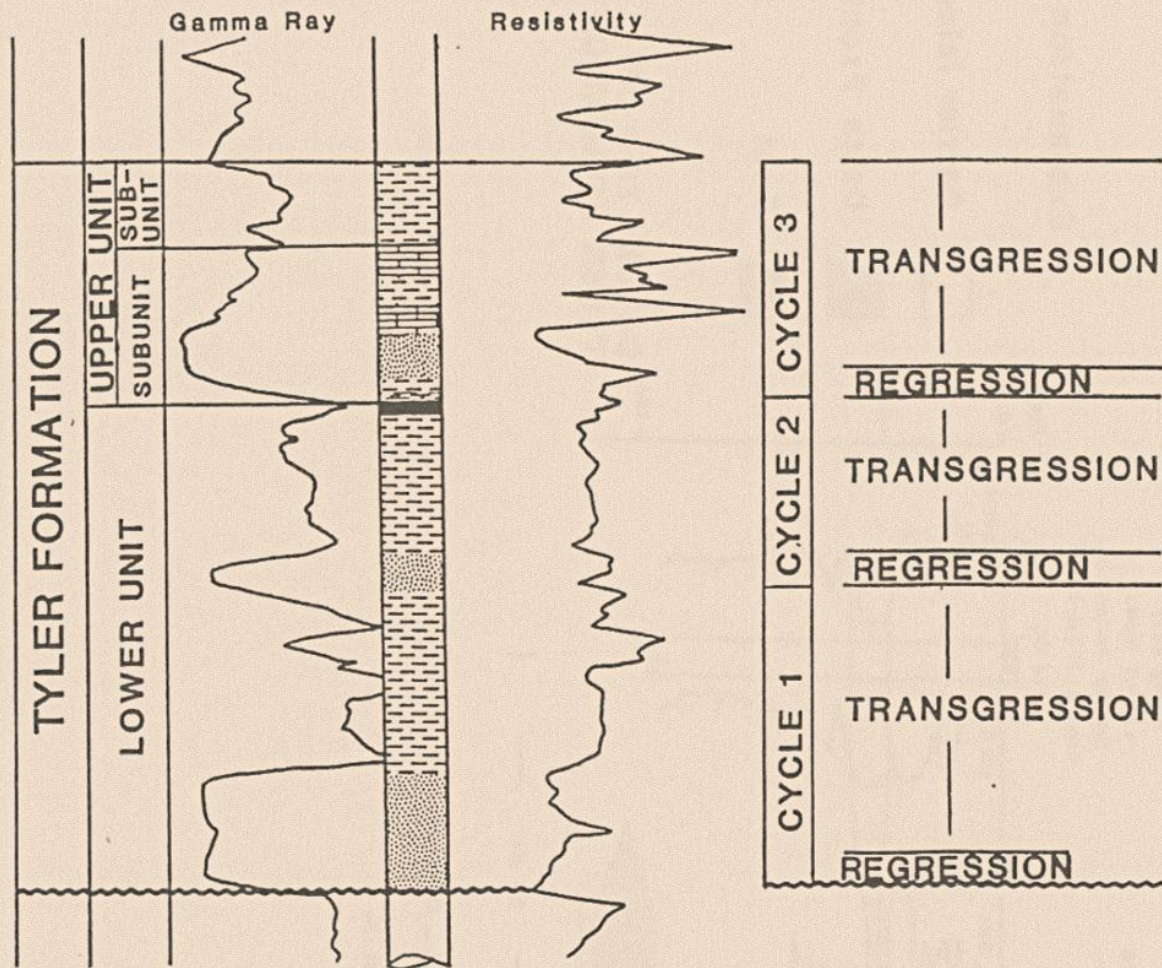
Systems	Rock Units		Permian	Minnekahta
Quaternary	Pleistocene			Oreche
	White River		Pennsylvanian	Broom Creek
	Golden Valley			Amsden
				Tyler
Tertiary	Fort Union Group			Otter
				Kibbey
			Mississippian	Charles
				Mission Canyon
				Lodgepole
	Hell Creek			Bakken
	Fox Hills			Three Forks
	Pierre			Birdbeak
	Judith River			Duperow
	Badre			Souris River
	Niobrara		Devonian	Dawson Bay
	Carlile			Prairie
	Greenhorn			Winnipegosis
	Belle Fourche			Asbern
	Mowry			Interlake
	Newcastle		Silurian	Stonewall
	Skull Creek			Stony Mountain
	Inyan Kara			Red River
				Winnipeg Group
Jurassic	Swift		Ordovician	Deadwood
	Rierdon			
	Piper			
Triassic	Spearfish		Cambrian	
Permian			Precambrian	

# Generalized stratigraphic column of the Williston Basin

From North Dakota Geological Survey  
[www.dmr.nd.gov](http://www.dmr.nd.gov)



FARMERS UNION CENTRAL EXCHANGE  
 Krushensky #6-34  
 SE NW Sec.34-140N.-99W.  
 Stark County



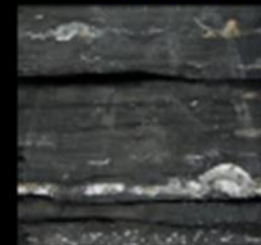
Red mudstone



Black shale



Organic-rich limestone



Thin coal



Cyclicality in the Tyler Formation from Sturm, 1987.



# Geochemistry

## SOURCE ROCK EXTRACTS

△ WINNIPEG SH.

● BAKKEN SH.

□ TYLER SH.

