

# Structural and Diagenetic Controls of a Fractured Carbonate Reservoir - Implications for Oil Deposit Development (A Case Study from the Zechstein of Poland)\*

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## Abstract

In the northwest part of Poland, in the Upper Permian (Zechstein) strata occur dolomitized carbonates (Main Dolomite, Ca<sub>2</sub>) in which 14 oil deposits have been found so far. One of them is the Wysoka Kamienska Oil Field. The complicated Wysoka Kamienska structure is cut by NW-SE trending faults. Main Dolomite carbonates, which host the oil deposit, are characteristic of carbonate platform slope lithofacies built of laminated limy mudstones, dolostones and dolomitic biolaminites, which can be considered as source rocks.

The maximum thickness of Ca<sub>2</sub> profiles reaches 65 m. Almost 90% of the profiles have porosities 0.1-2% but in the last 10% representing upper parts porosities reach 23%. Permeability varies from >1 to 10 mD. Total organic content is from ca 0.5% to 1.25% and organic matter is sapropelic. Tiny clusters of fine grained bituminite occur in sapropelic streaks.

Vitrinite reflectance (R<sub>o</sub>) values measured in several lense-like carbonate grains syngenetic with the sediment bitumen vary from 0.38-0.62% (mean 0.49%). This suggests low maturity kerogen and low hydrocarbon potential. R<sub>o</sub> measured on redeposited grains of vitrinite ranges from 0.79% to 1.85%. Values of T<sub>max</sub> are 414-430°C (close in biolaminites and lime mudstones) which suggests the final stage of microbial transformation of organic matter and initial stage of thermocatalytic changes.

Crude oil has a density of 0.877 g/cm<sup>3</sup>, a viscosity of 40-50 cSt (35-44 cP) and contains 30-35% of the gasoline fraction, about 5% paraffins and about 1% sulfur. The accompanying gas contains up to 90% hydrocarbons and 5-9% nitrogen.

High porosities are related to fractures filled with oil. Fractures possibly developed by extension tectonics during the Zechstein and were activated during Late Cretaceous/Palaeogene inversion of the Middle Polish Trough. Other porosity is in vugs which were developed at different stages of burial; most are related to late stage diagenesis and dissolution contemporaneous with fracturing of the carbonate reservoir. Vugs are occluded by late diagenetic anhydrite cement. The most important are therefore fractures in which oil is trapped. Hence the Wysoka Kamienska Oil Field is an example of a fractured carbonate reservoir.

There are two concepts of oil origin: (1) in situ generation, and (2) migration from basal parts. Based on data obtained, it is suggested that the oil deposit contains both partly syngenetic HCs and partly epigenetic (the latter related most possibly to fracturing).

### **Selected References**

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Mawson, M., and M. Tucker, 2009, High-frequency cyclicity (Milankovitch and millennial-scale) in slope-apron carbonates; Zechstein (Upper Permian), north-east England: *Sedimentology*, v. 56/6, p. 1905-1936.

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Slowakiewicz, M., and Z. Mikolajewski, 2011, Upper Permian main dolomite microbial carbonates as potential source rocks for hydrocarbons (W. Poland): *Marine and Petroleum Geology*, v. 28/8, p. 1572-1591.

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Geofizyka Torun Geophysical Services, 1980, 2D seismic in Wysoka Kamienska, Poland: Web accessed 27 January 2012, <http://www.geofizyka.pl/>



# **Structural and diagenetic controls of a fractured carbonate reservoir – implications for oil deposit development (a case study from the Zechstein of Poland)**

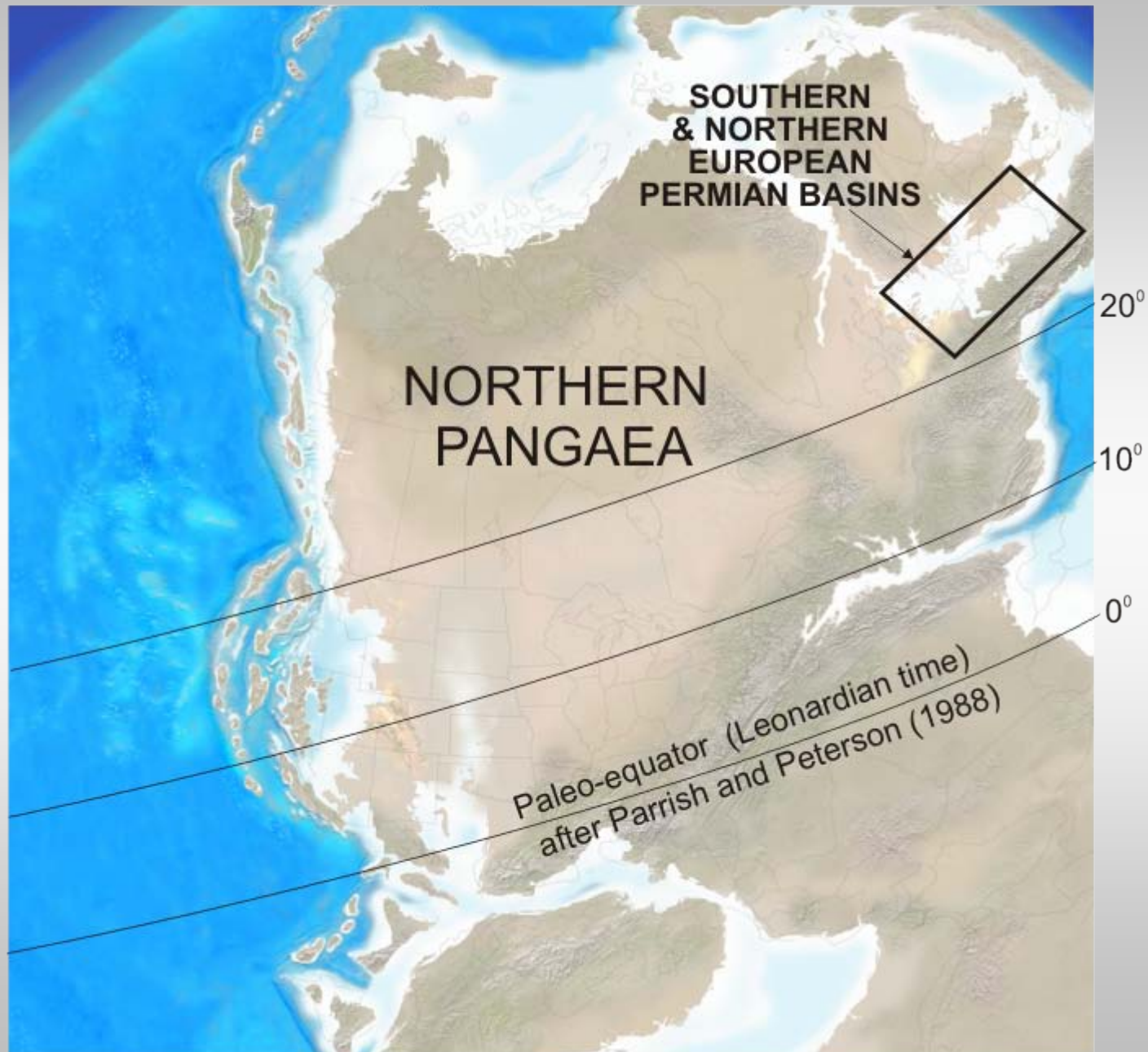
***Andrzej Gąsiewicz<sup>1</sup>, Zbigniew Mikołajewski<sup>2</sup>,  
Mirostaw Słowakiewicz<sup>1</sup>, Maciej Tomaszczyk<sup>1</sup>***

