Hydrocarbon Plays from West Poland: Zechstein Limestone and Main Dolomite

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Underexplored Plays - Part III
31-X-2018 & 01-XI-2018 Stavanger

Hydrocarbon Plays from West Poland: Zechstein Limestone (Ca1) and Main Dolomite (Ca2)

Presentation outline:

Palaeogeography of Zechstein

- Southern Permian Basin and Northern Permian Basin
- Correlation of carbonate units between SBP and NPB

Zechstein Limestone (Brońsko Gas Field)

- Hydrocarbon Play.
- Pattern Recognition from Seismic.

Main Dolomite (BMB and LMG oil & gas fields)

- Hydrocarbon Play.
- Pattern Recognition from Seismic.
- Analysis of Seismic Attributes.
- Seismic Modeling.

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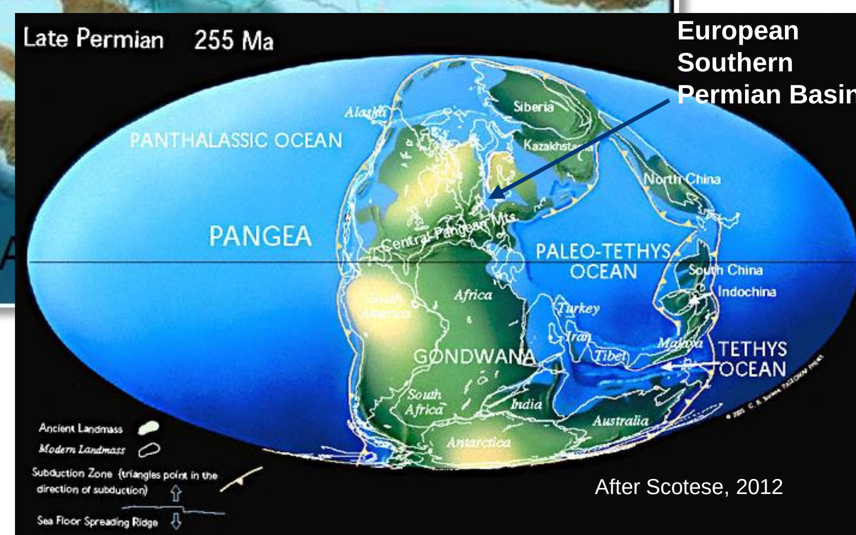
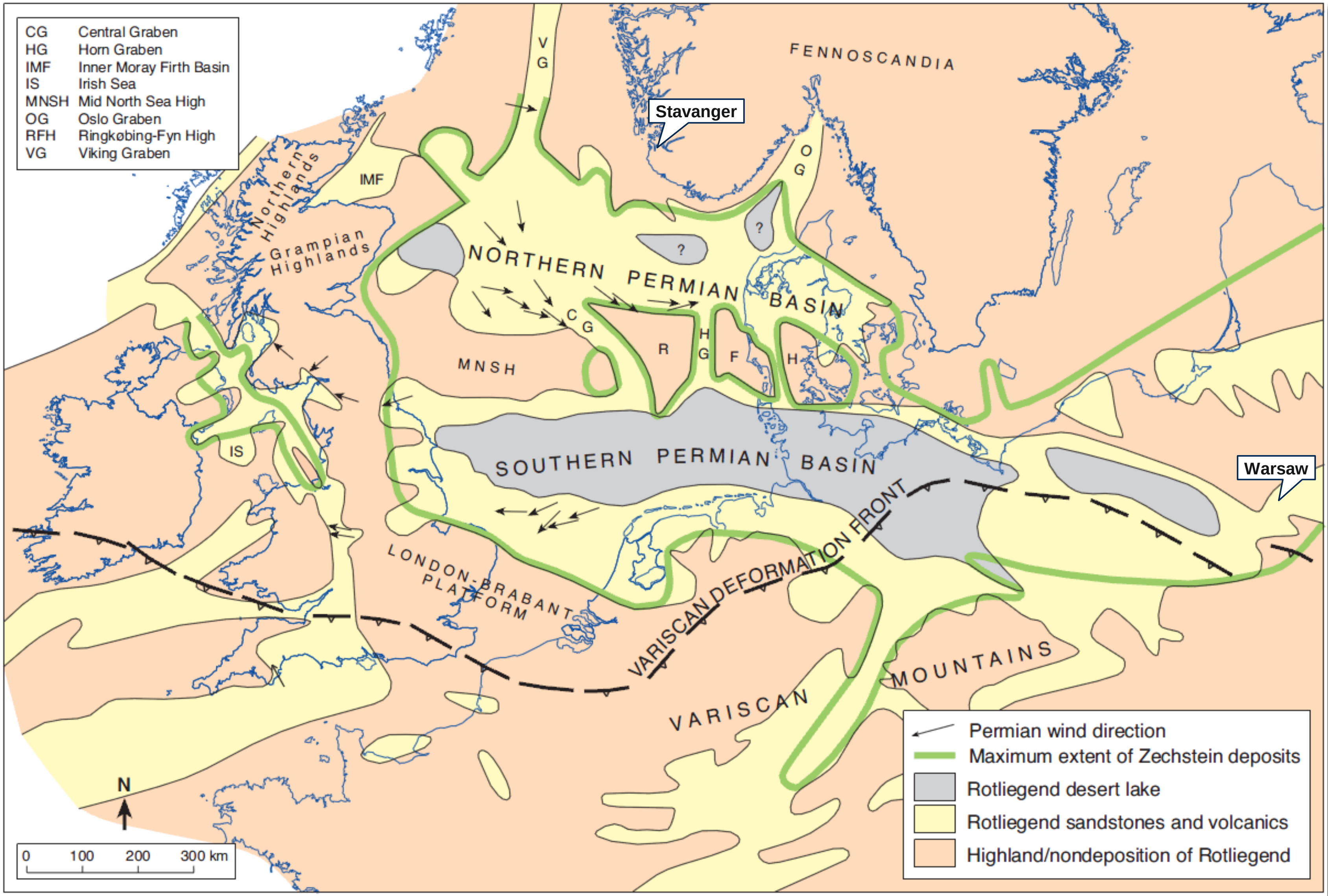
Late Permian Paleogeography from Blakely (2014)

Tucker, 2016



Zechstein Sea Connected to Pantalassa Ocean 2000km to N/NE.
Possible connection to Paleo-Tethys through the Polish Sub-Basin to the SE ?? Palaeo-latitude: 10-20°. Climate extremely arid.

Sketch map of Permian sedimentary basin in north-west Europe



Millennium Atlas: Petroleum Geology of the Central and Northern North Sea, 2003

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Polish Zechstein Basin
….stratigraphy

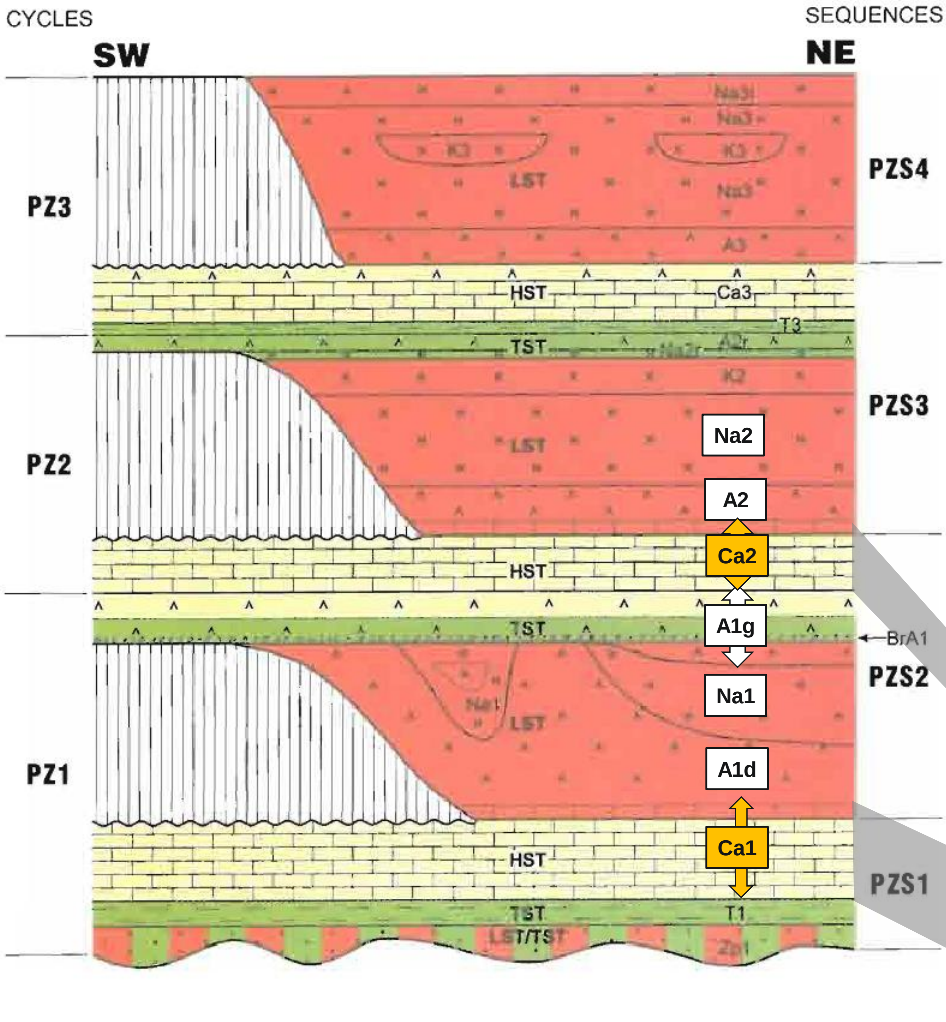
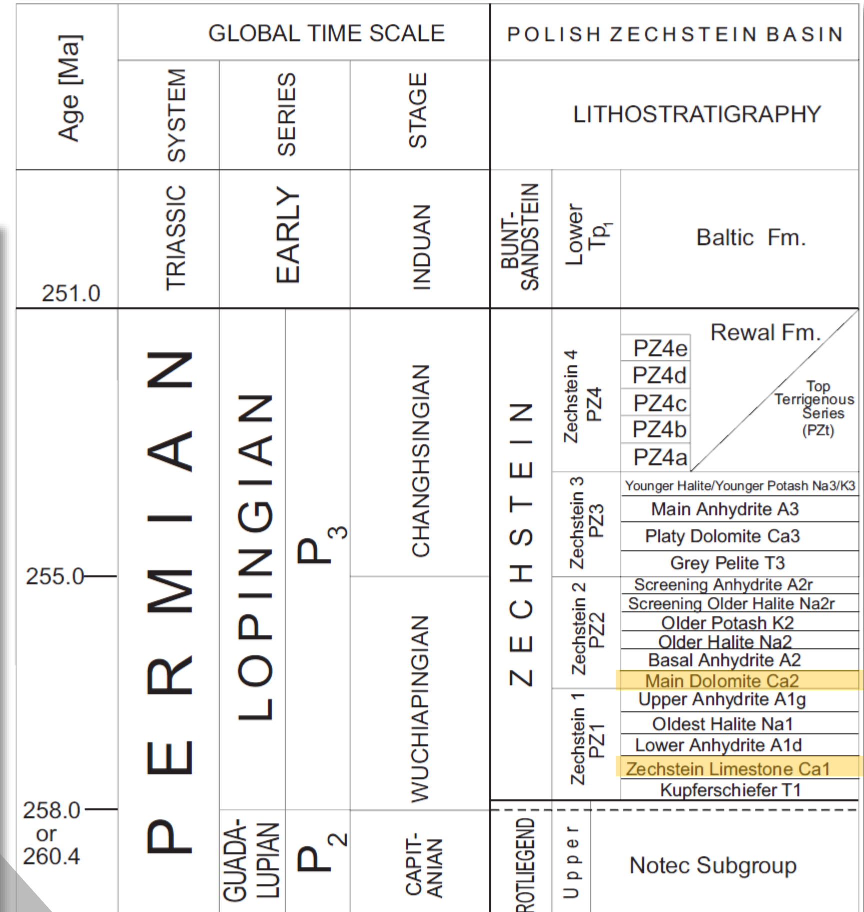
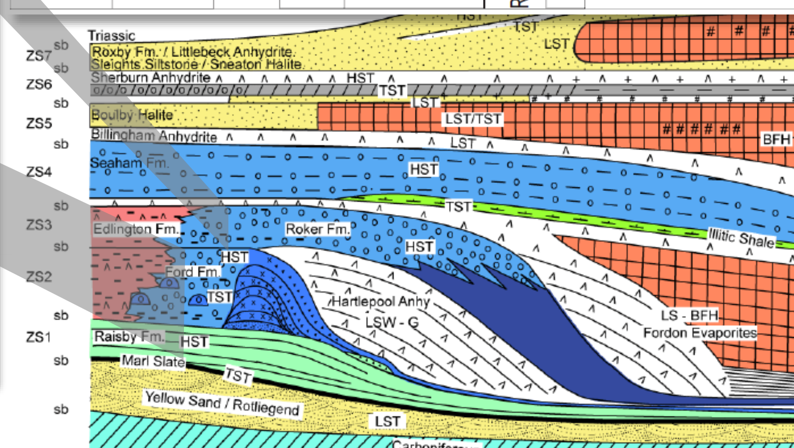