STRAIGHT  
CHAIN

TYPE I OILS

TYPE III OILS

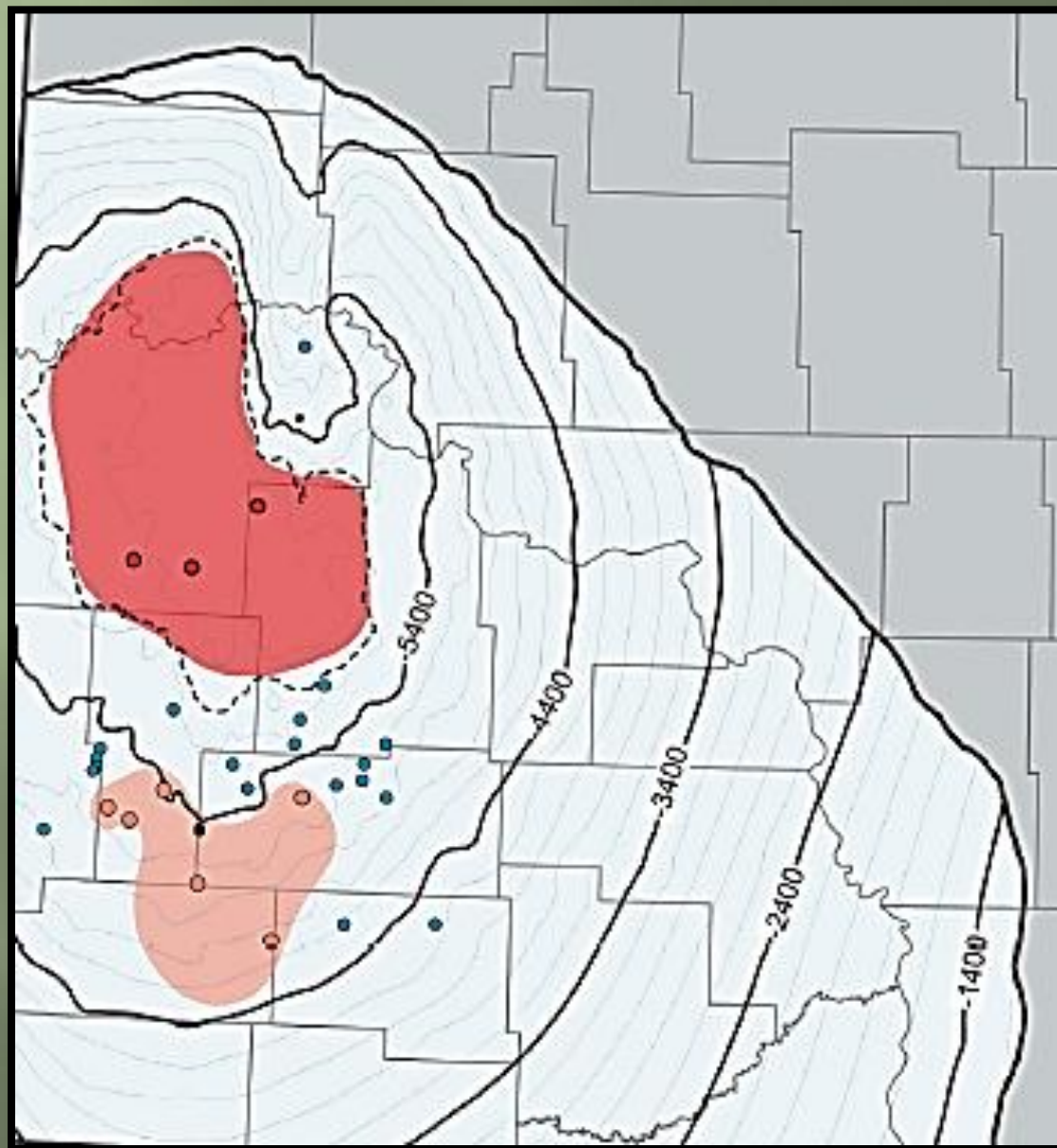
TYPE II  
OILS

BRANCHED  
CHAIN

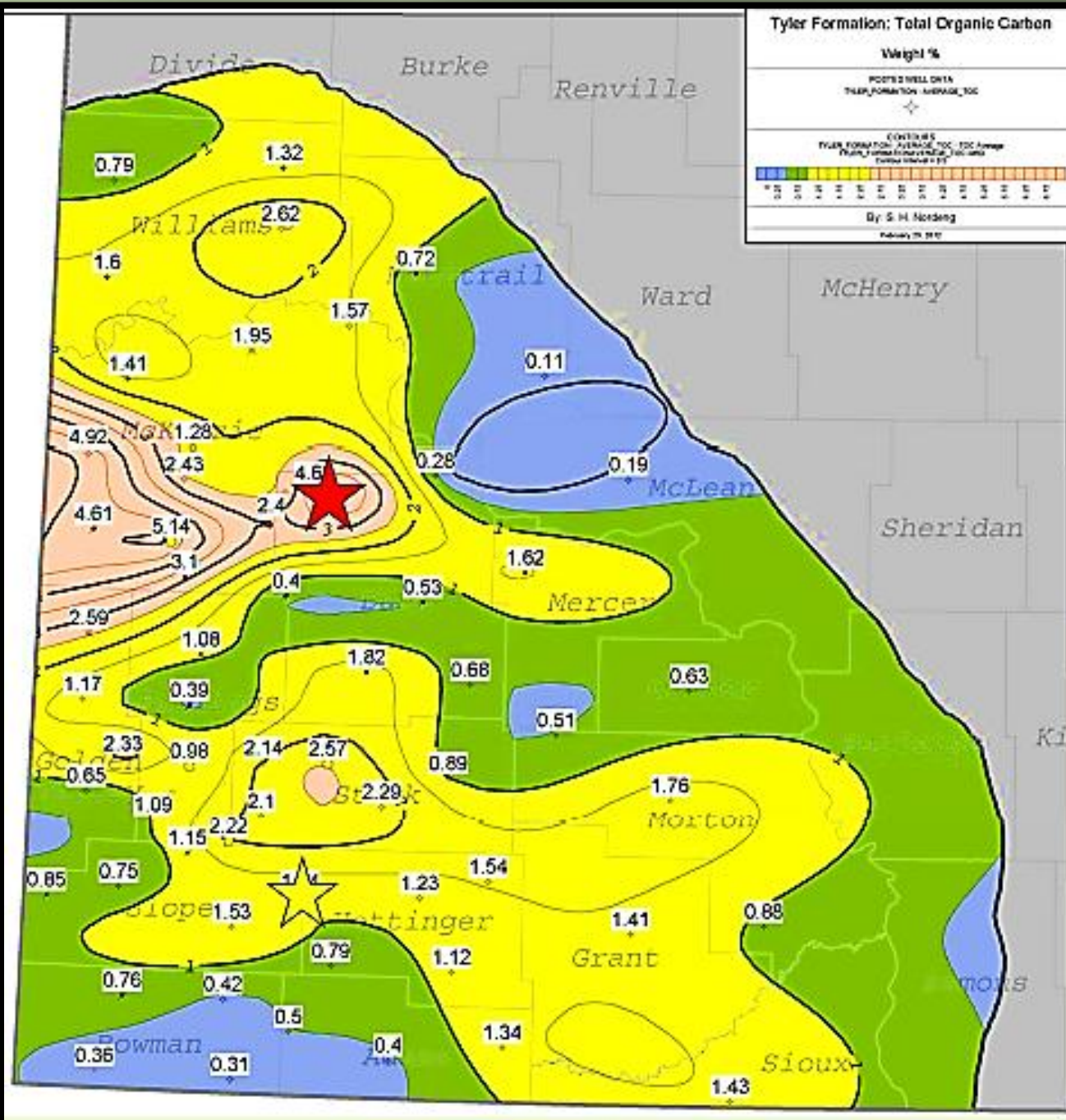
CYCLIC  
(NON-AROMATIC)