***<sup>1</sup>Polish Geological Institute, Polish Geological Survey, Poland***

***<sup>2</sup>Polish Oil and Gas Company (PGNiG SA), Poland***

# PALAEOGEOGRAPHY

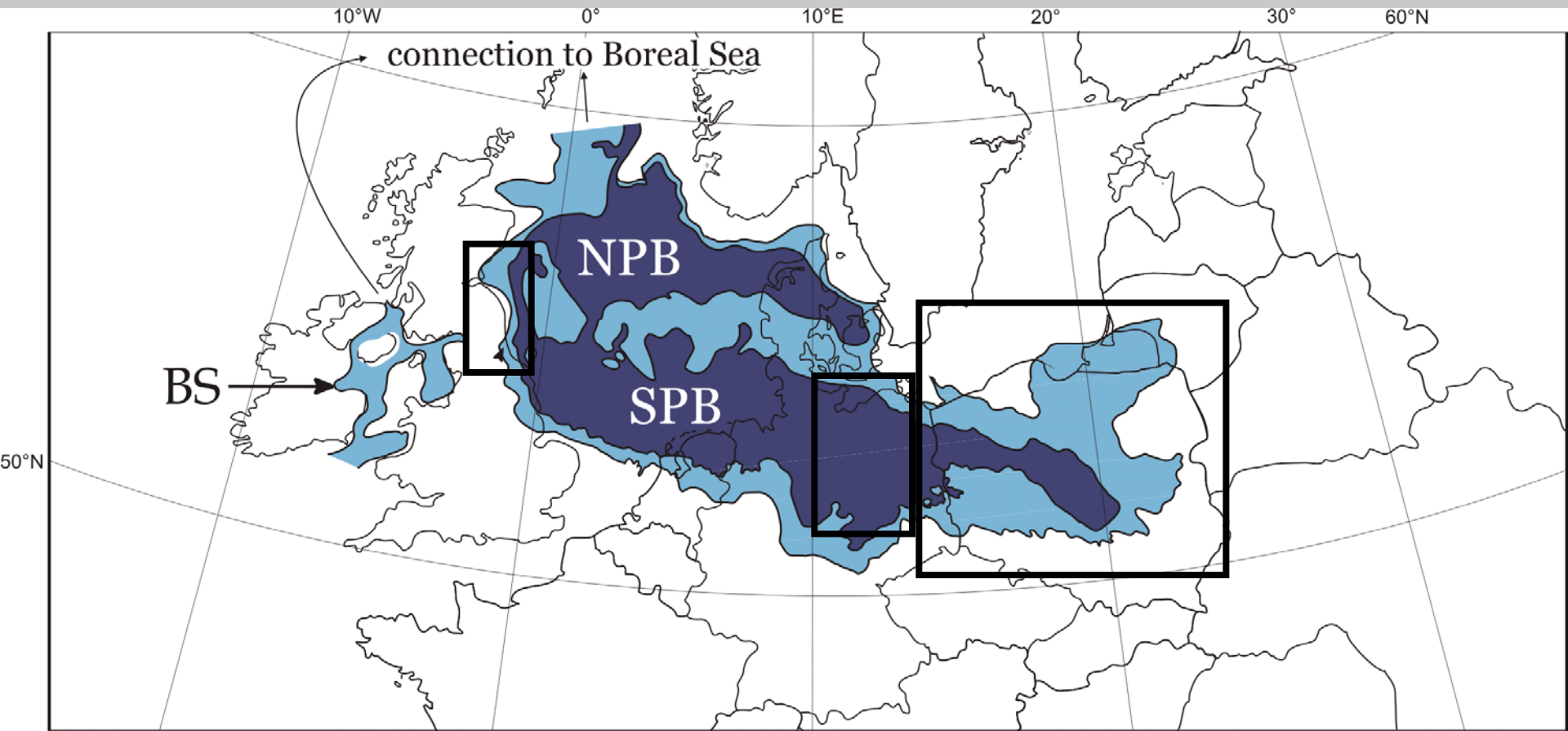
MIDDLE PERMIAN (275 Ma)



Paleogeography after Blakey 2005 see Słowakiewicz et al. 2008)

# Stratigraphy

			UK part of SPB			
			Polish part of SPB	S part of North Sea	Land	
Zechstein	z2	A2r	Screening Anhydrite	Deck Anhydrite	Fordon Formation	Z2Aii
		Na2r	Older Screening Halite	Stassfurt Halite		Z2S
		K2	Older Potash			
		Na2	Older Halite			
		A2	Basal Anhydrite	Basal Anhydrite	Z2Ai	
	Ca2	Main Dolomite	Haupt Dolomite	Roker Formation	Z2C	
	z1	A1g	Upper Anhydrite	Werra Anhydrite	Hartlepool Anhydrite	Z1A
		Na1	Oldest Halite			
		A1d	Lower Anhydrite			
		Ca1	Zechstein Limestone	Zechsteinkalk	Cadeby Formation	Z1C
T1		Kupferschiefer	Kupferschiefer	Marl Slate	KS	
			Upper Rotliegend	Yellow Sands		

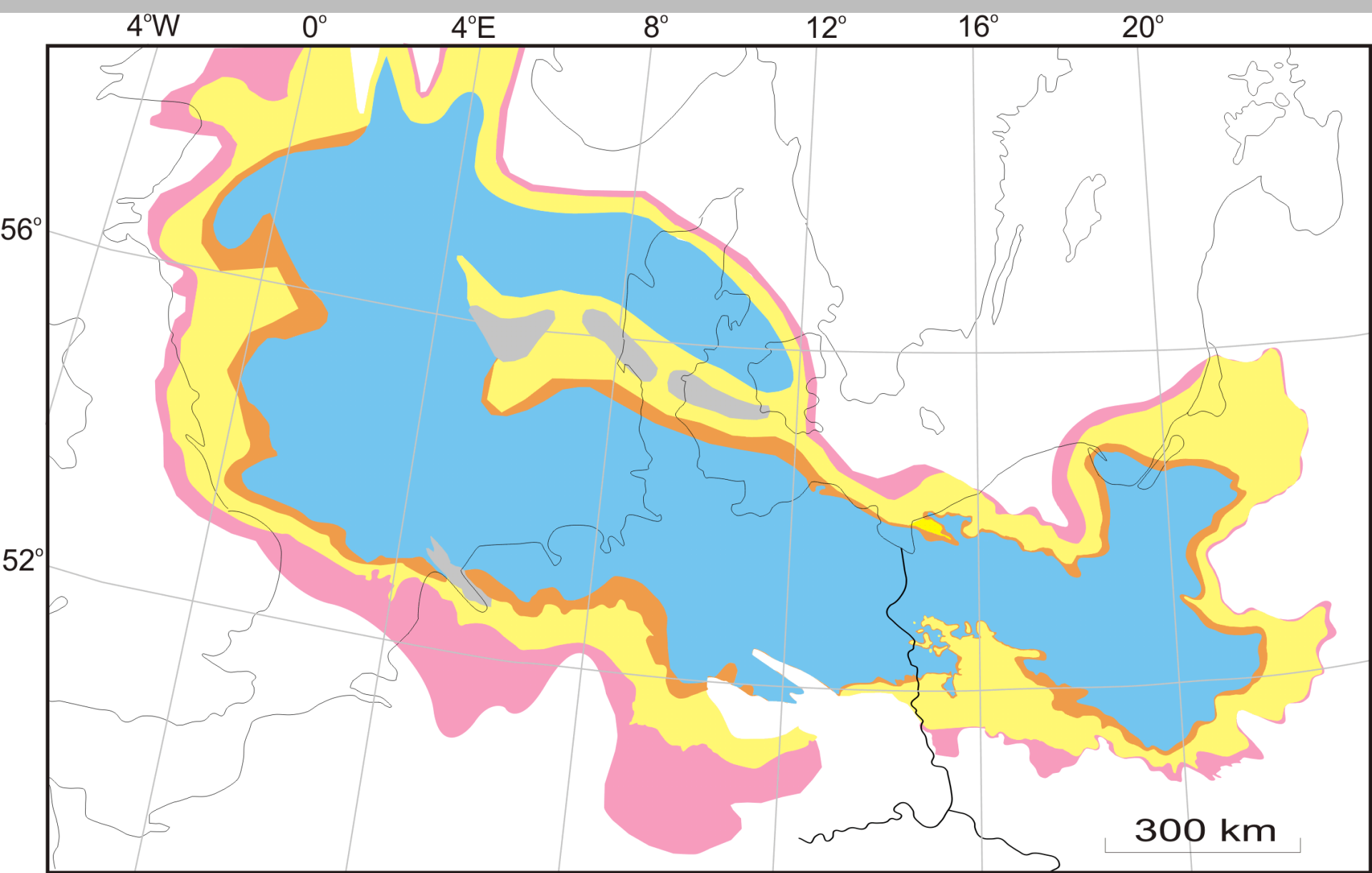


shallow-water (platform-top & slope)

deep-water (basin)