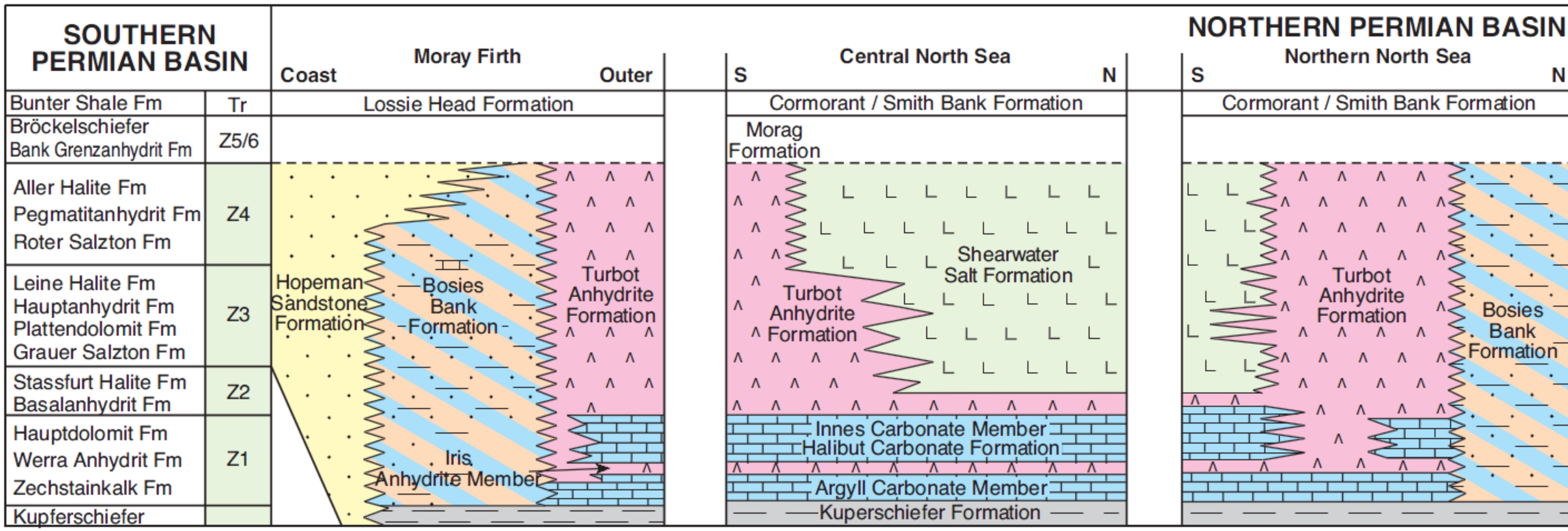
Fig. 3. Polish Zechstein chronostratigraphy and depositional sequences PZS1 to PZS4

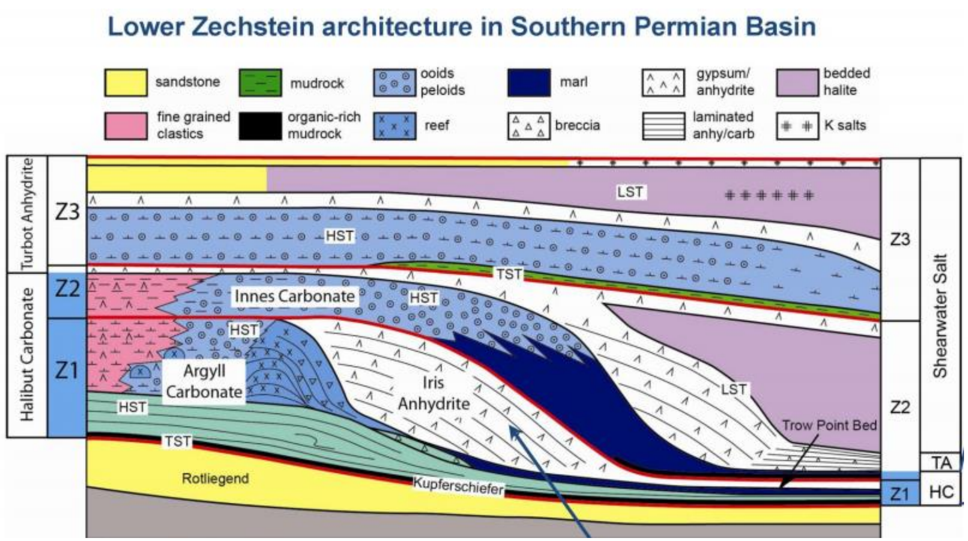




Wagner & Peryt. 1997
Słowakiewicz & Mikołajewski, 2009
Tucker, 2016

Comparison of the Zechstein development of the NPB with the classic SPB





Halibut Carbonate Formation

Two carbonate sequences of the Halibut Carbonate Formation (Figure 8.1) were deposited at times of free circulation of sea water during the first two Zechstein cycles. The intervening Iris Anhydrite Member represents restricted marine conditions, possibly that of a sabkha late in cycle Z1. The Z1 Argyll Carbonate Member and Iris Anhydrite Member (Figure 8.19) correlate with the classical German Zechsteinkalk and Werraanhydrit respectively in the Southern Permian Basin. The upper carbonate correlates with the Innes Carbonate Member of the Hauptdolomit (Cameron, 1993a; Taylor, 1998). The

Evans et al. 2003
Madeleine et al. 2018

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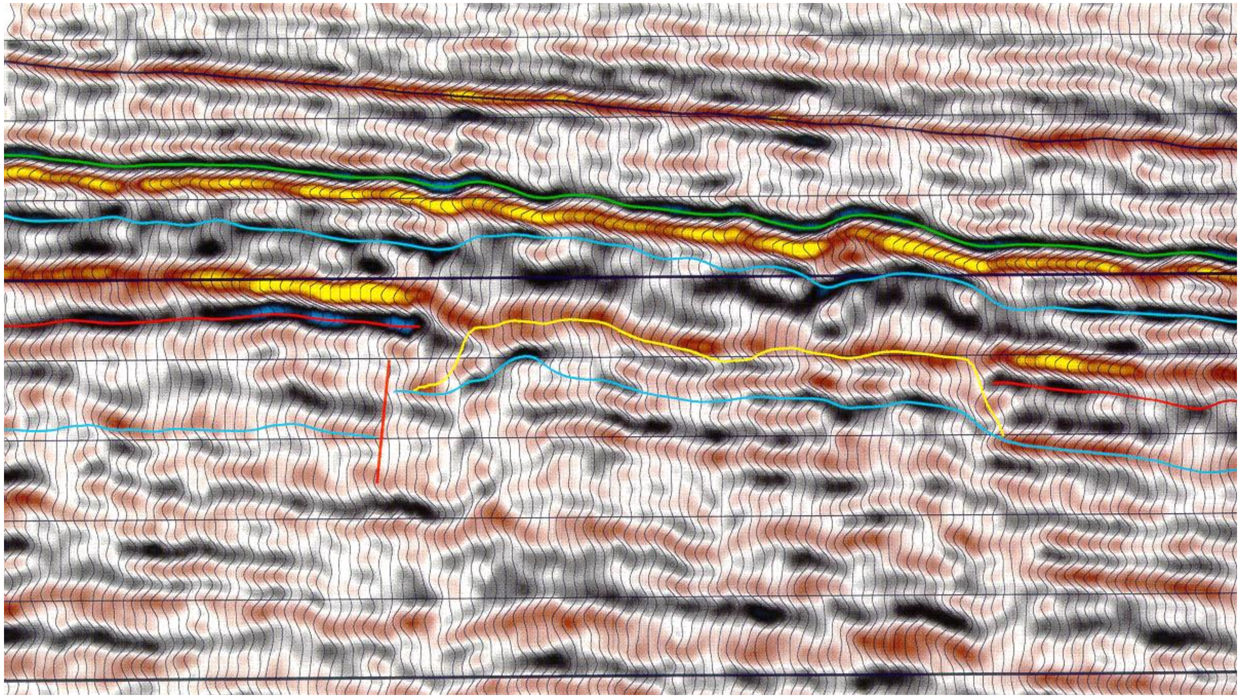
Zechstein Limestone – Ca1

(≈ Argyll Carbonate Member)