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

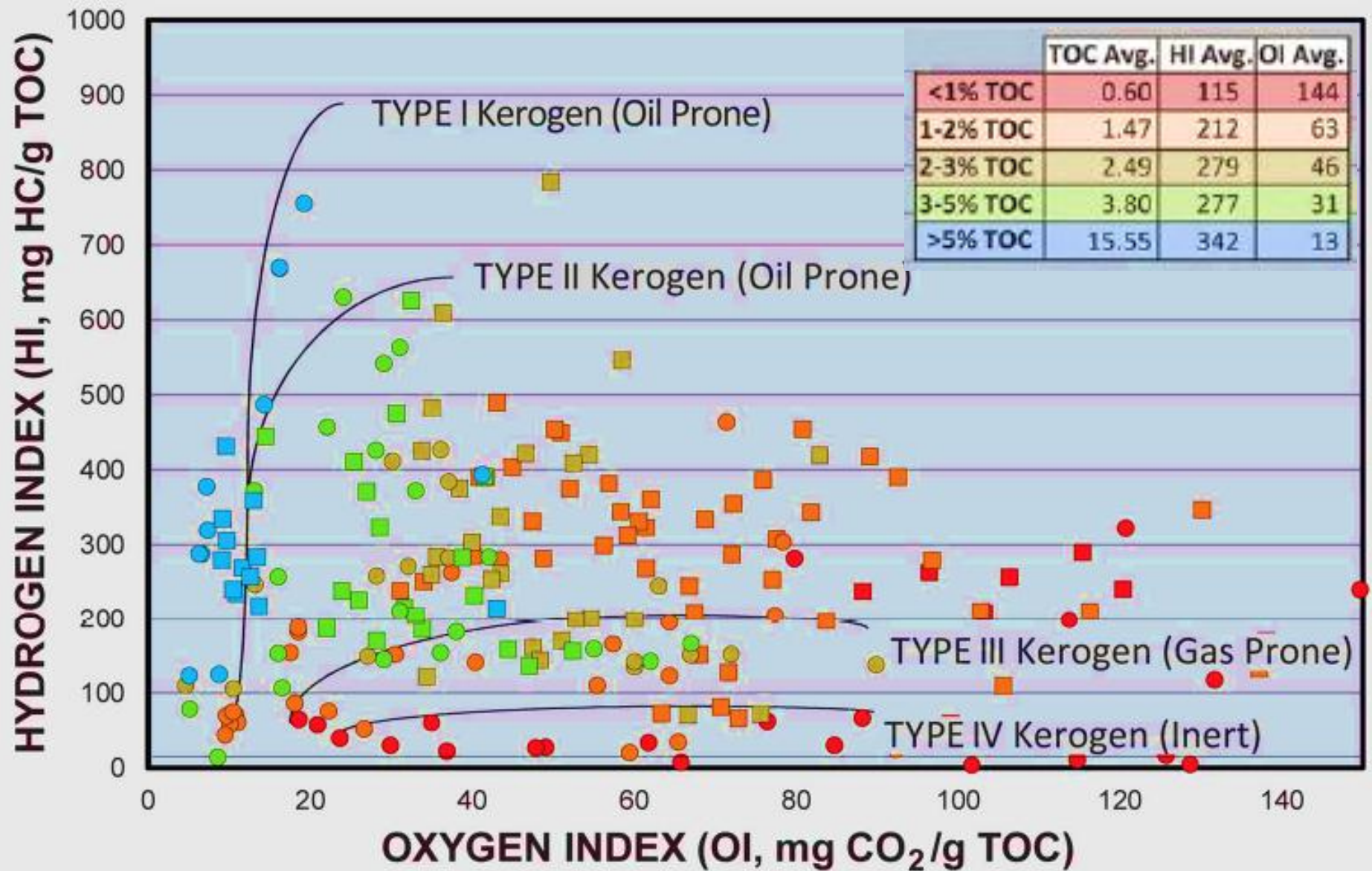


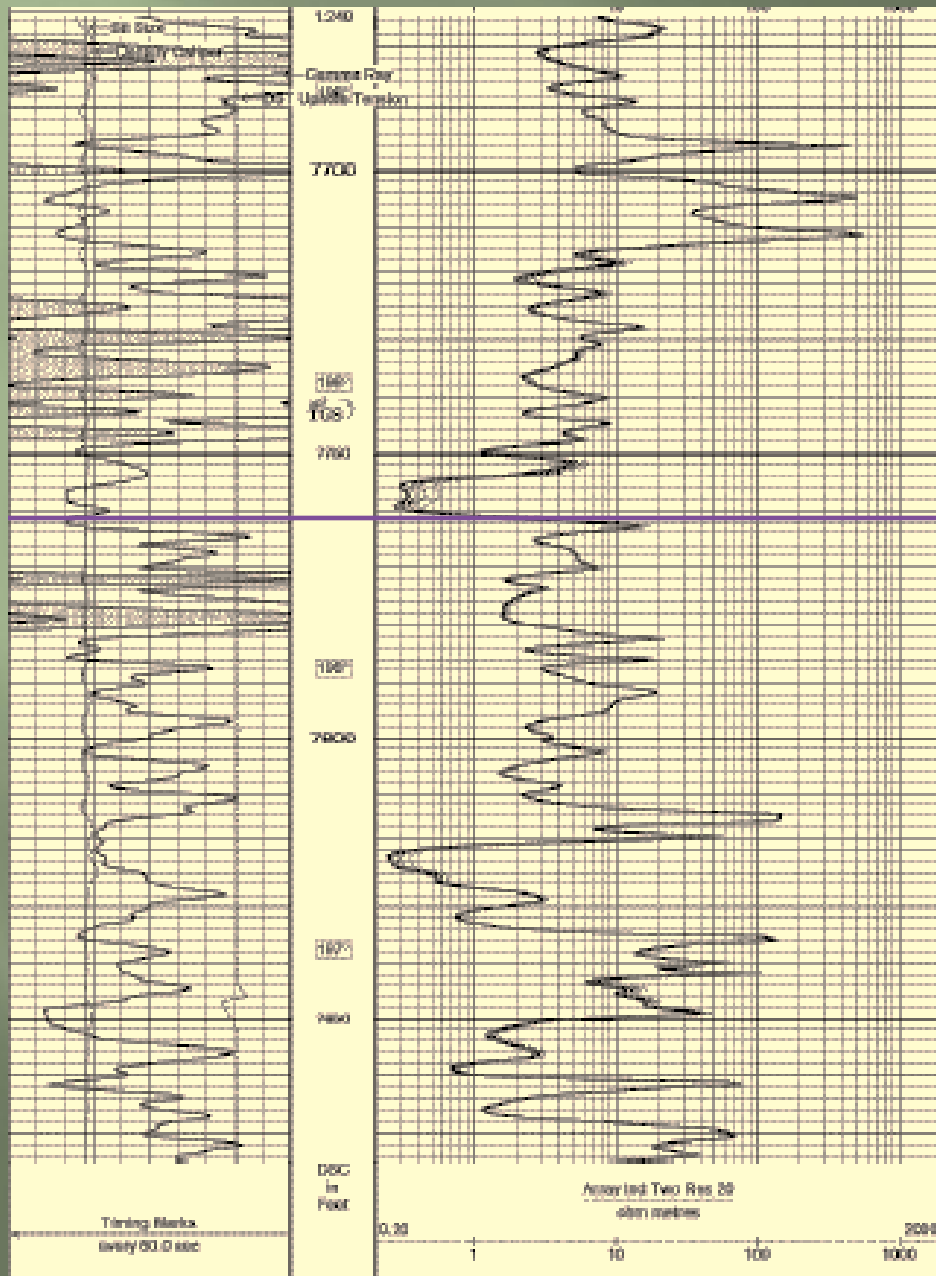
Northern and southern fields with abnormally high fluid pressures. Blue dots represent DST with normal fluid pressures, light red dots are pressures in southern field ranging from 3900-4400 psi, and the red dots in northern field range from 4400-4700 psi; from Nesheim and Nordeng, 2011.