BS – Bakevelia Sea

Smith 1980, Mawson & Tucker 2009



 sabkha & salina  inner platform  slope  basin  highs

# **Slope facies thickness**

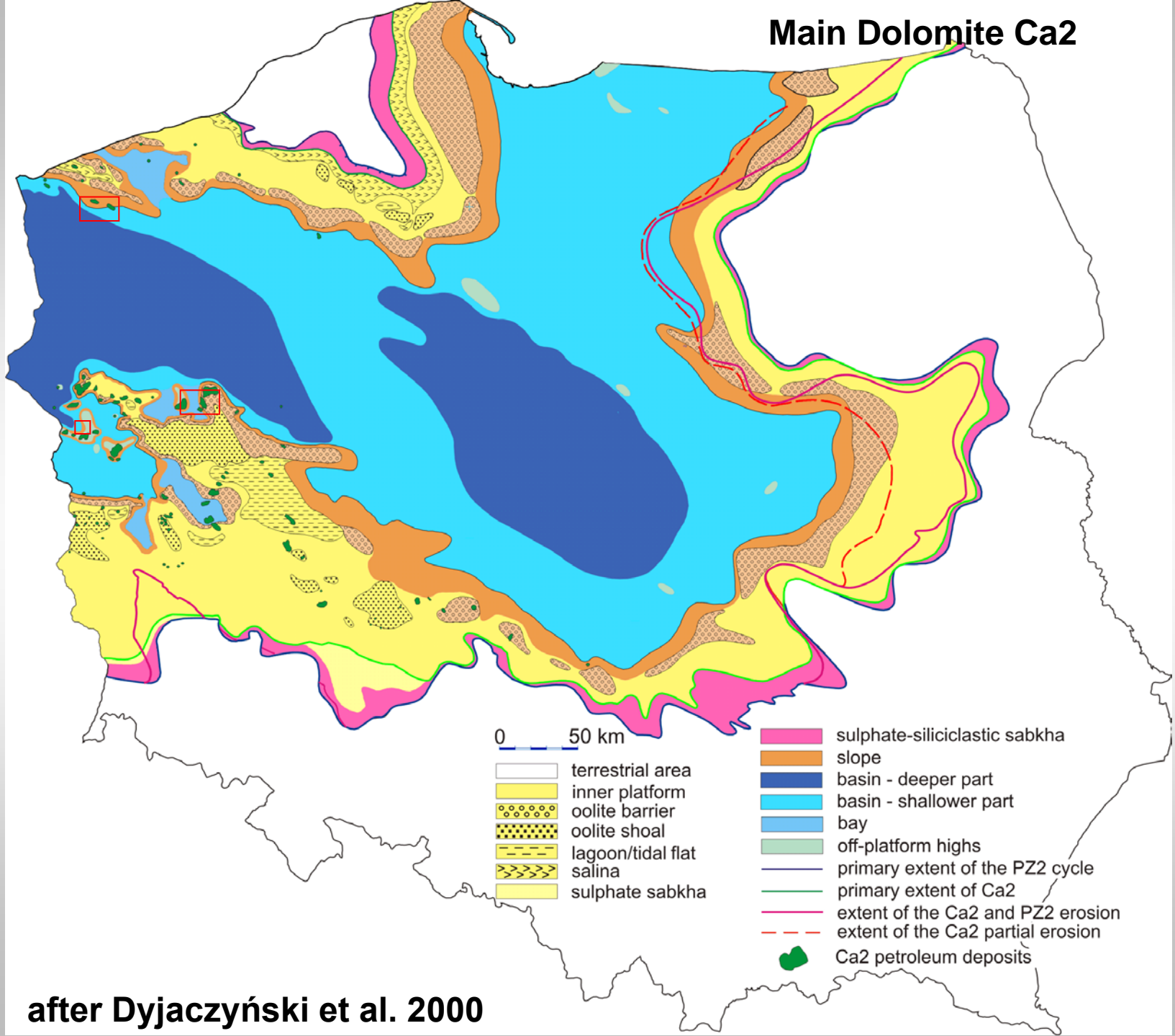
**Main Dolomite: 40-65 m**

**Roker Fm.: ~100 m**

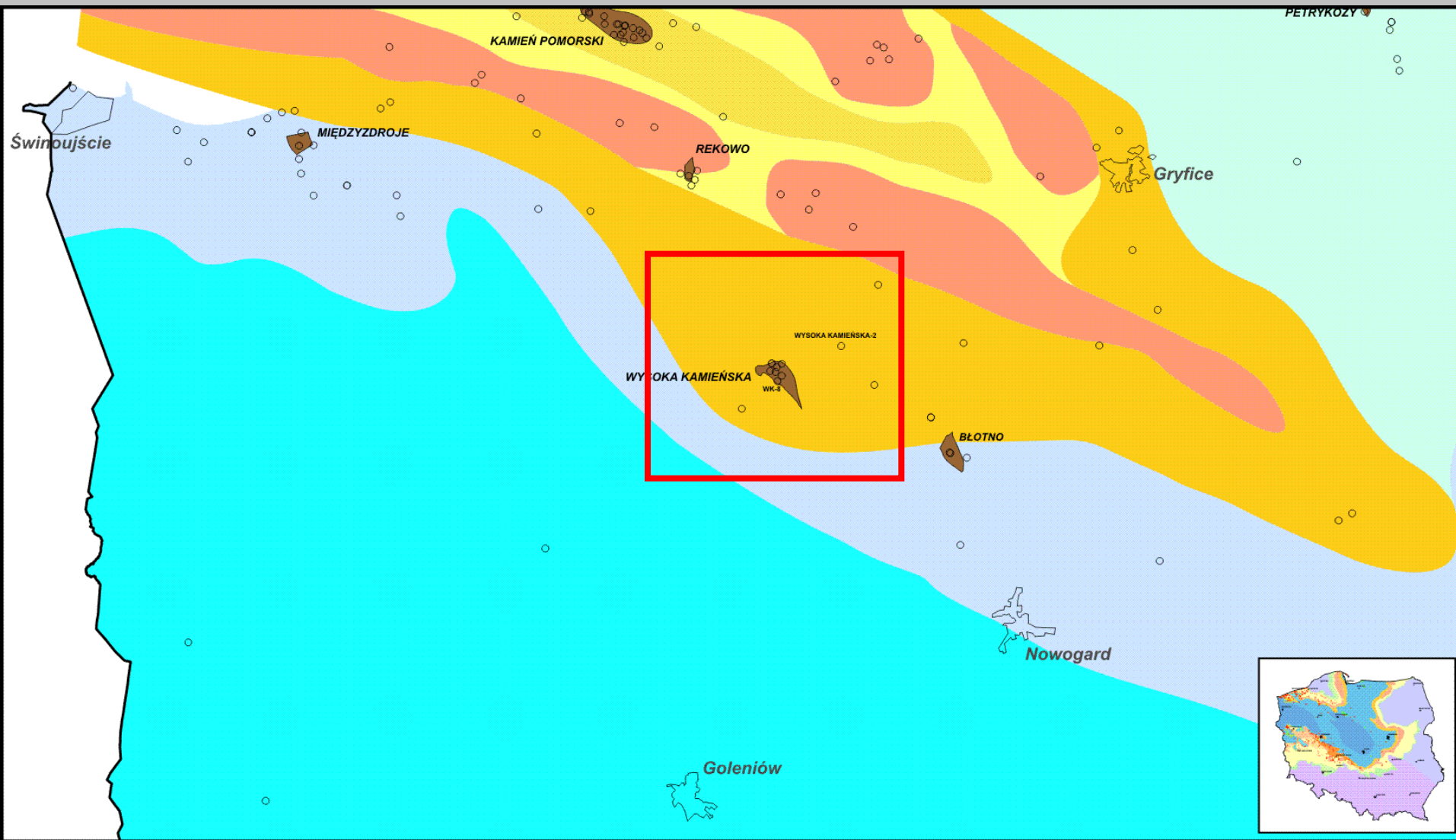
**Stassfurt Karbonat: 10-250 m**



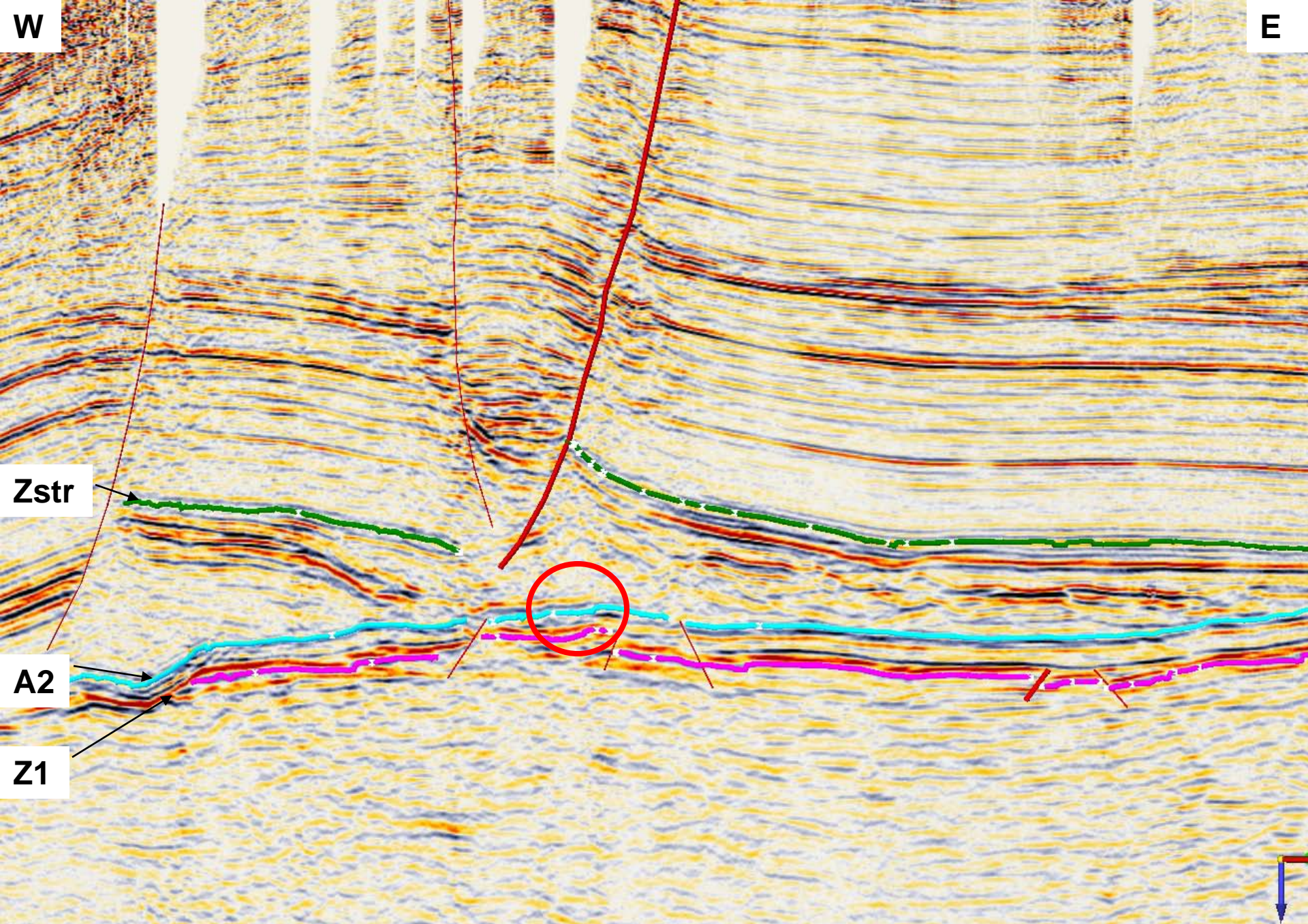
# Main Dolomite Ca<sub>2</sub>



after Dyjaczynski et al. 2000



Northern rim of the Main Dolomite carbonate platform in Poland (after Dyjaczynski et al., 2000; oil deposits after Buniak & Mikołajewski 2011)



Wysoka Kamieńska 2D seismic survey, Geofizyka Toruń 1980

## Some facts

Wysoka Kamieńska oil deposit discovered in 1978 with W. Kamieńska-1

reserves: 1.8 mln t, associated gas: 91% HC and 5-9% of nitrogen

Density of crude oil: 0.859-0.877 g/cm<sup>3</sup>

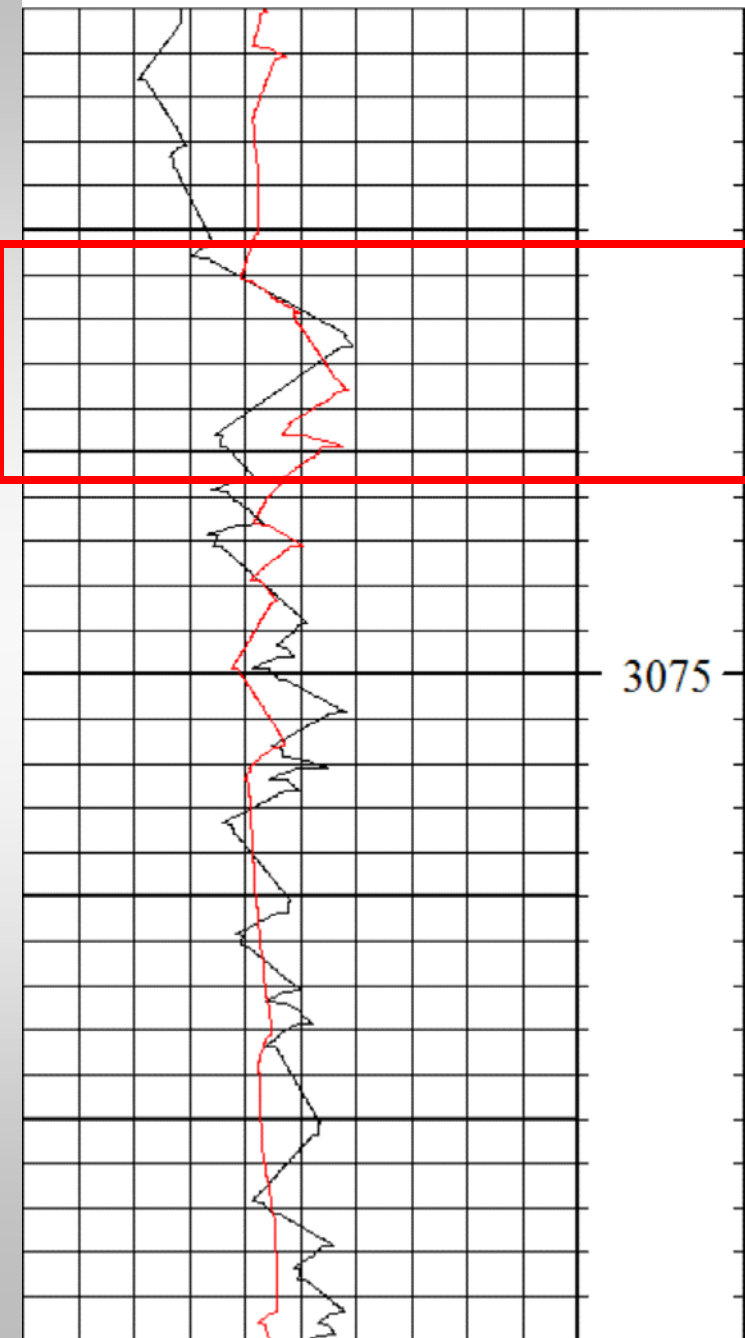
Viscosity: 40-50 cSt (35-44cP)

30-35% of the gasoline fraction

5% paraffins

1% sulfur

# WYSOKA KAMIENSKA-8



Rdzeń wiertniczy Głębokość w metrach (młara wiertnicza)	Litologia	Tekstury sedymantacyjne	Ziarno (mm)	Płytki cienkie	Struktury sedymantacyjne	Barwa	Stan zachowania materiału rdzeniowego	INTERPRETACJA	
								Środowisko depozycji	Strefy paleogeograficzne
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									

Środowisko depozycji  
L.ST + R.BN 93%; R.BN 7%

niemal wyłącznie osady podłoża stoku platformy węglanowej

A2  
Ca2

sublitoralne muły węglanowe poniżej podstawy falowania [pf] z przejawami działania słabych, dennych prądów trakcyjnych i sedymantacji z zawiesiny, biostabilizacja osadu: przerosty mikrobialne

R.BN

3071,8

rdzeń miejscami spleśniany  
znacznie ubytki rdzenia

L.ST. + R.BN

sublitoralne muły węglanowe poniżej pf z

Almost 90% of the profiles have porosities 0.1-2% but in the last 10% representing upper parts porosities reach 23%.

Permeability vary from  $>1$  to 10 mD.