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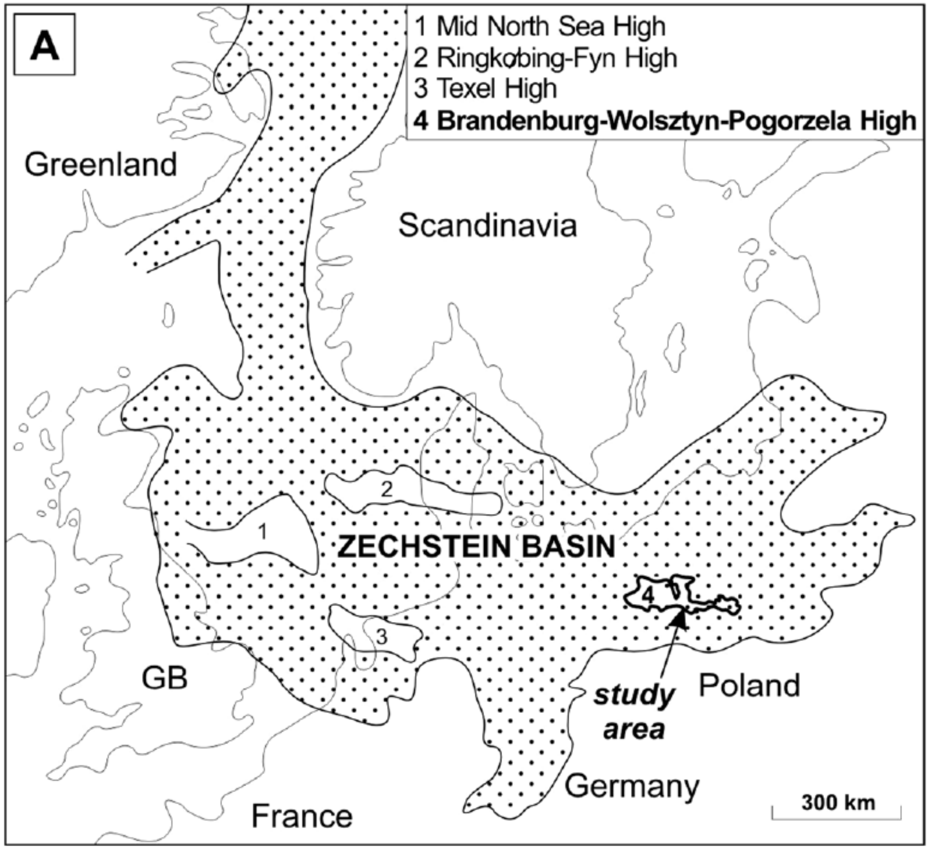
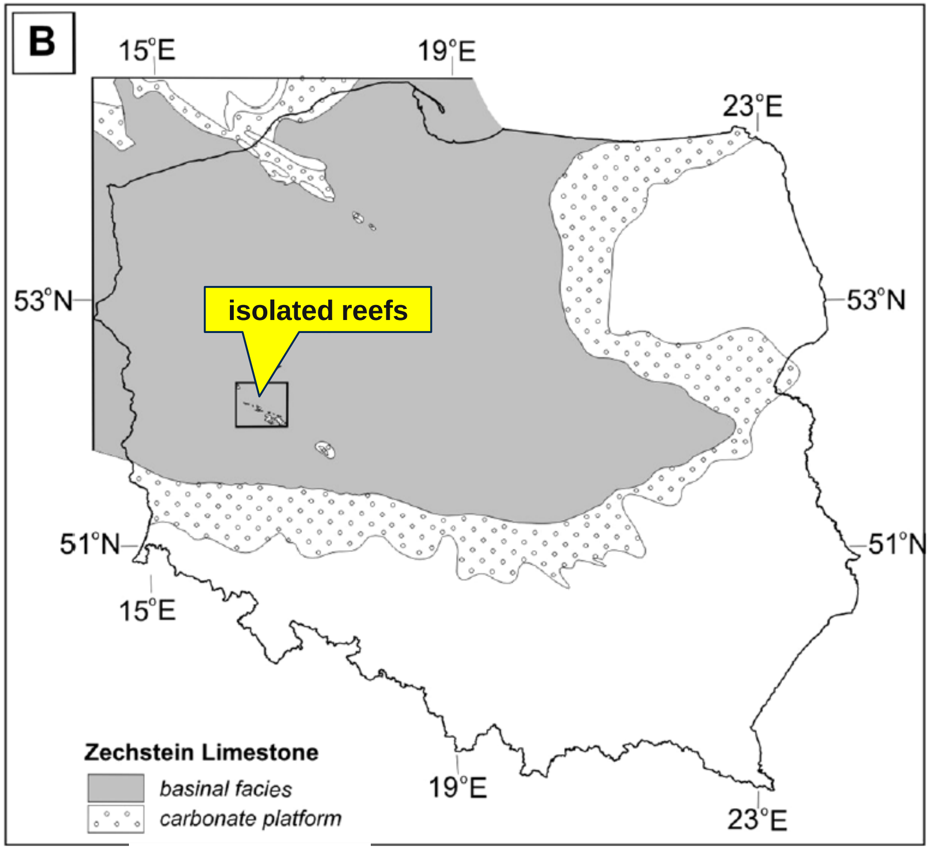
Zechstein basin, showing the position of the Brandenburg-Wolsztyn-Pogorzela palaeo-High

Basin facies of the Zechstein Limestone in Poland, showing the occurrence of isolated reefs related to the Brandenburg-Wolsztyn-Pogorzela palaeo-High.





(rimmed platform)