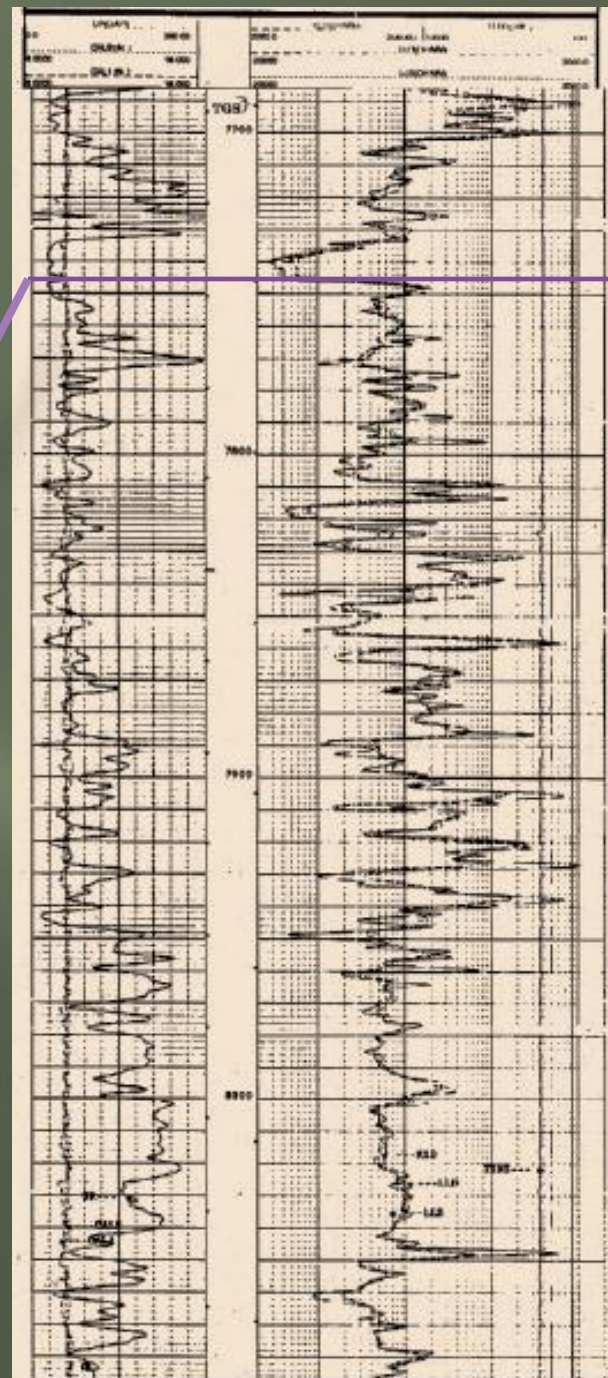
Average total organic carbon content (TOC wt.%) for the entire Tyler section, Nordeng and Nesheim, 2012







Vanvig1 3300701639



Paasch 11-26 3300701303

IA IIA IIIB IVB VB VIB VIIB VIII IB IIB IIIA IVA VA VIA VIIA																VIII GASES															
1 H 1.00797																	1 H 1.00797	2 He 4.0026													
3 Li 6.939	4 Be 9.0122	Periodic Table of Elements														5 B 10.811	6 C 12.0112	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.183										
11 Na 22.98976	12 Mg 24.304															13 Al 26.9815	14 Si 28.086	15 P 30.9738	16 S 32.06	17 Cl 35.453	18 Ar 39.948										
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.9332	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.909	36 Kr 83.80														
37 Rb 85.47	38 Sr 87.62	39 Y 88.905	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc (99)	44 Ru 101.07	45 Rh 102.905	46 Pd 106.4	47 Ag 107.870	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.904	54 Xe 131.30														
55 Cs 132.905	56 Ba 137.34	57 La 138.905	58 Ce 140.12	59 Pr 140.907	60 Nd 144.24	61 Pm (147)	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.924	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.97	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.967	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.980	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	90 Th (232)	91 Pa (231)	92 U 238.03	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (249)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (256)	103 Lr (257)															

Rare Earth Elements

LREE

MREE

HREE

## Periodic Table of Elements

LREE

MREE

HREE

Rare Earth Elements

*REE fractionation does occur: basically according to their relative sizes and the conditions of the water mass. We can use these to determine differences in REE signatures*

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.

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



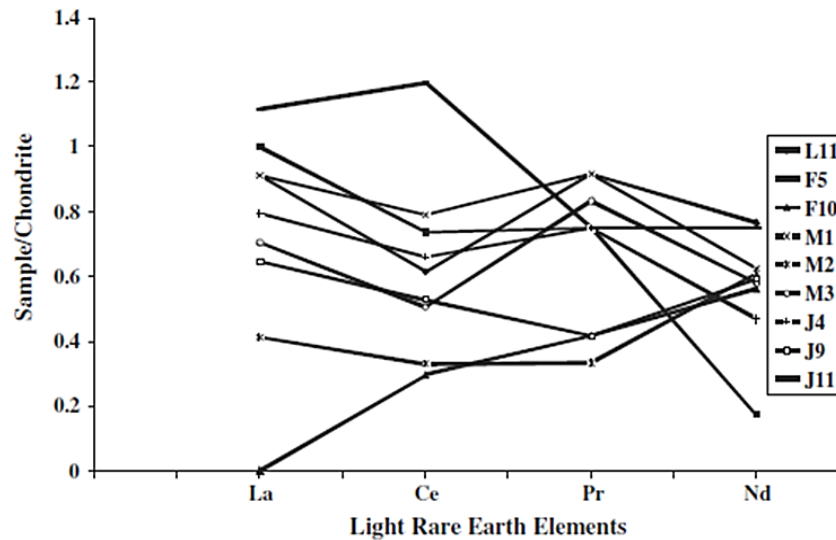


Fig. 3b. Chondrite-normalized LREE patterns for oils offshore fields in the Niger Delta.