# *Slope lithofacies: northern margin*



**Wysoka Kamińska-8, 3085.8 m**

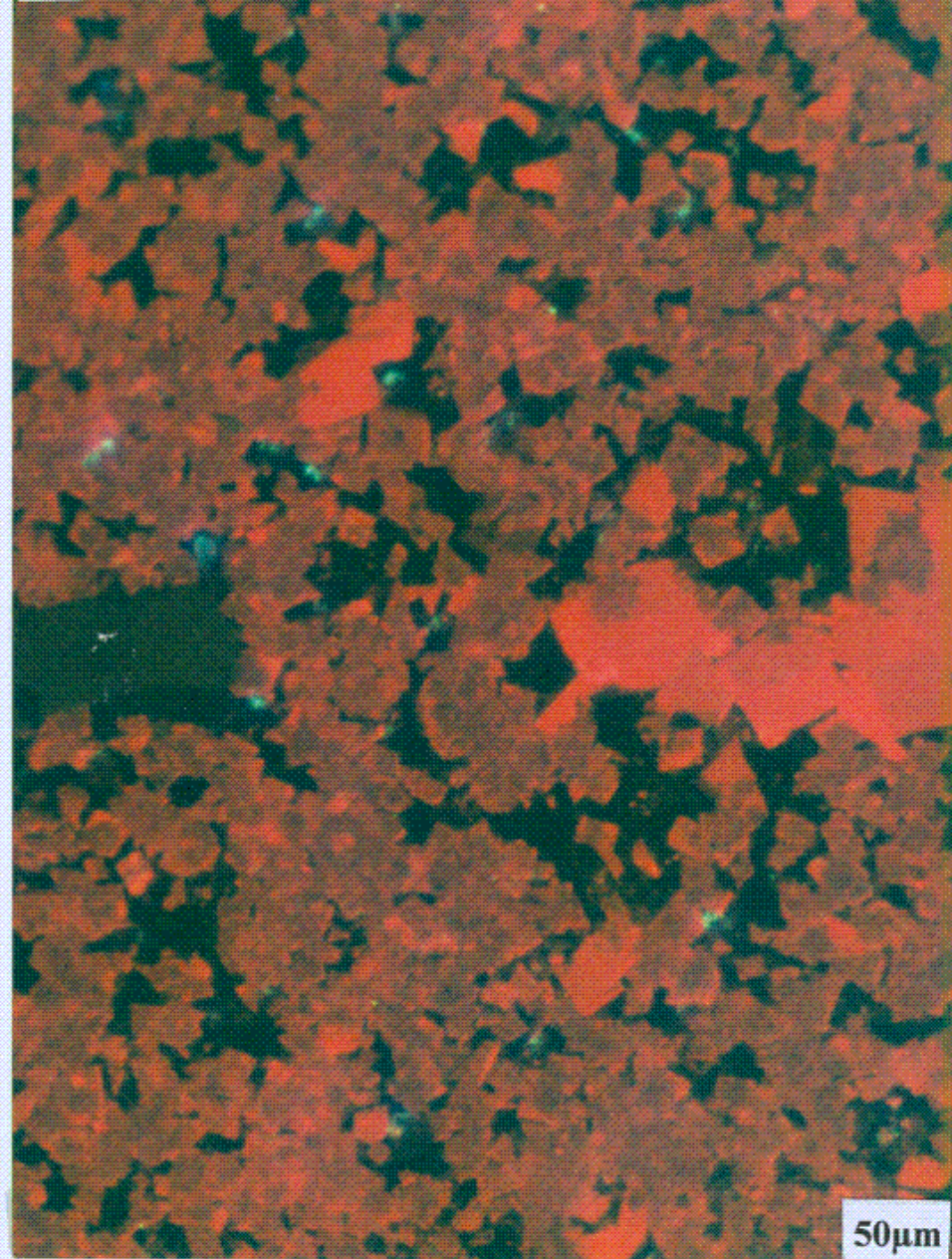
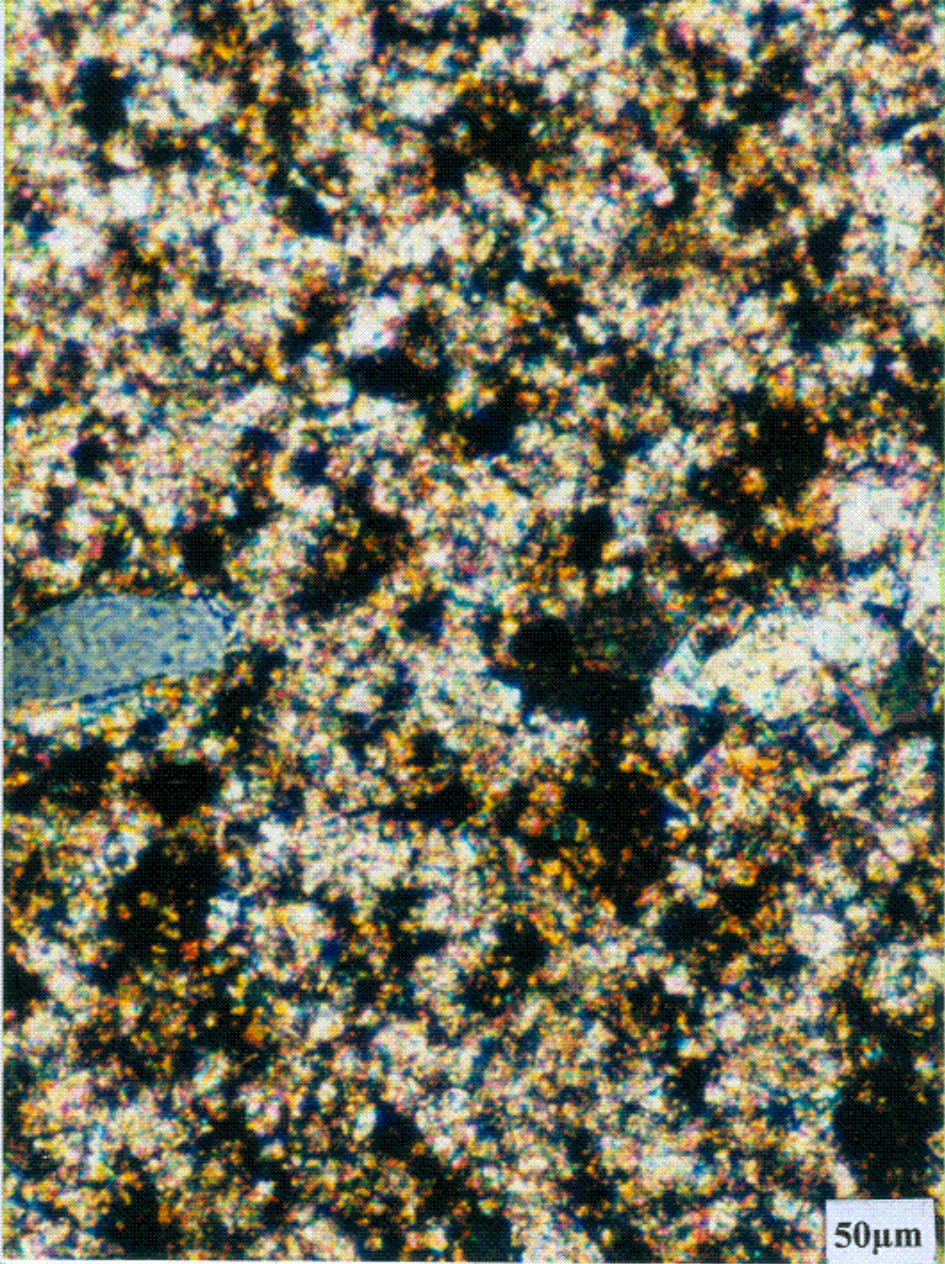
**Wysoka Kamińska-8, 3106.8 m**