Peryt et al. 2014

Palaeogeomorphology of the basal Zechstein across the Wolsztyn High

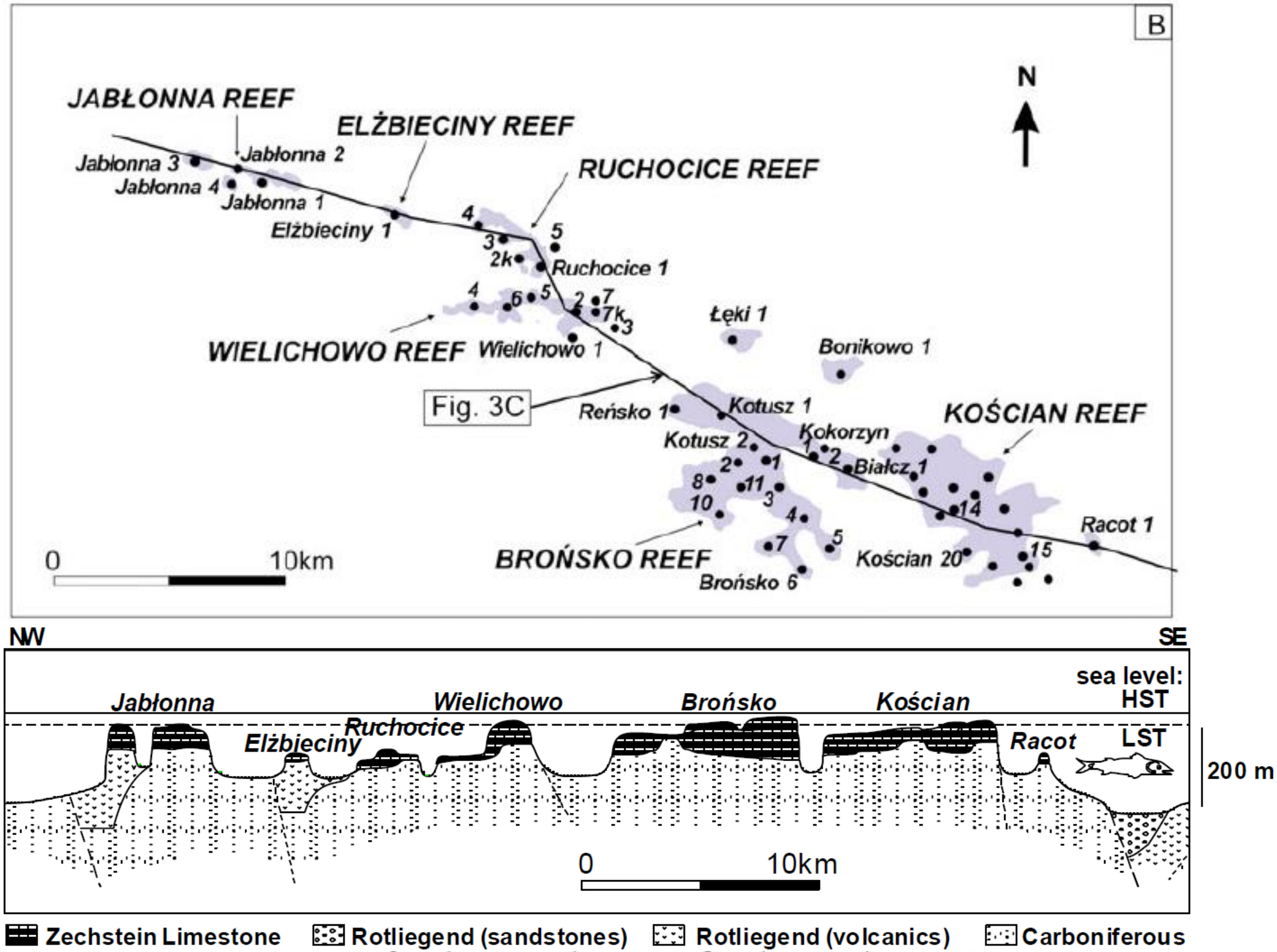


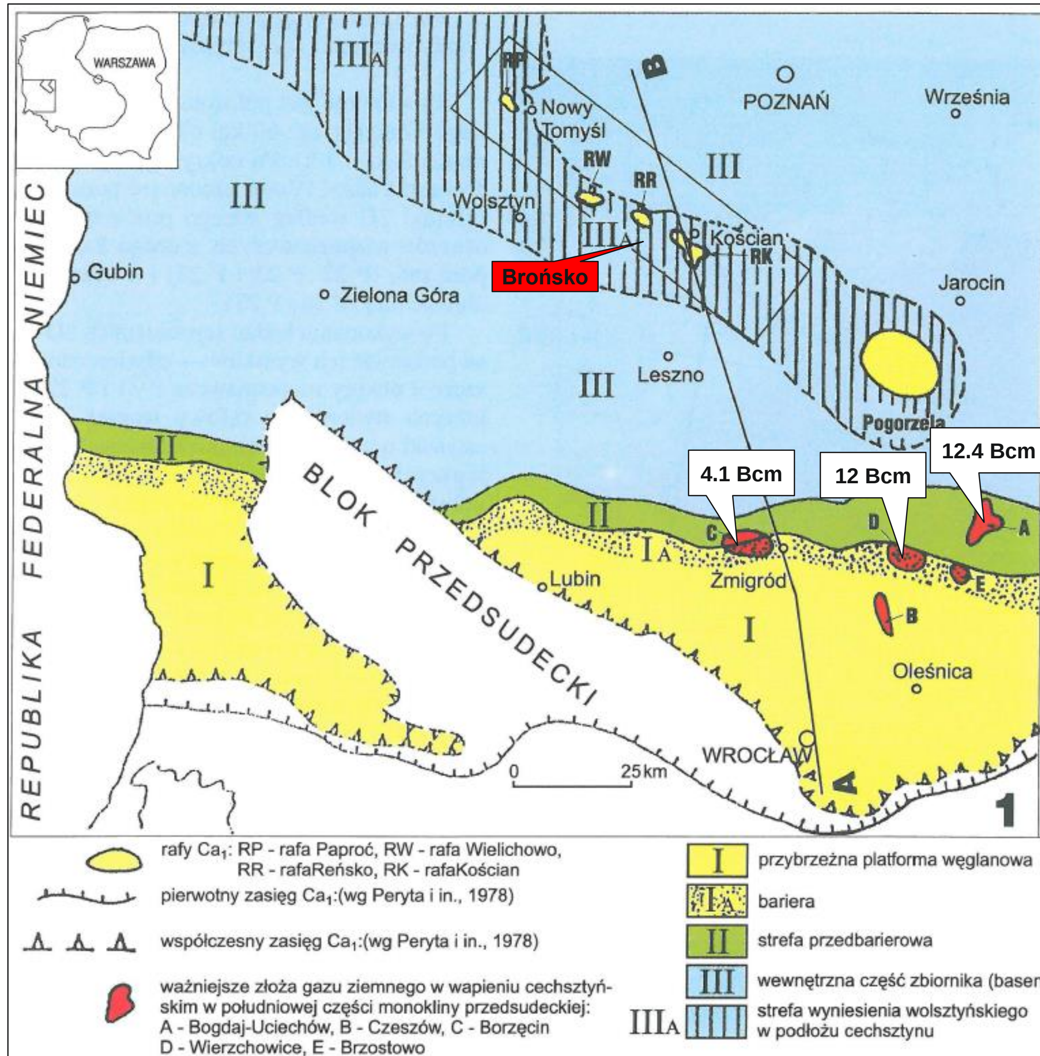
Figure 3. (A) Palaeogeomorphology of the basal Zechstein across the Wolsztyn High along the line shown in Figure 2 (after Hryniv and Peryt, 2010); A1d—Lower Anhydrite, A1g—Upper Anhydrite, A2—Basal Anhydrite, Ca2—Main Dolomite, Na1—Oldest Halite, Na2—Older Halite; r—reefs of the Zechstein Limestone; the Z1 evaporites are dotted; (B) Location map showing the distribution of reefs and the wells drilled; (C) Cross-section (along the line shown in Figure 3B) showing a reef complex developed on various facies, in terms of age and lithology, of basement blocks associated with Wolsztyn High area (after Kiersnowski *et al*., 2010, figure 6B). This figure is available in colour online at wileyonlinelibrary.com/journal/gj

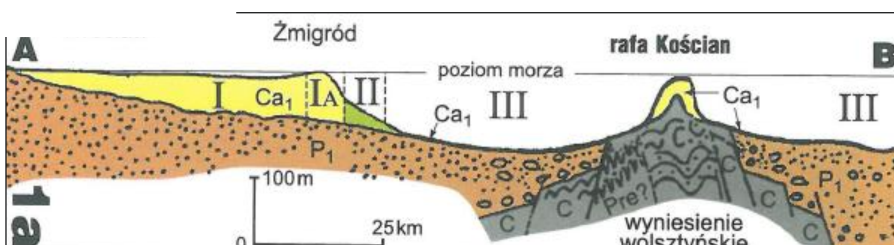
Palaeogegraphy of the Ca1 HC play – source rock

The Zechstein Limestone (Ca1) belongs to the same petroleum system as the Rotliegend sandstones (with Carboniferous source rocks).

Late Carboniferous bituminous shales (Lower Namurian (?) and Westphalian A to C) coal-bearing sequences are the source rocks for the gases in the Rotliegend/Ca1 reservoirs.

III type of kerogen with admixture of I/II type





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Harz Mts. outcrops of the Ca1 reefs

Westerstein reef
Stromatolitic reefs of Ca1

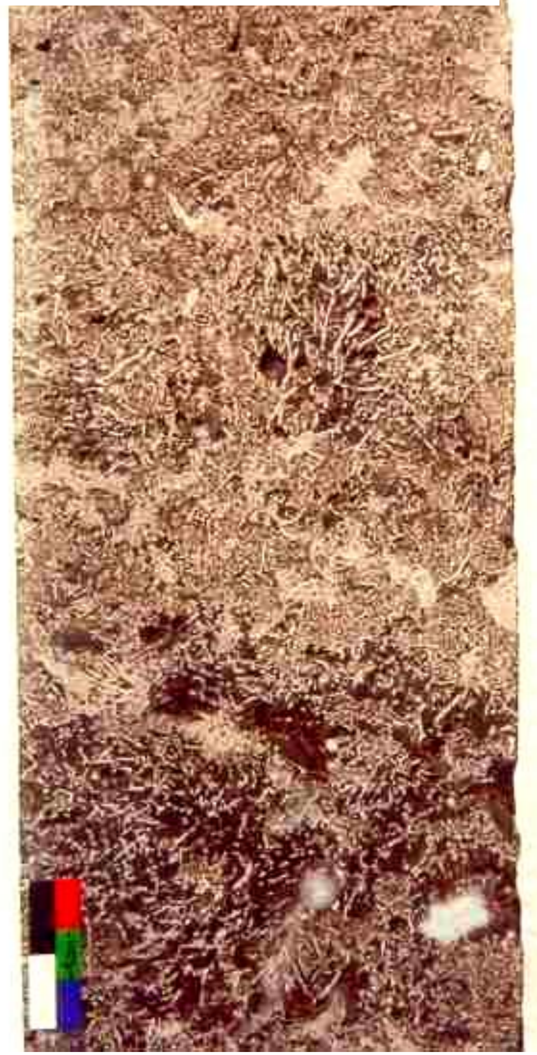
Top of the Ritterstein
High Energy facies of Ca1

Kotusz-2 (Brońsko Reef)

Horridonia biofacies,
lower part of biofacies

Kotusz-2 (Brońsko Reef)

Branched and columnar
bryozoan zoaria - bryozoan bafflestone



Kościan-19 (Kościan Reef)

Five Zechstein units can generally be recognised below the Werra Anhydrite, the evaporite which caps the Zechstein Limestone, in the Wolsztyn Ridge area:
1 - breccia; 2 - bioclastic grainstones with extraclasts; 3 - bioclastic grainstones and packstones with abundant anhydrite;
3 - bioclastic wackestones-grainstones with intraclastic; 4 - breccia and carbonate crusts; 5 - stromatolitic-pisolitic carbonates.

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Origin of porosity in the Ca1 reefs

According: Poszytek & Suchan, 2015

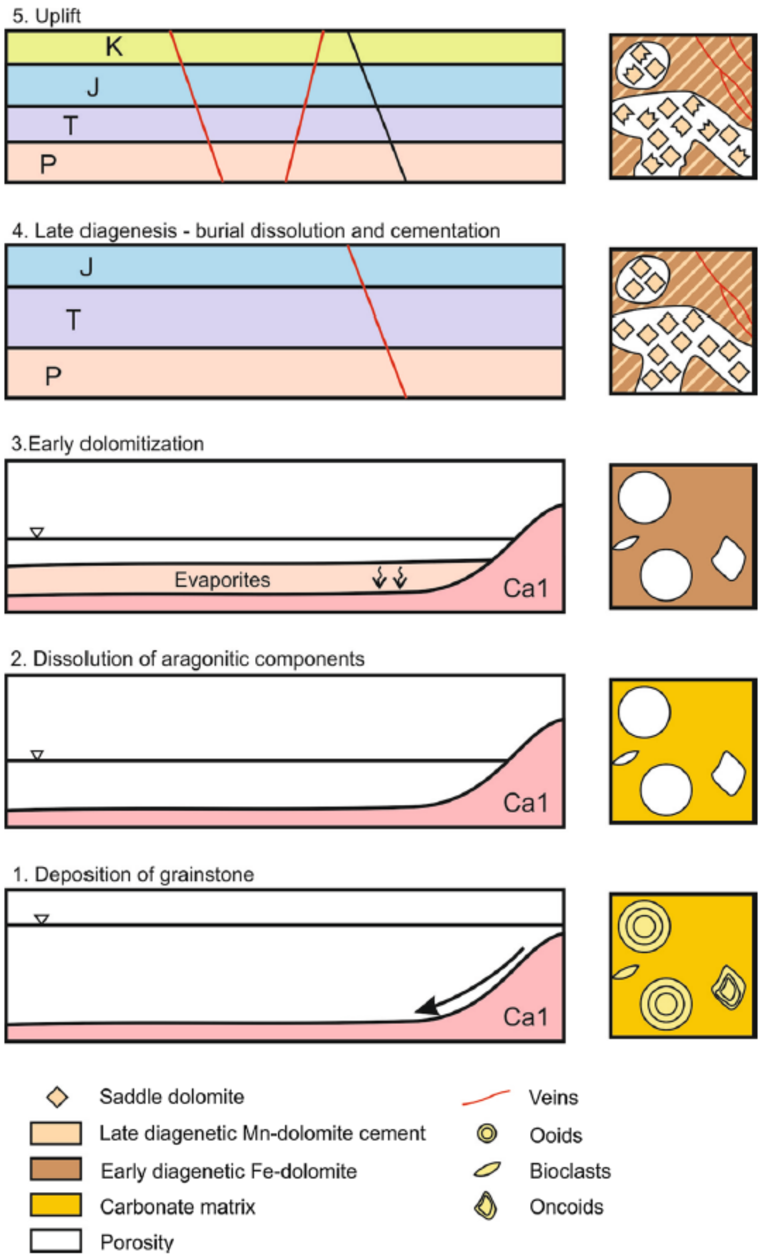
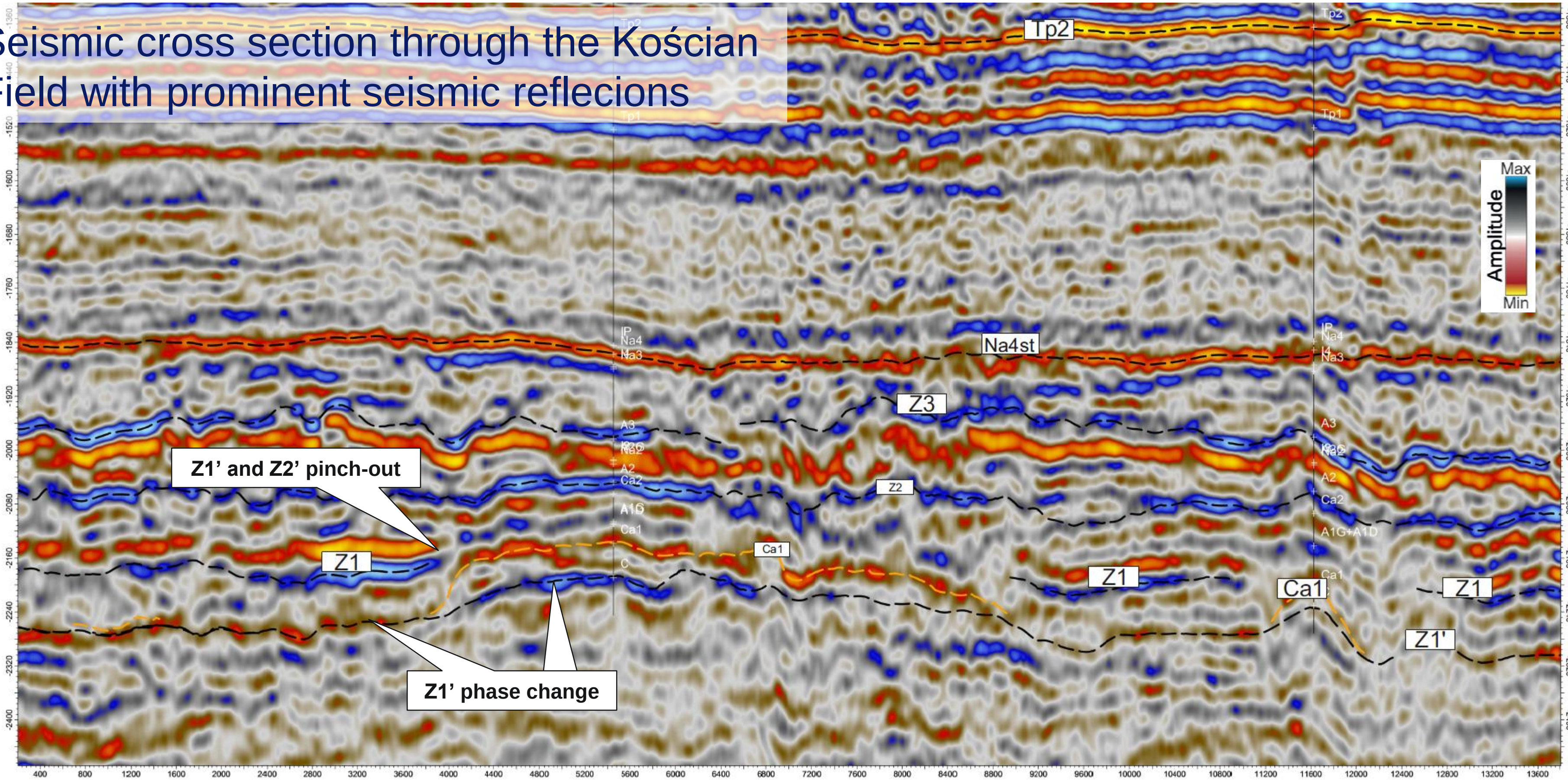
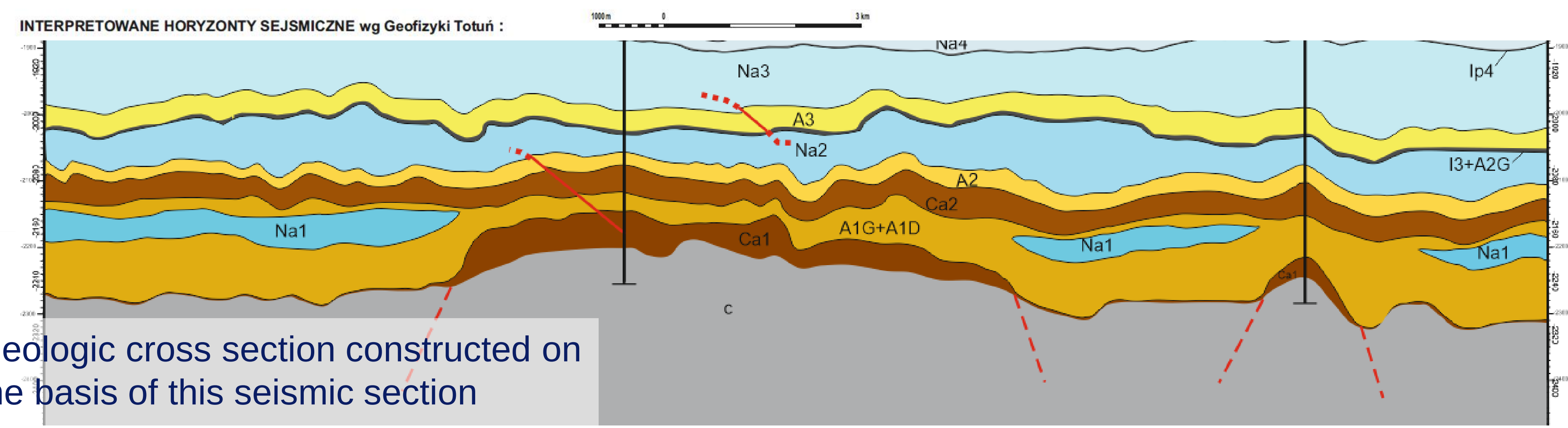