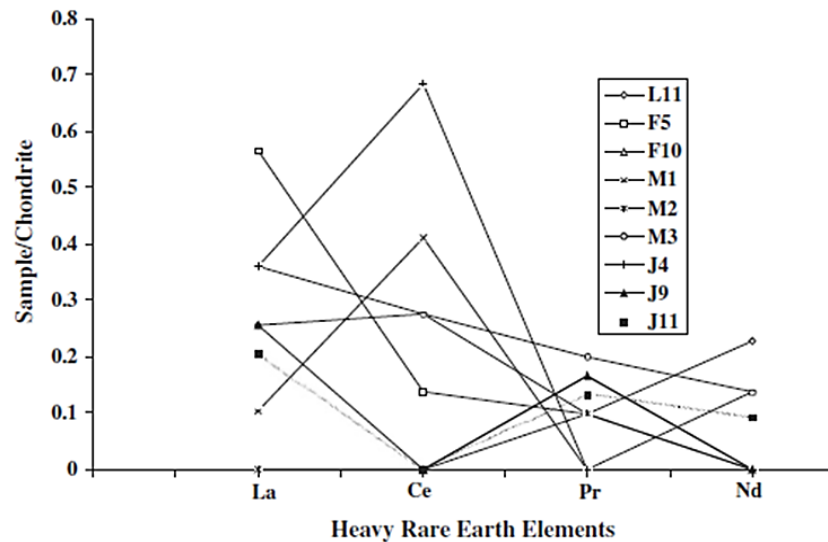
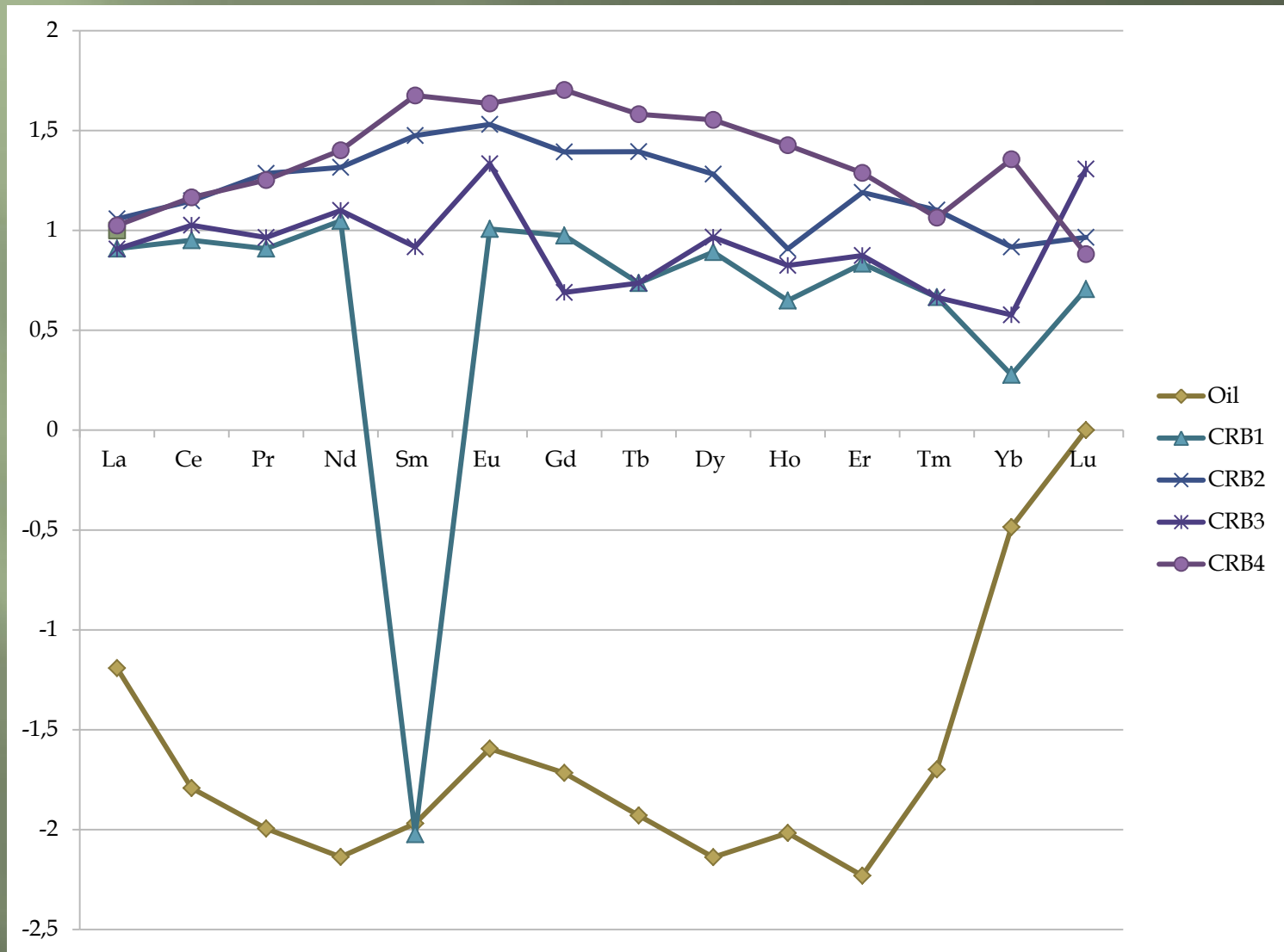


Fig. 4. Chondrite-normalized HREE pattern for oils from offshore fields in the Niger Delta.