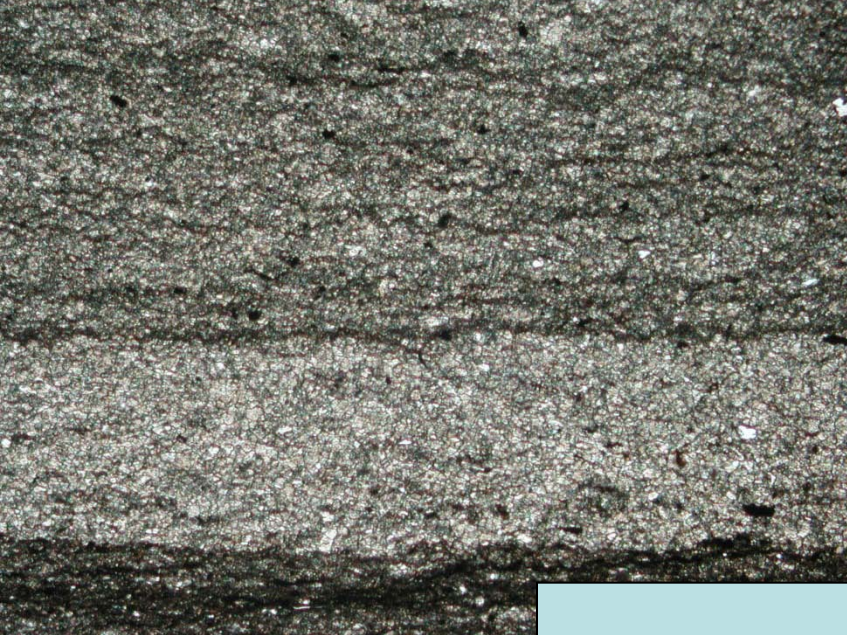
Wysoka Kamińska-8, 3091.8 m

Wysoka Kamińska-8, 3





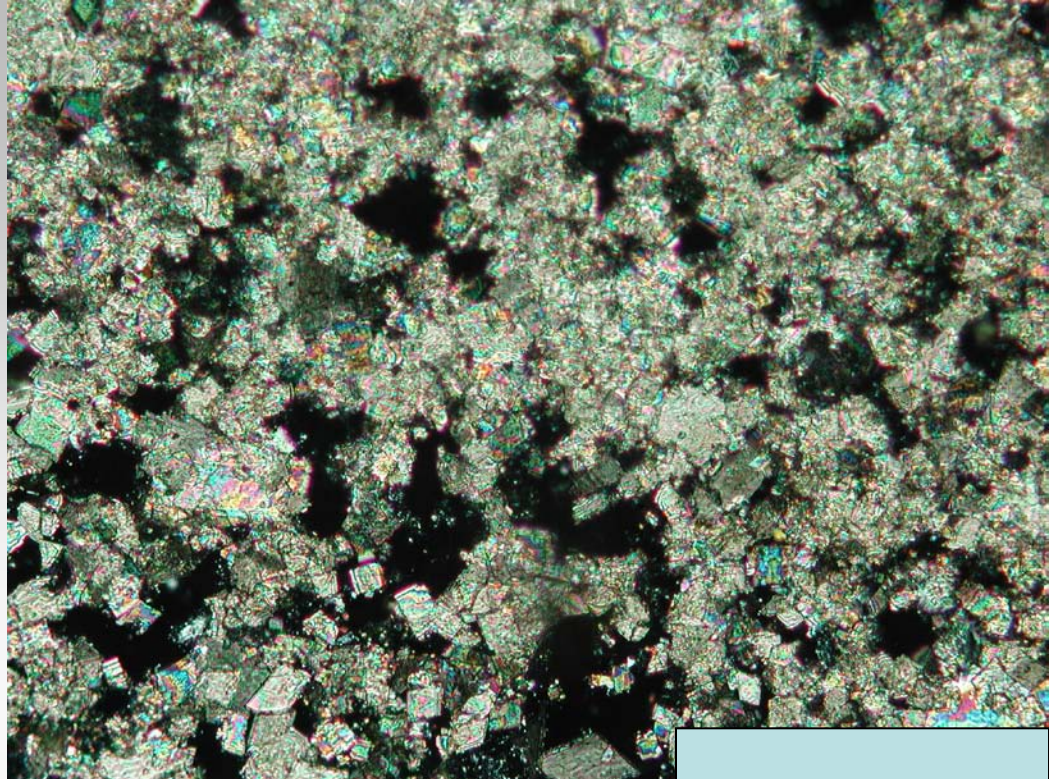
**Wysoka Kamińska-8, 3070.8 m**



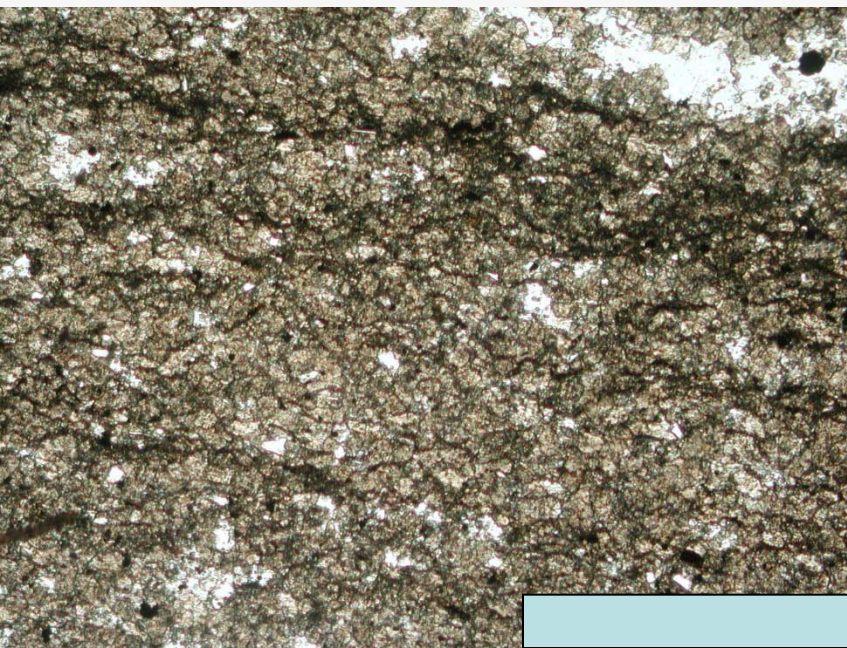
3074 m

Scale 0.25 mm

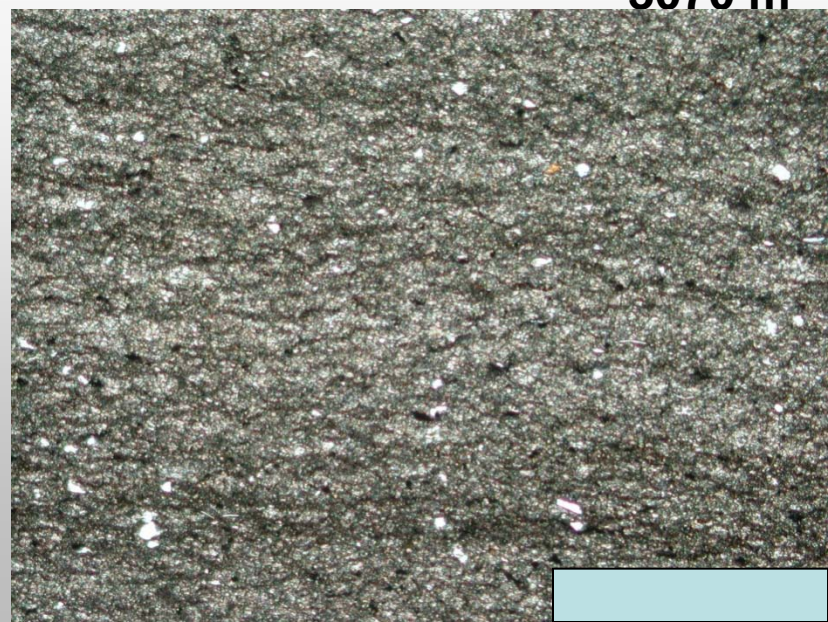
3069.4 m

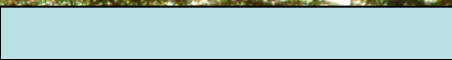
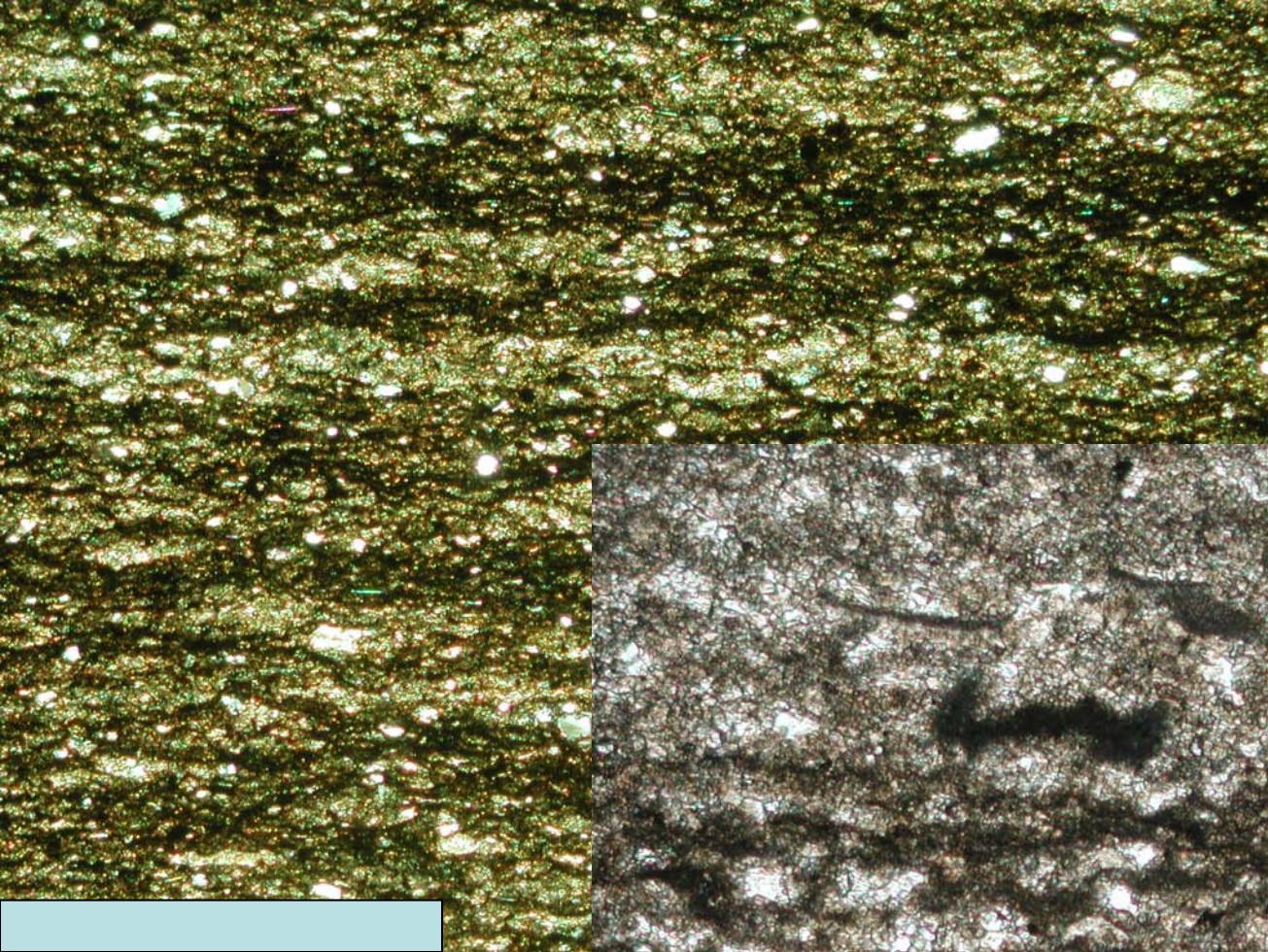