Fig. 8 Five stages in the origin of porosity in the tight-gas reservoir horizon. **1** Formation of grainstone by redeposition of unconsolidated sediment from carbonate platform, **2** dissolution of aragonitic components—formation of vugs increasing porosity, **3** early dolomitization and recrystallization by evaporitic waters during deposition of anhydrite and salts—increasing intercrystalline porosity, **4** during burial dissolution and cementation of grainstone by Mn-rich dolomite—the main stage of porosity and tight-gas rock formation, **5** partial dissolution of dolomite and formation of fractures filled by anhydrite

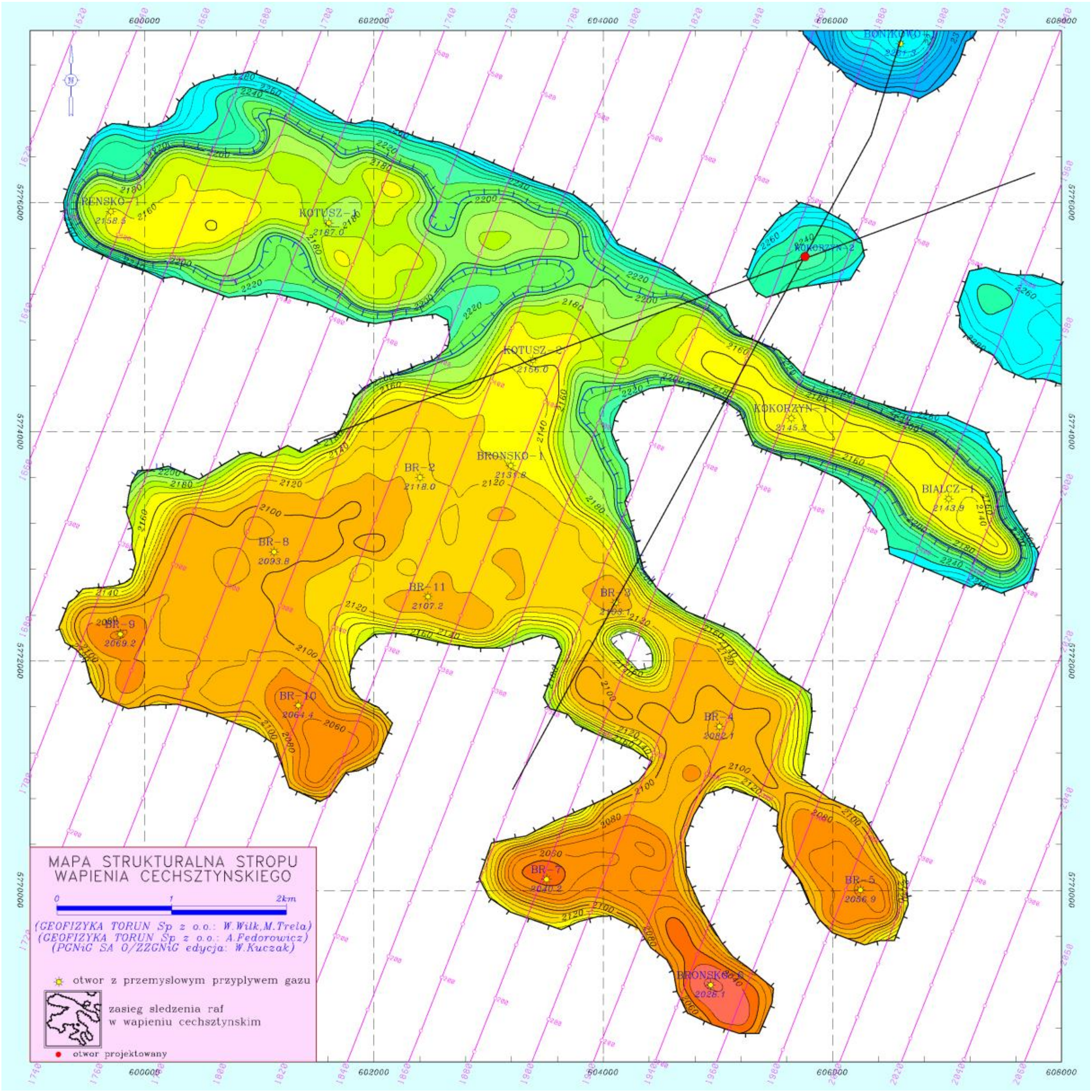
Seismic cross section through the Kościan Field with prominent seismic reflecions





Geologic cross section constructed on the basis of this seismic section

STRUCTURAL MAP OF the Ca1 TOP THE BROŃSKO FIELD



Discovery – 1998
Start of production - 2001
Area – 29.6 km^2
Gas in place: 28 Bcm
Reserves: 23.8 Bcm
RF: 0.85
Annual production: 780 MMcm
Column height – 176m

Gas composition [%vol]:
C1 – 75.14%
C2 – 0.94%
C3 – 0.05%
…
N2 – 23.29%
CO2 – 0.4%
He – 0.14%

Ca1
Porosity: 10-20%
Permability: 0-400mD (av. 42mD)

Reservoir pressure - 24.61 MPa.