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

# Oil vs CRB 1-4

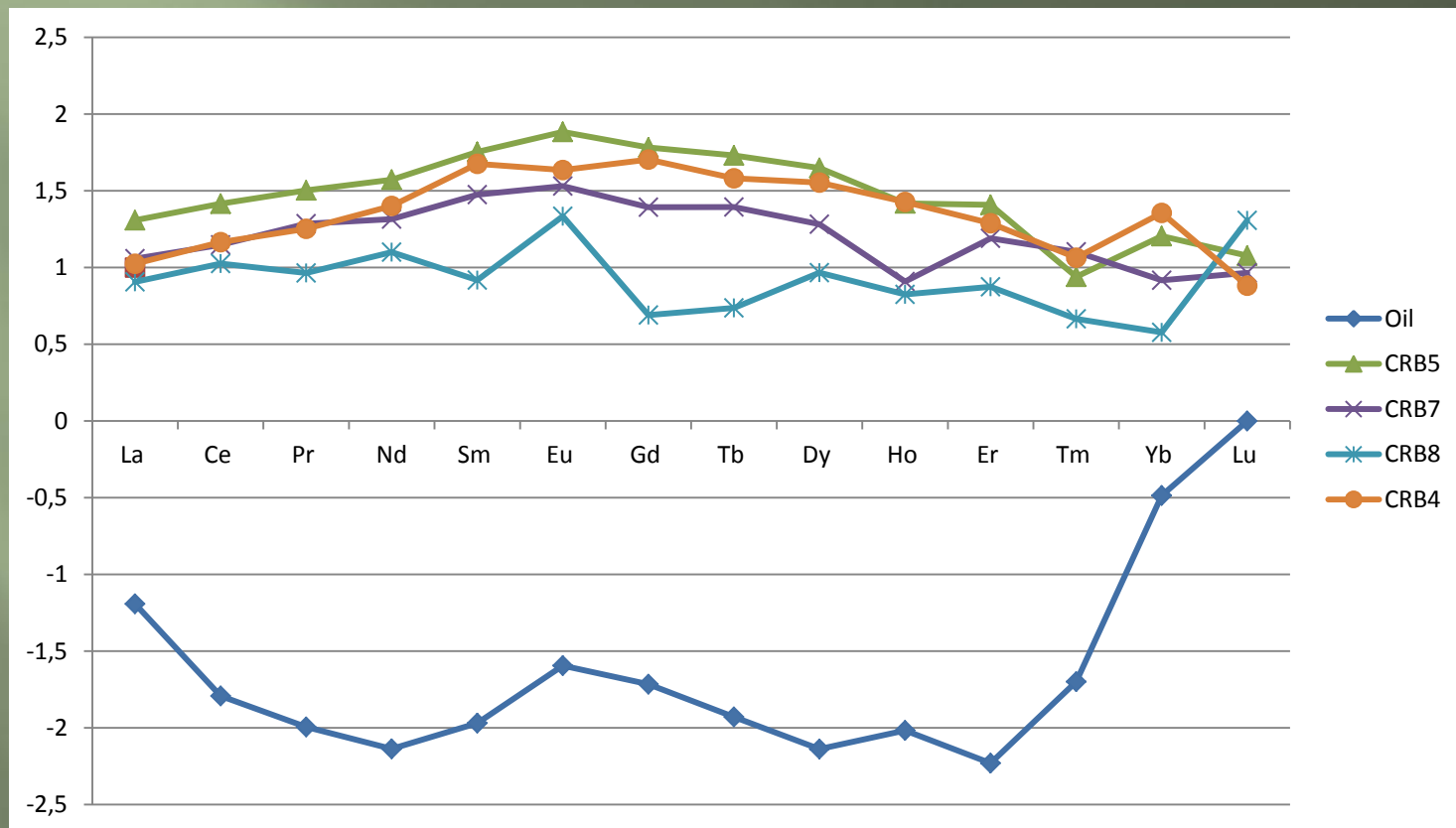
Log REE



CRB3 (cryptocrystalline limestone) trend is most similar

# Oil vs CRB 5-8

Log REE

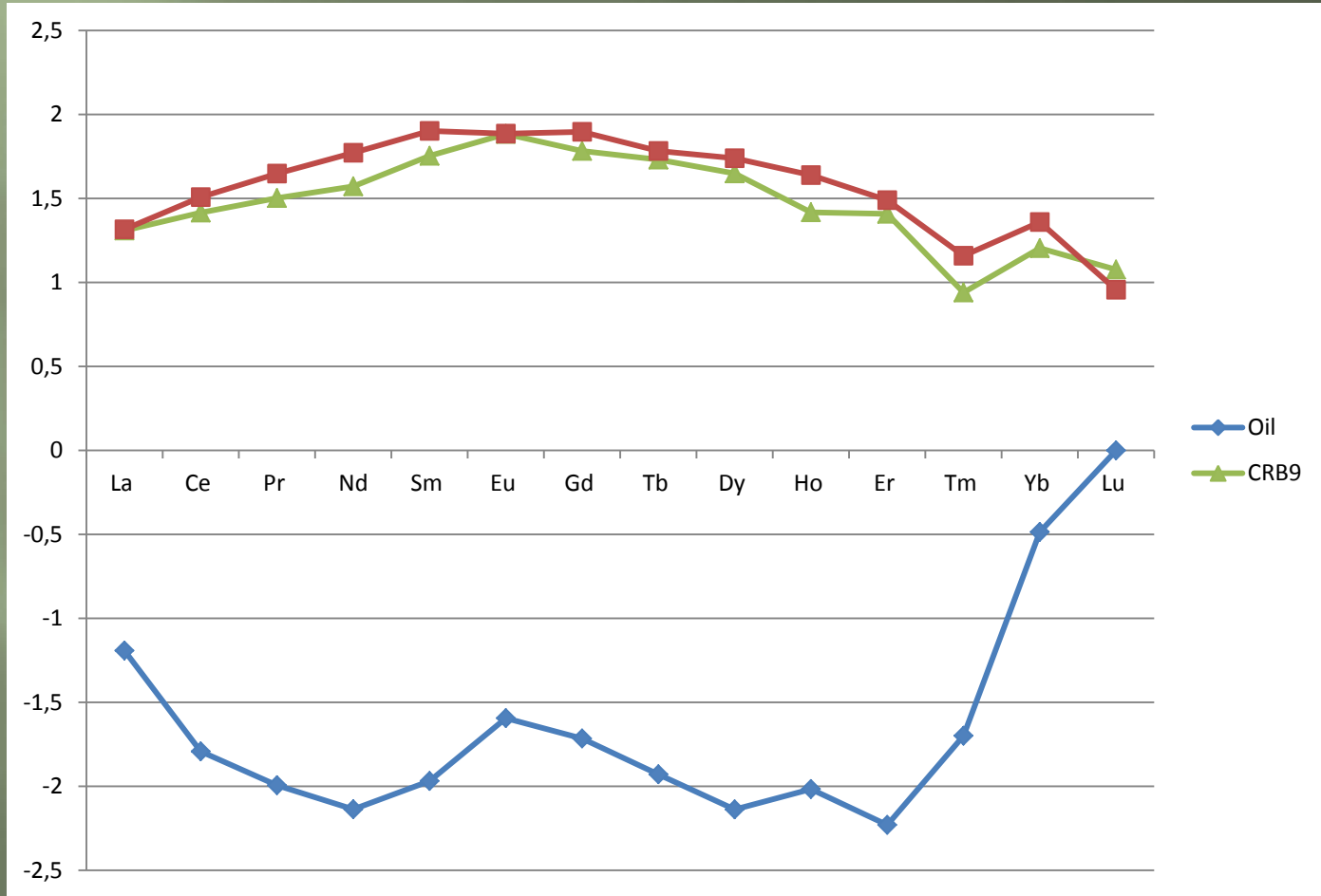