3070 m



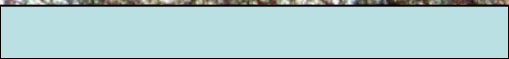
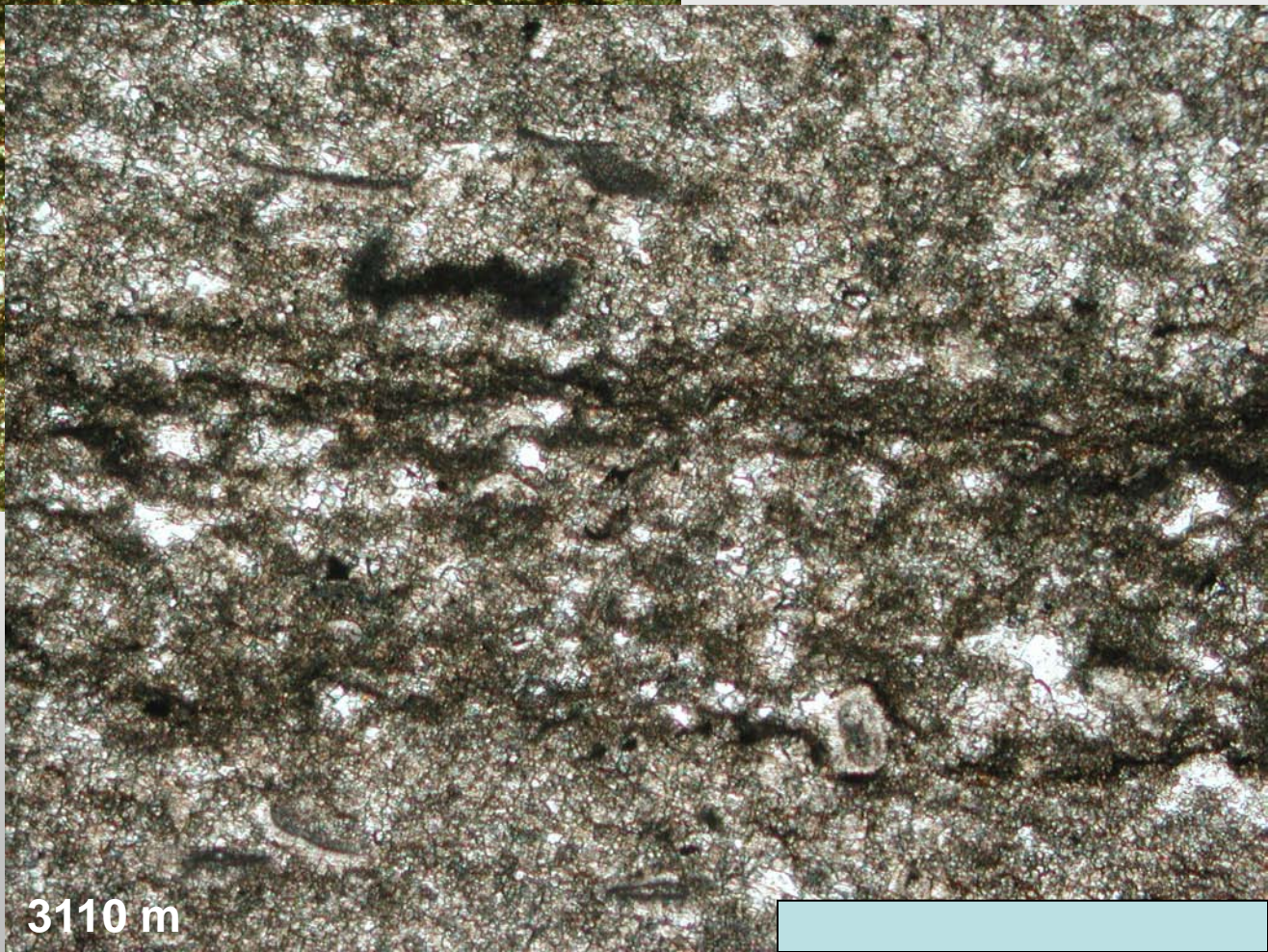
3076.8 m





**3107 m**

**Scale 0.25 mm**



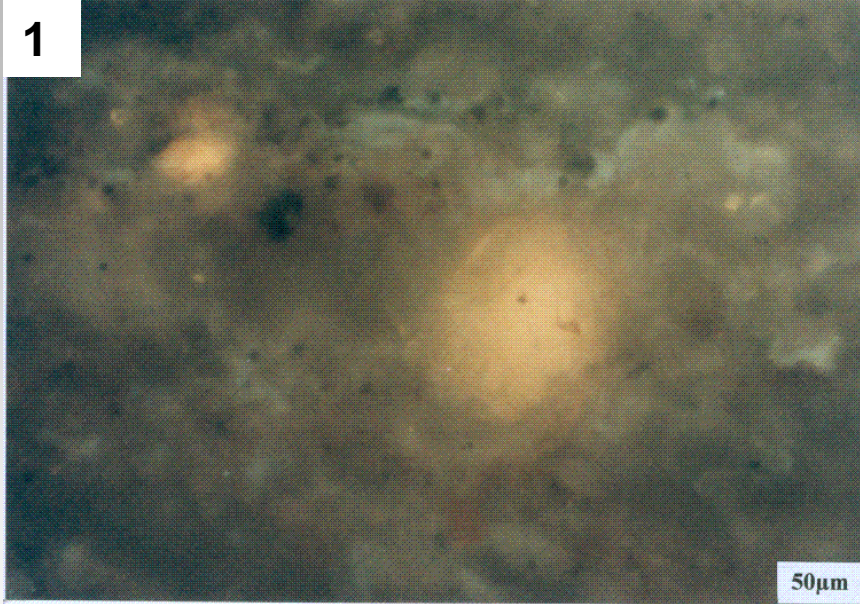
**3110 m**

Vitrinite reflectance measured in several  
lense-like carbonate grains: 0.38 to 0.62%  
(mean 0.49%)

This suggests low maturity kerogen and low hydrocarbon  
potential

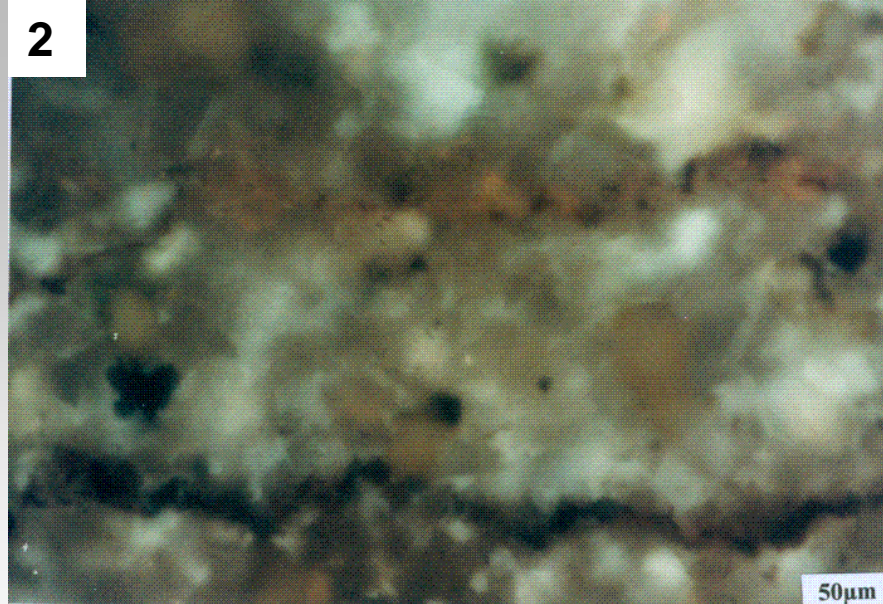
Vitrinite reflectance measured on  
redeposited grains of vitrinite ranges from  
0.79 to 1.85%