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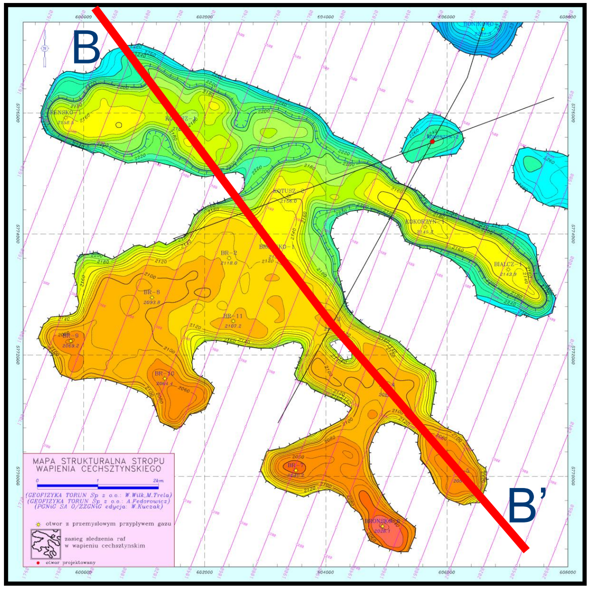
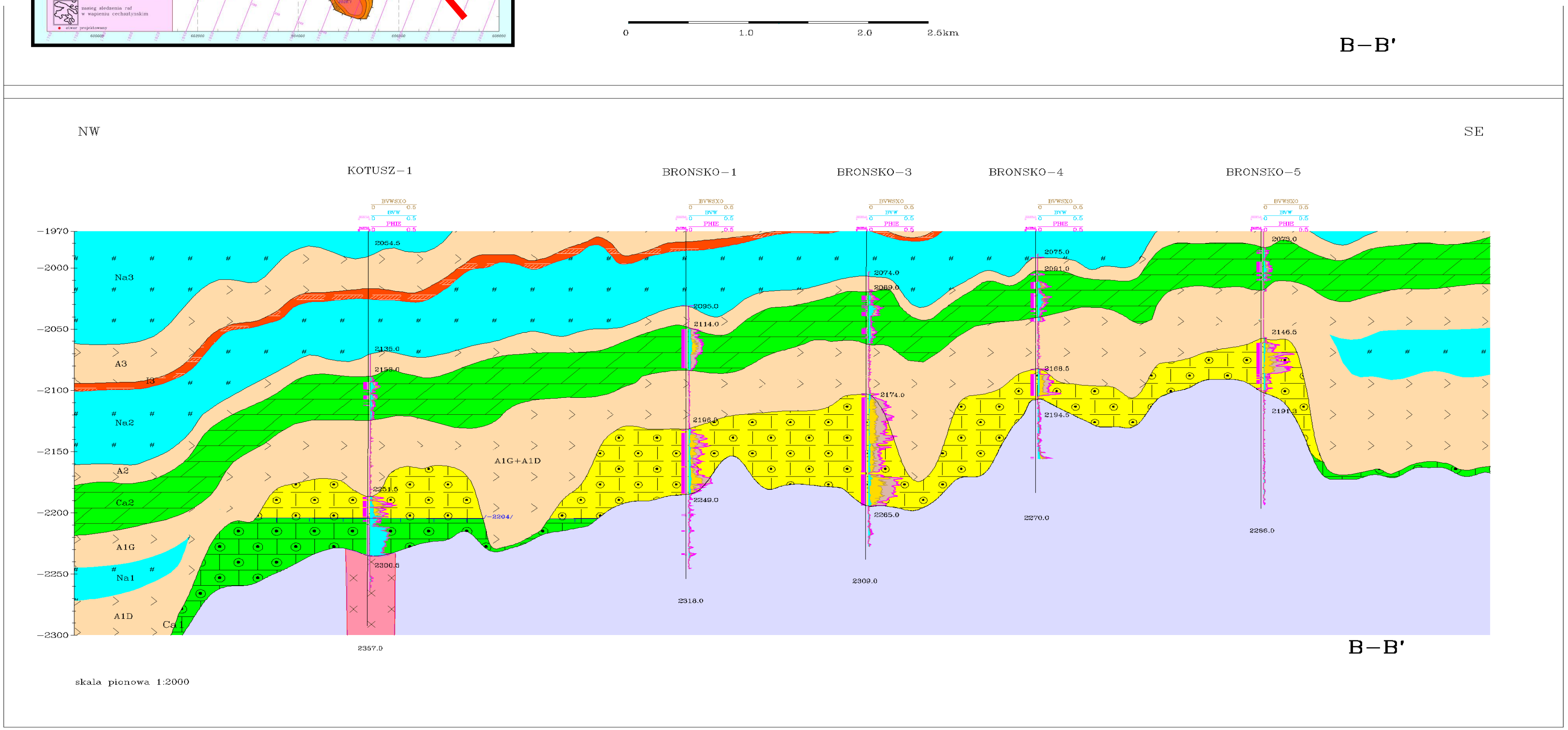
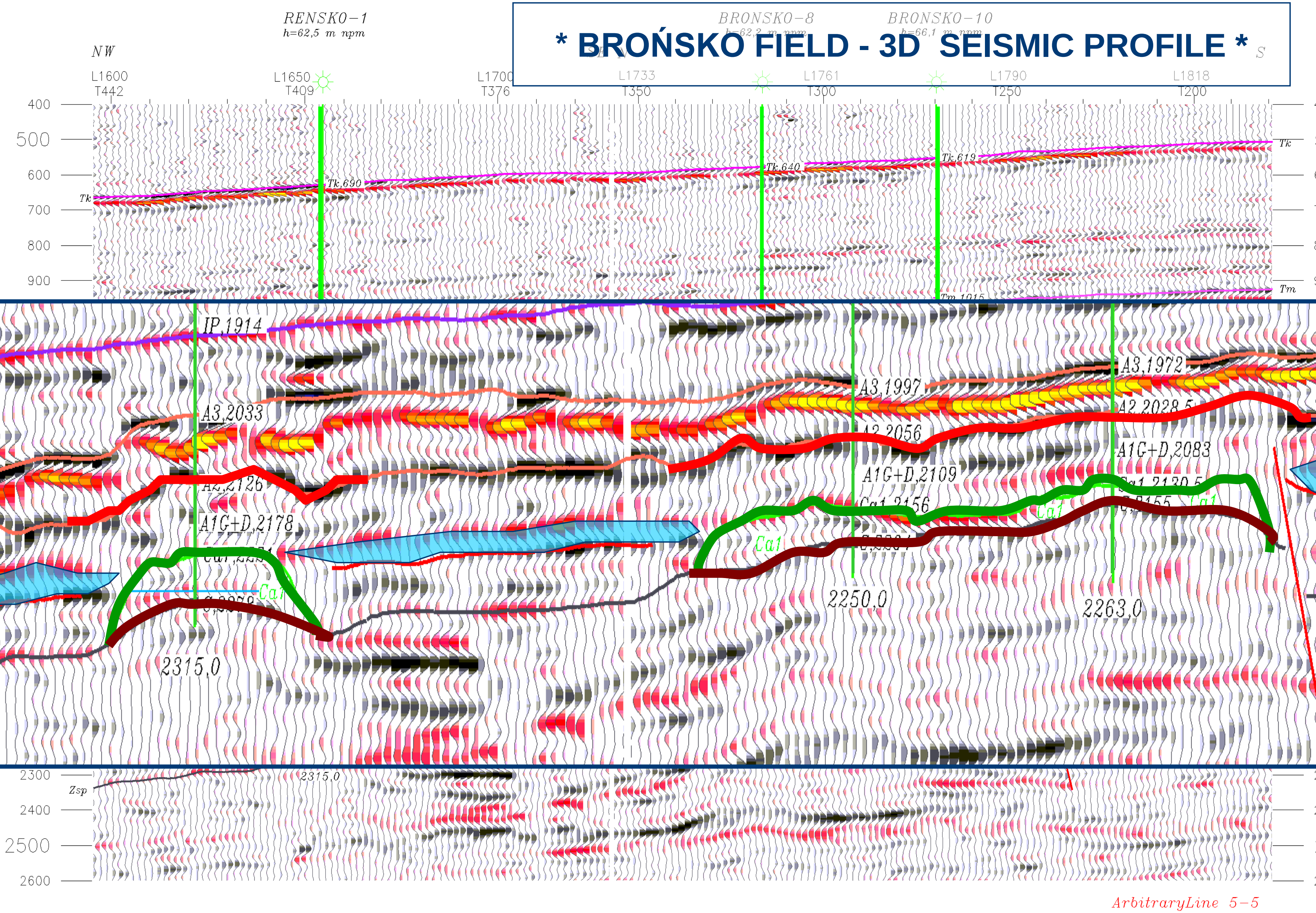


Cross-section through the Brońsko Field

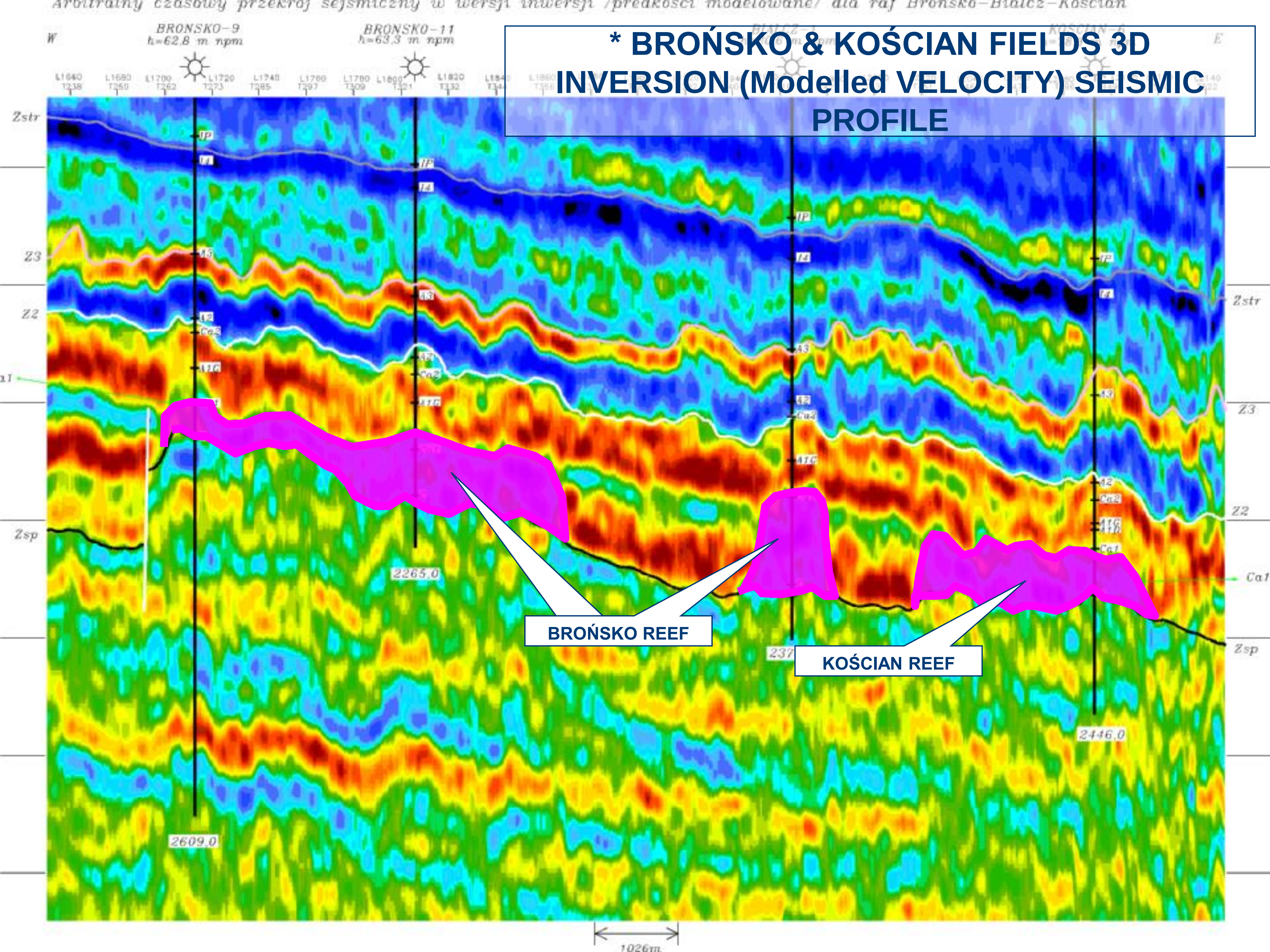
Carboniferous:
Gas in place: 2.6 Bcm
Porosity: 1.26%
Permability: 0.01mD
Production: 30 m^2/min