CRB8 (sh/lss) trend is most similar



# Oil vs CRB 9-10

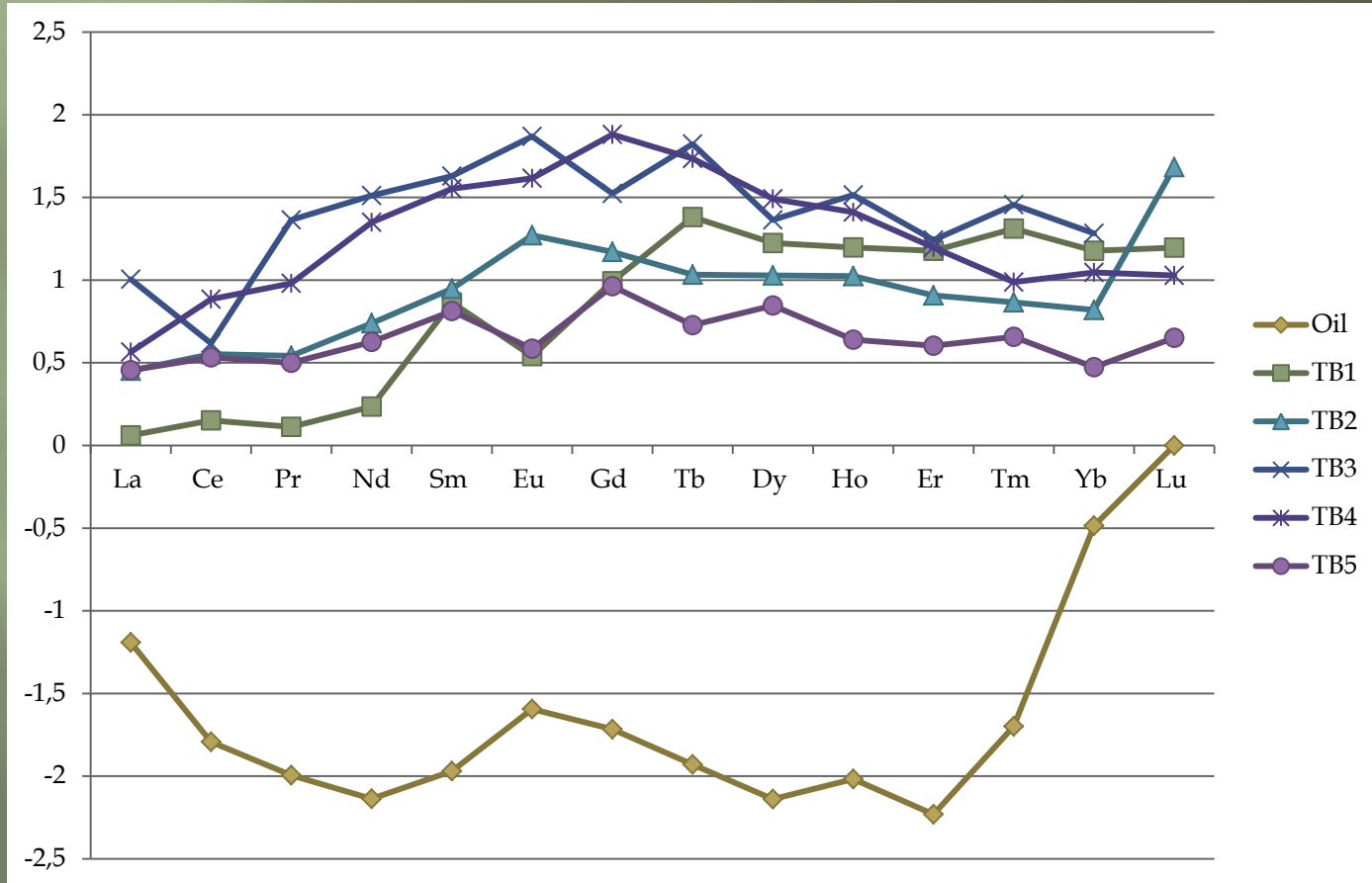
Log REE



No noticeable similarity

# Oil vs TB 1-5

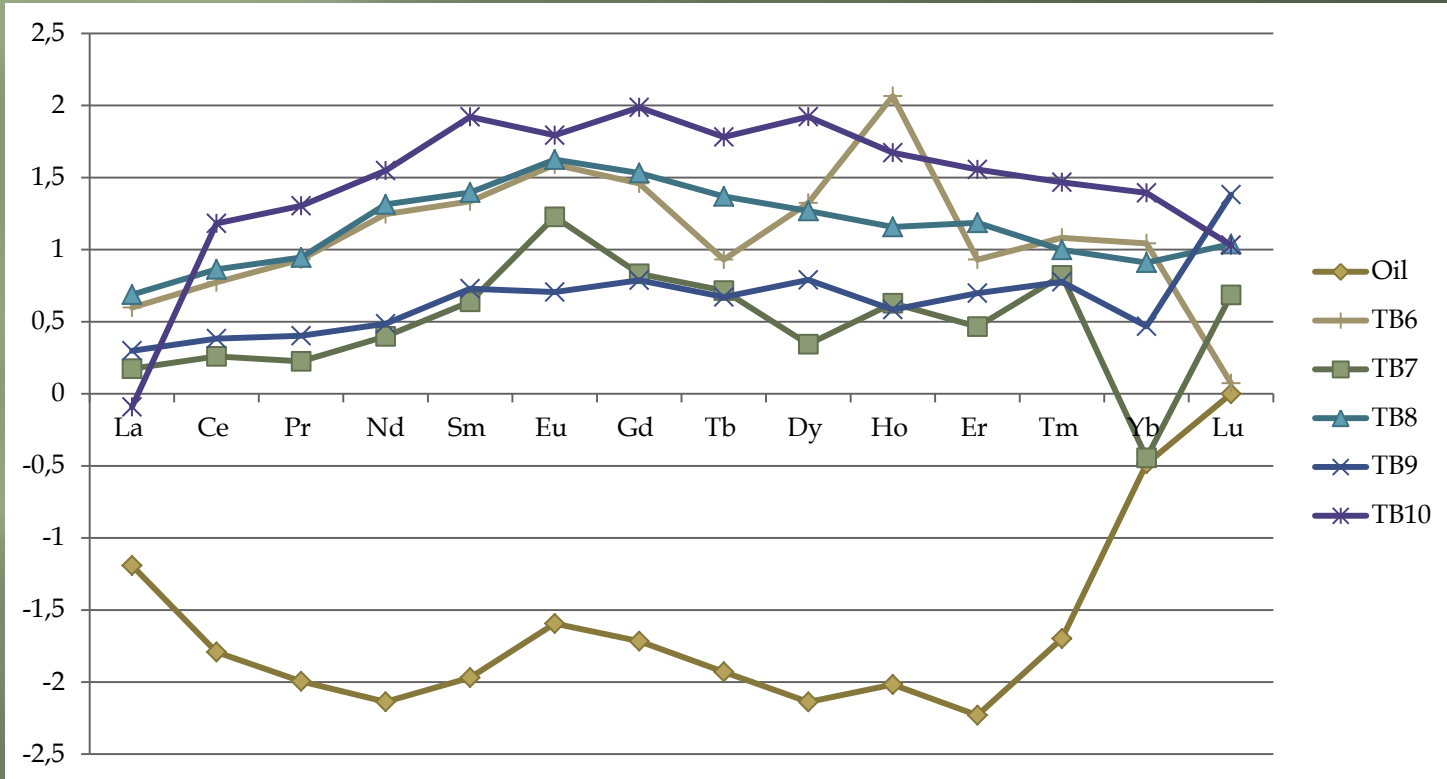
Log REE



TB2 trend is most similar

# Oil vs TB 6-10

Log REE