1



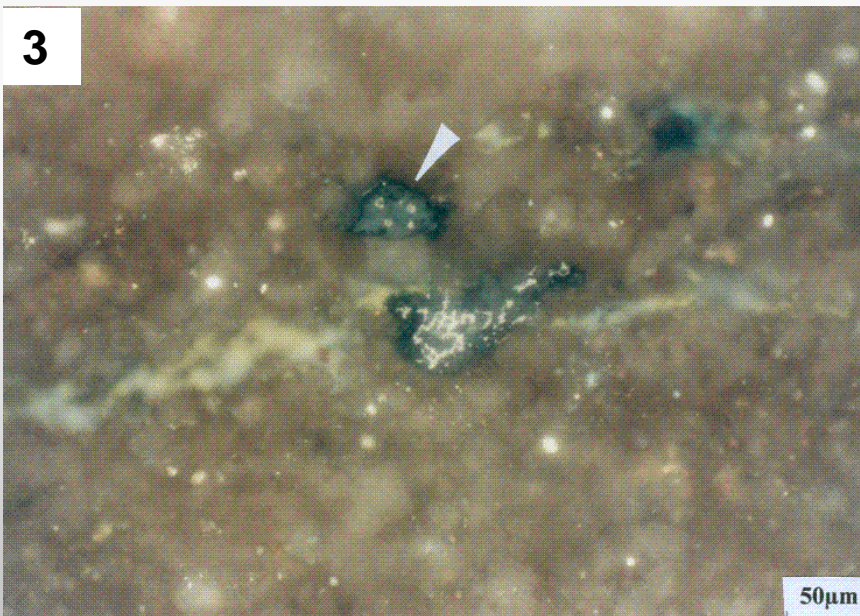
**Wysoka Kamieńska-8, 3073.2 m**

2



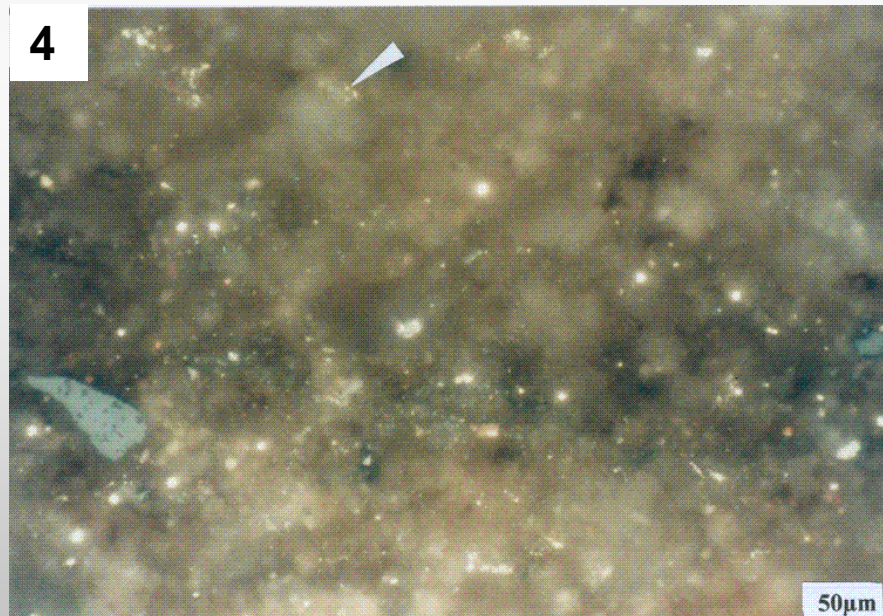
**Wysoka Kamieńska-8, 3070.8 m**

3

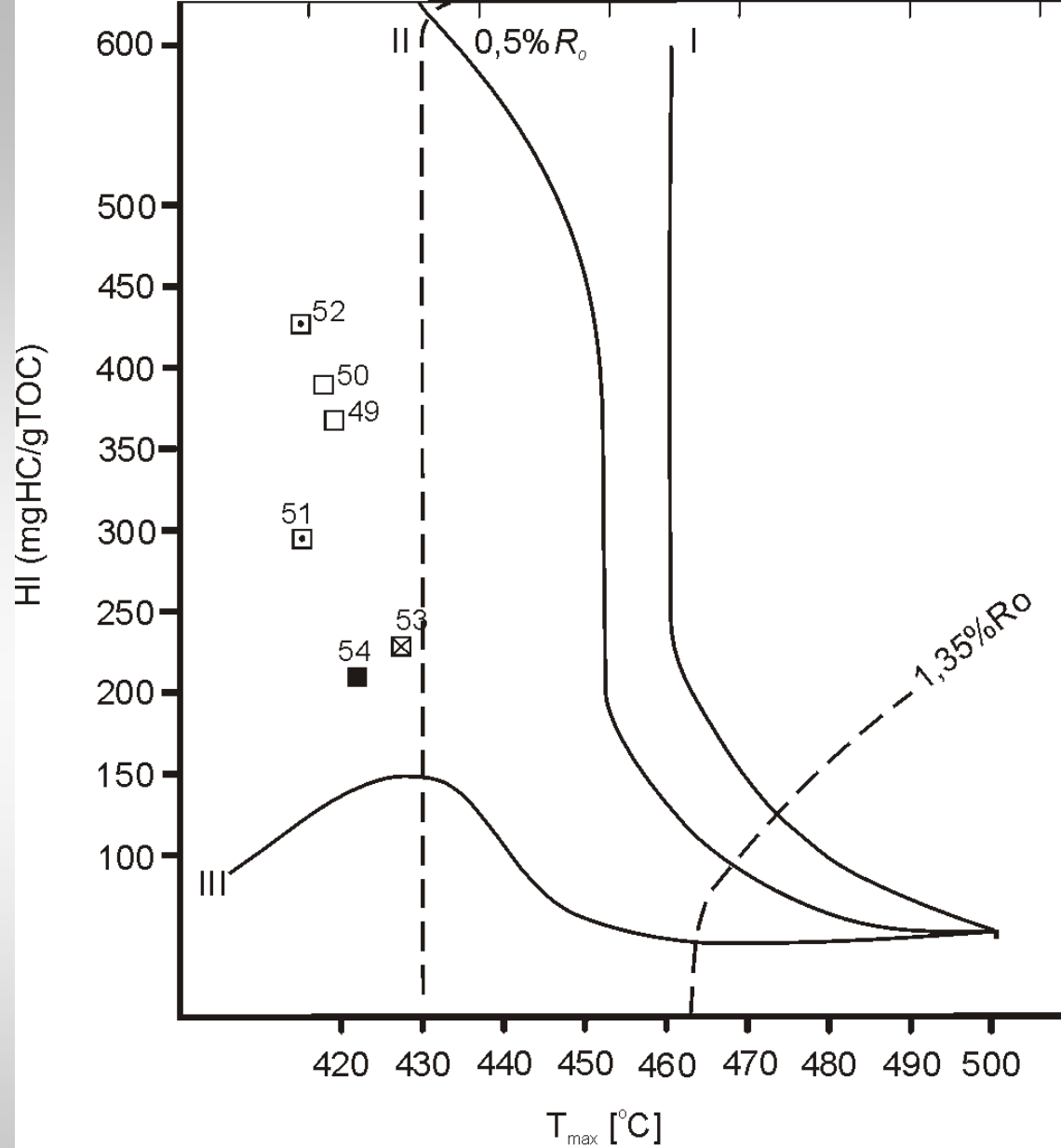


**Wysoka Kamieńska-8, 3073.2 m**

4



$T_{\max} = 414-430^{\circ}\text{C}$  (close in biolaminites and lime mudstones) what suggests final stage of microbial transformation of organic matter and initial stage of thermocatalytic changes.



Wysoka Kamieńska-8

49 & 50-3070.8

51 & 52-3073.1

53-3105.1

Wysoka Kamieńska-2

54-3099.6

TOC content is from ca 0.5% to 1.25%  
and organic matter is sapropelic.



# Conclusions

1. High porosities are related to fractures filled with oil. Fractures possibly developed by extension tectonics during the Zechstein and were activated during Late Cretaceous/Palaeogene inversion of the Middle Polish Trough.
2. Other porosities come from vugs which were developed at different stages of burial. Most of them are related to late stage of diagenesis and dissolution contemporaneous with fracturing of the carbonate reservoir.
3. Wysoka Kamieńska is a fractured carbonate reservoir.
4. There are two concepts about oil origin: in situ generation and migration from basinal parts. It is suggested that the oil deposit contains both partly syngenetic HCs and partly epigenetic (the latter related to most possibly fracturing).

# Acknowledgments



Polish Oil and Gas Company (PGNiG SA) for providing materials and permission to use them