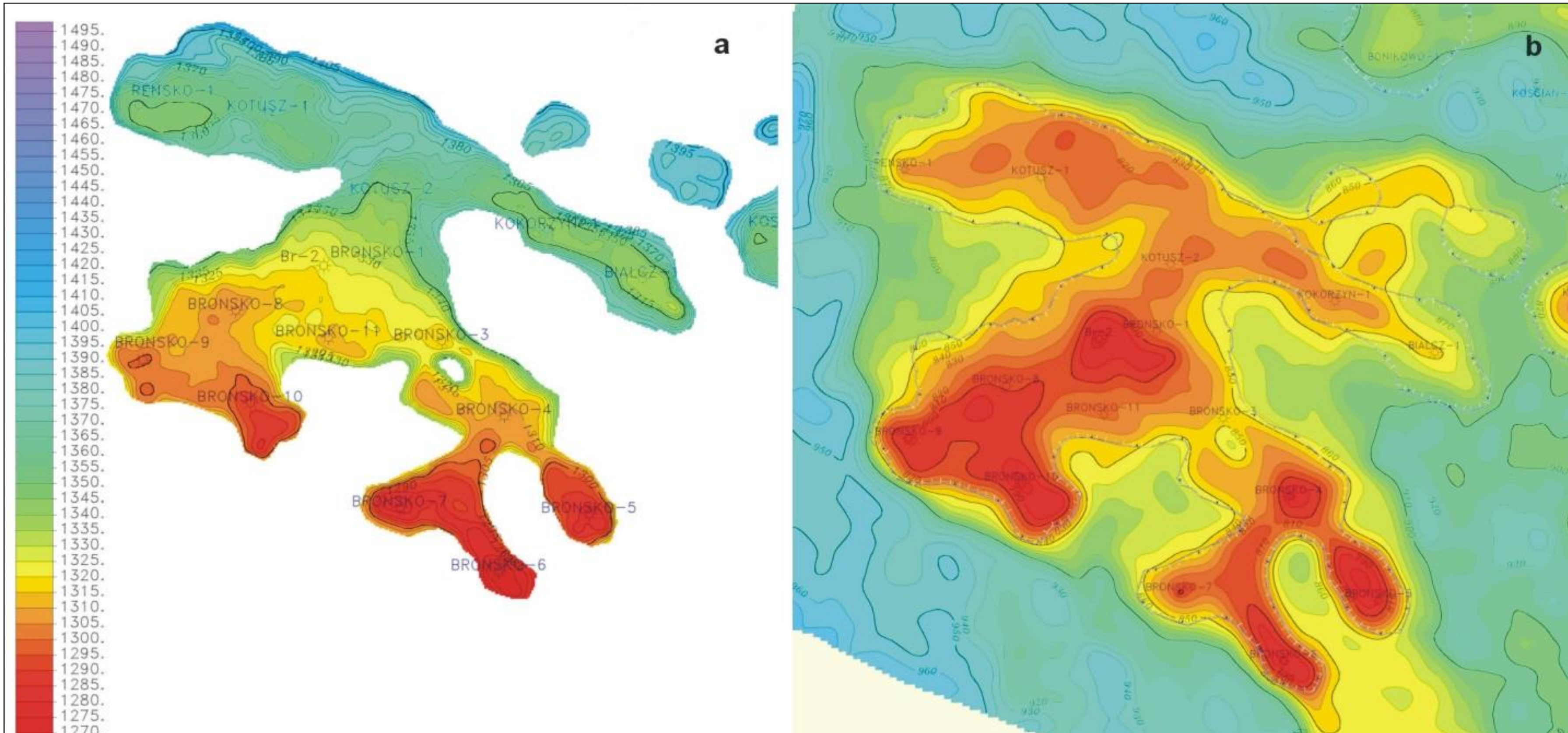
* BROŃSKO FIELD - 3D SEISMIC PROFILE *



* BROŃSKO & KOŚCIAN FIELDS 3D INVERSION (Modelled VELOCITY) SEISMIC PROFILE



Brońsko Gas Field



a – depth structure map of top of Ca1 (basal limestone)
b – Z1’-Tp2 thickness map showing paleo-high in the basement below the reef

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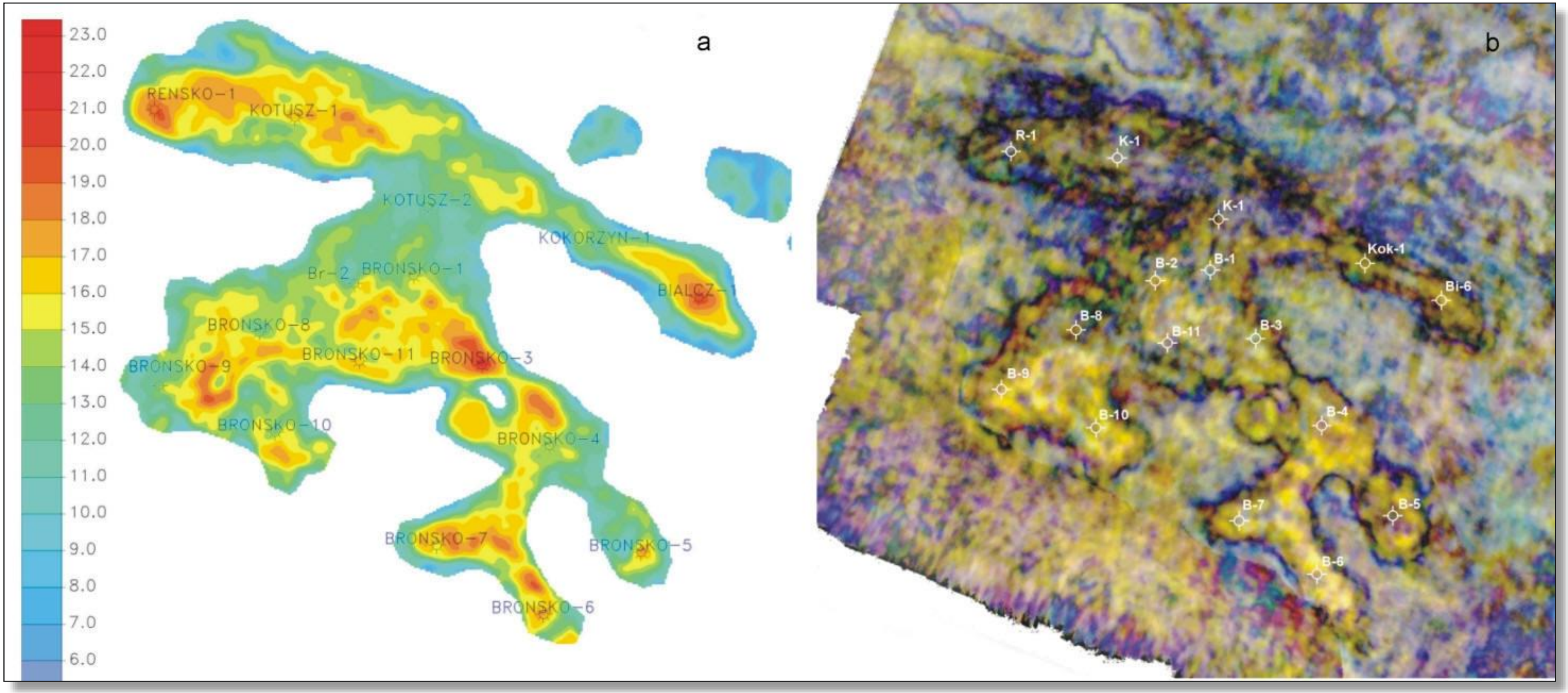
Brońsko Gas Field