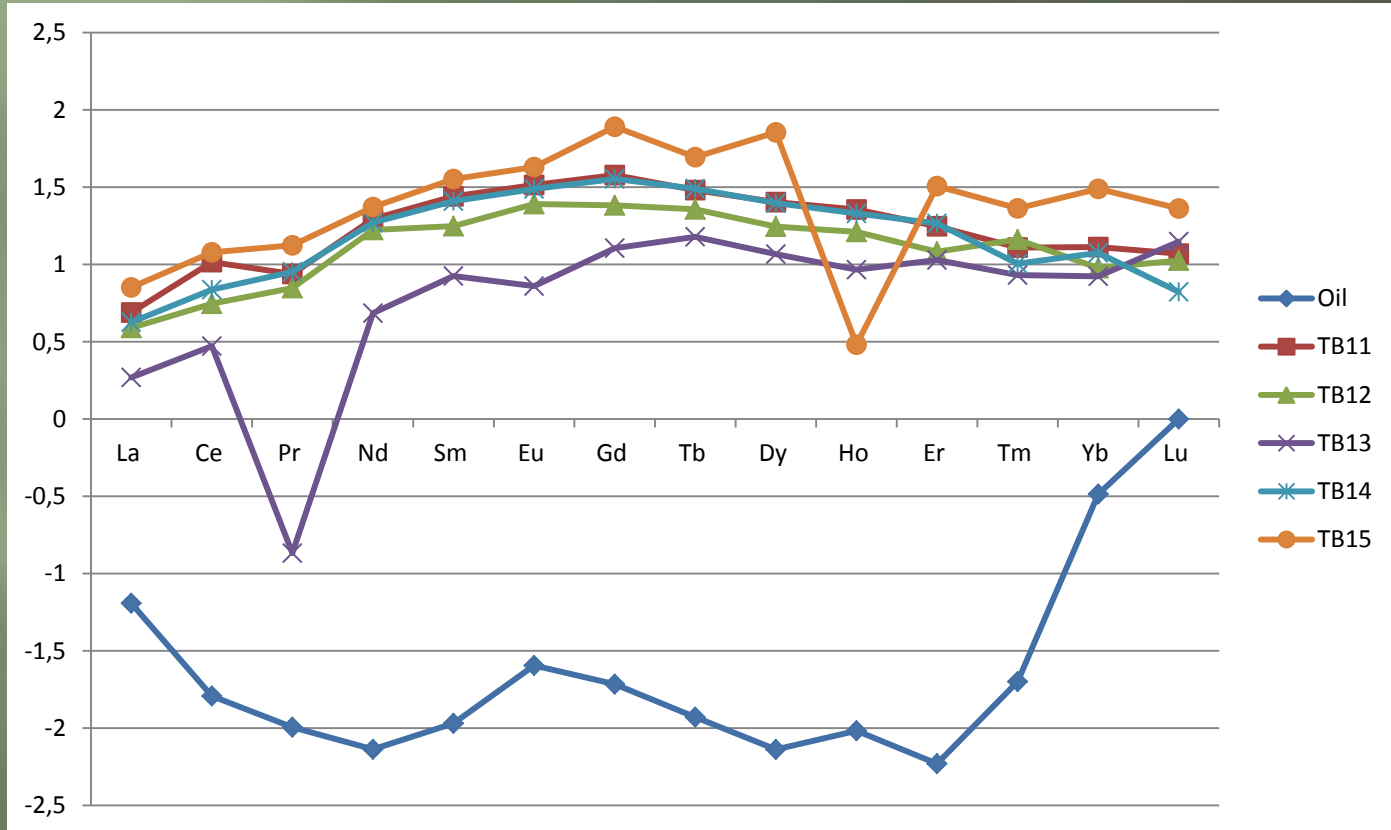


TB7 trend is most similar



# Oil vs TB 11-15

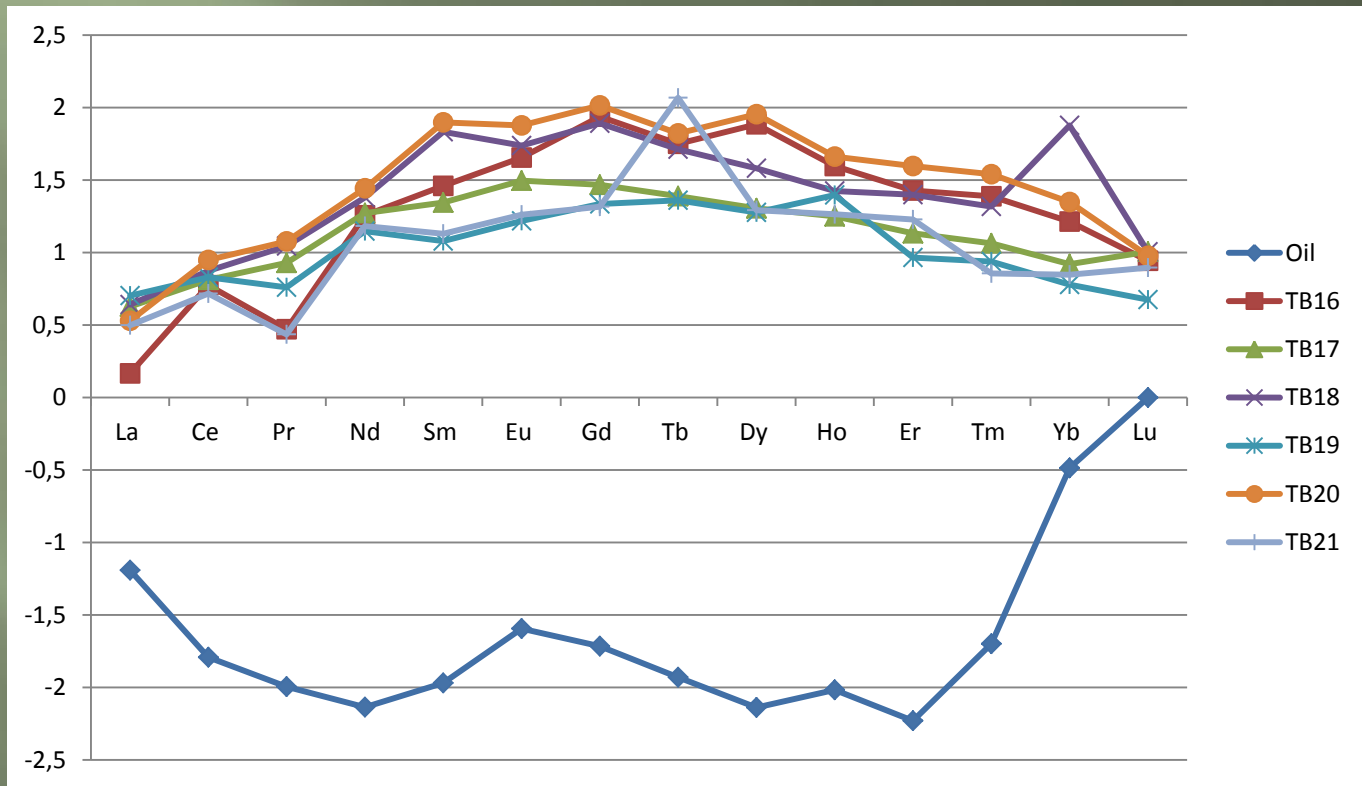
Log REE



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 paleoenvironments that the REE signatures infer.