a – inversion porosity
b – spectral decomposition – blend of 16, 18 and 28 Hz

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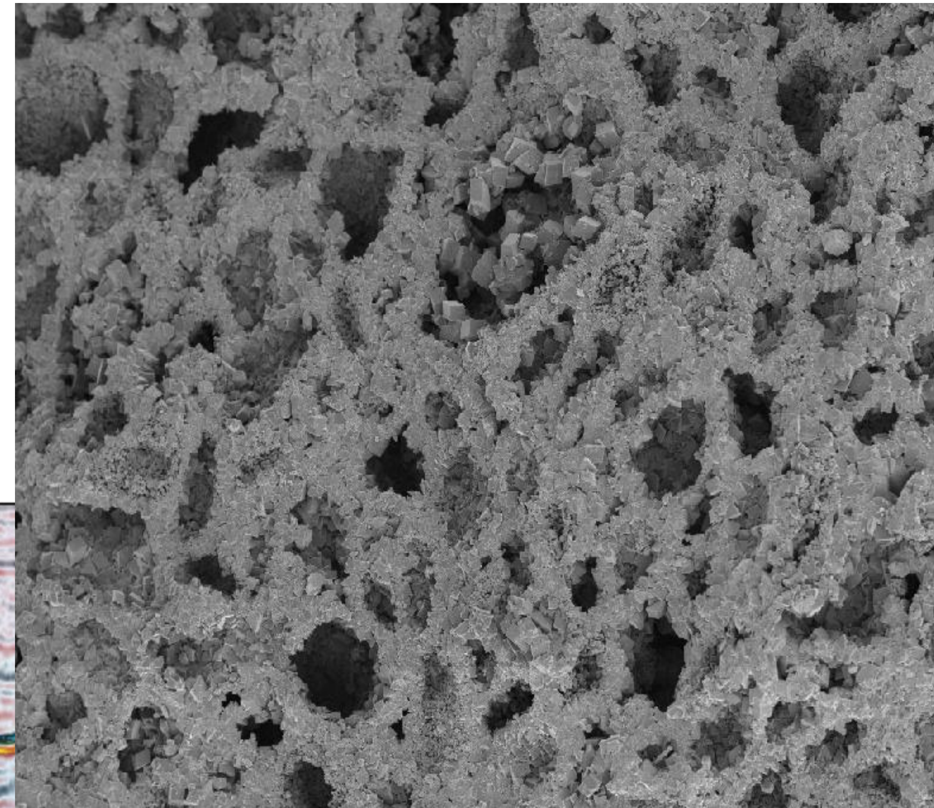
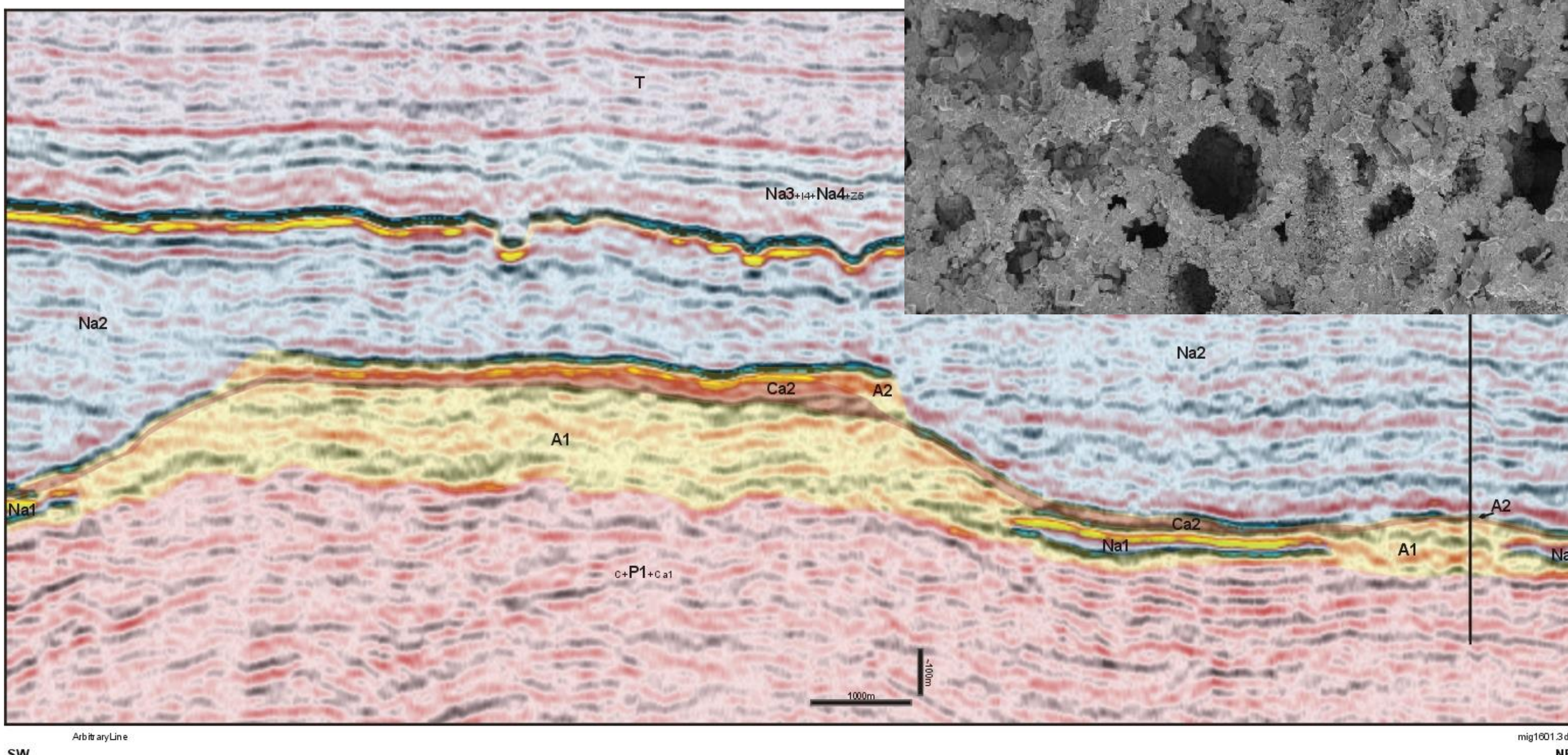
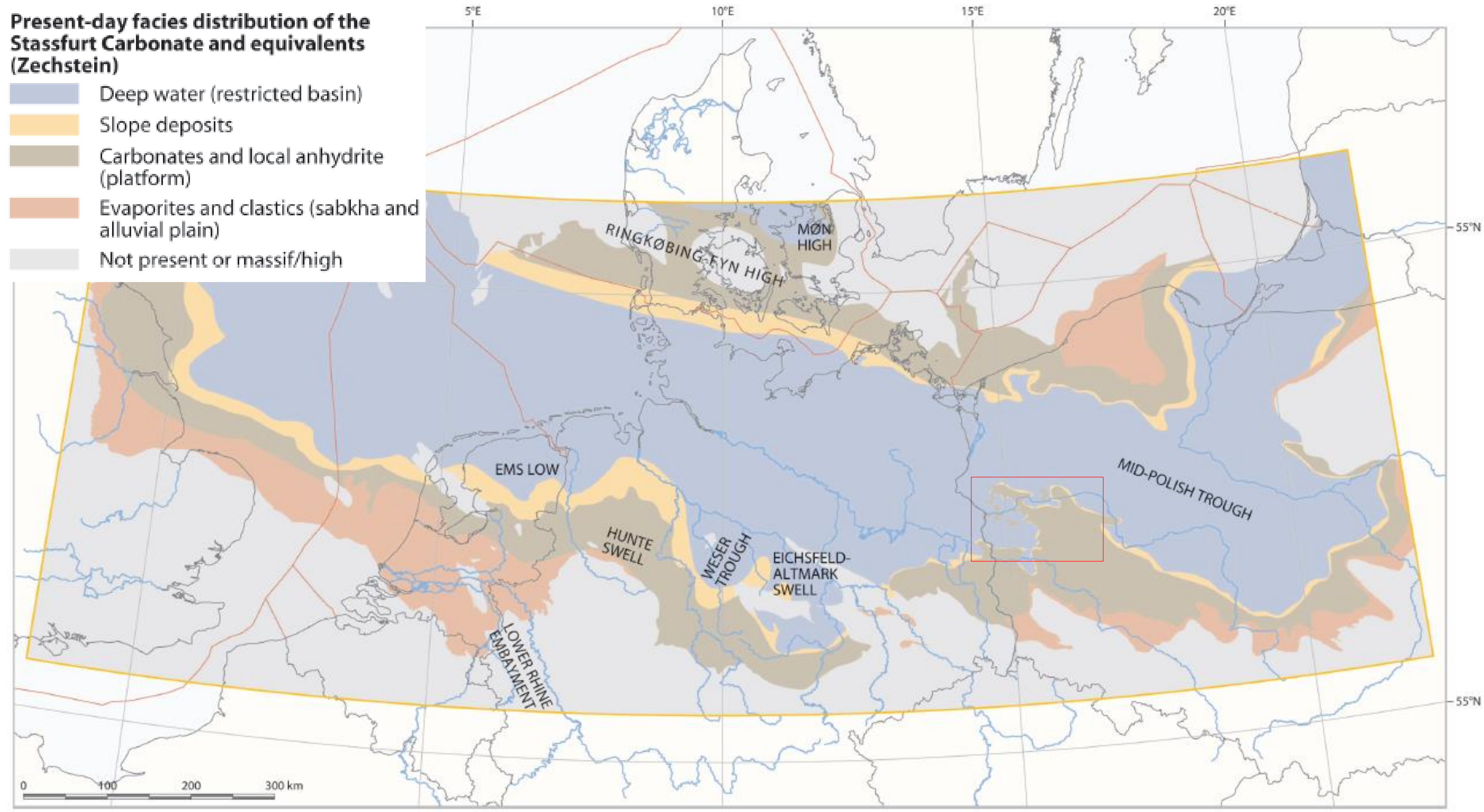
Main Dolomite – Ca2

(≈ Innes Carbonate Member)





Late Permian (Zechstein Z2) tectonic evolution. Wuchiapingian, 255 Ma



Petroleum Geological Atlas of the Southern Permian Basin Area, 2010

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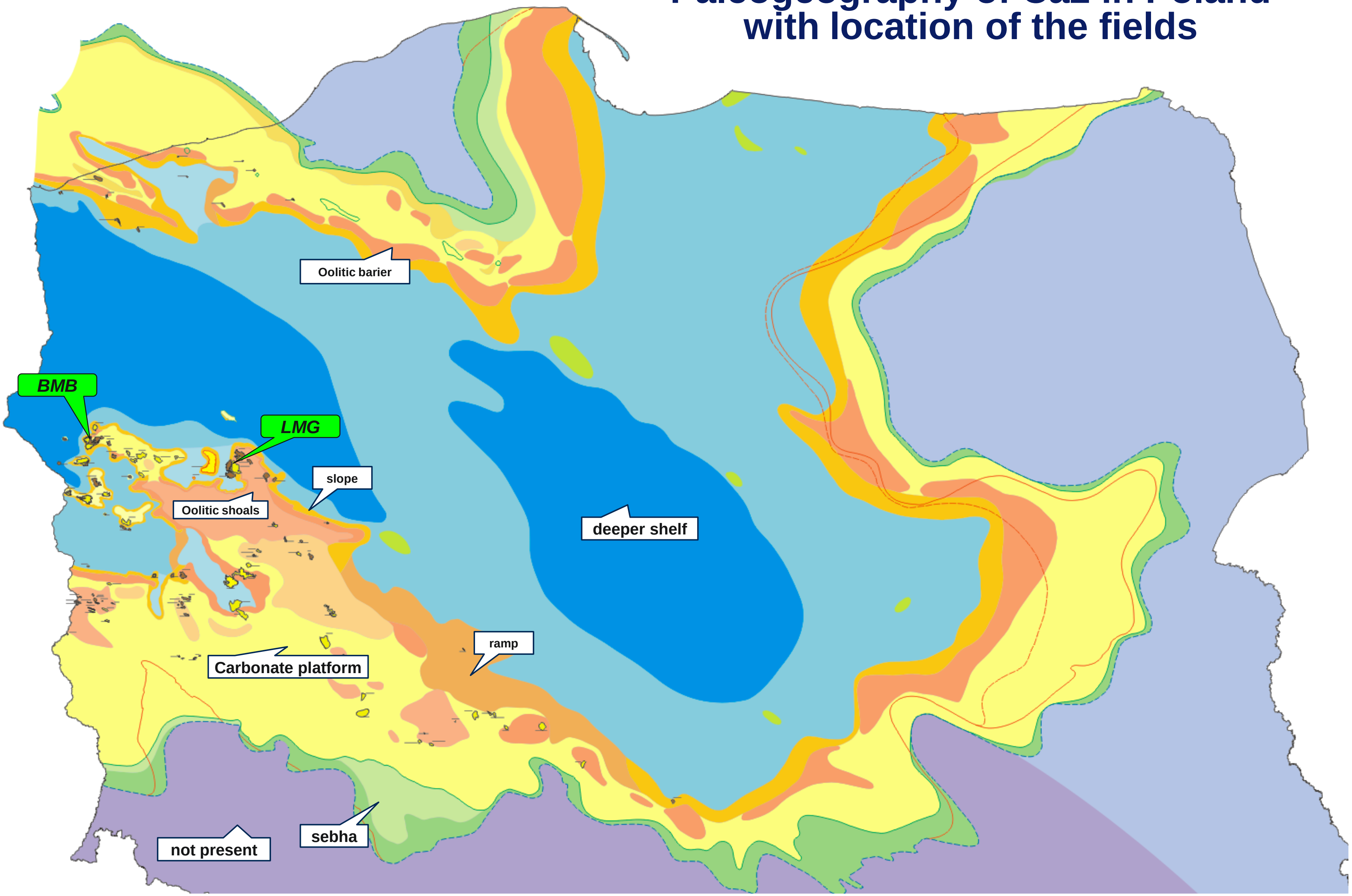
Paleogeography of Ca2 in Poland with location of the fields



BMB – **B**arnówko – **M**ostno - **B**uszewo
LMG – **L**ubiatów - **M**iędzychód - **G**rotów

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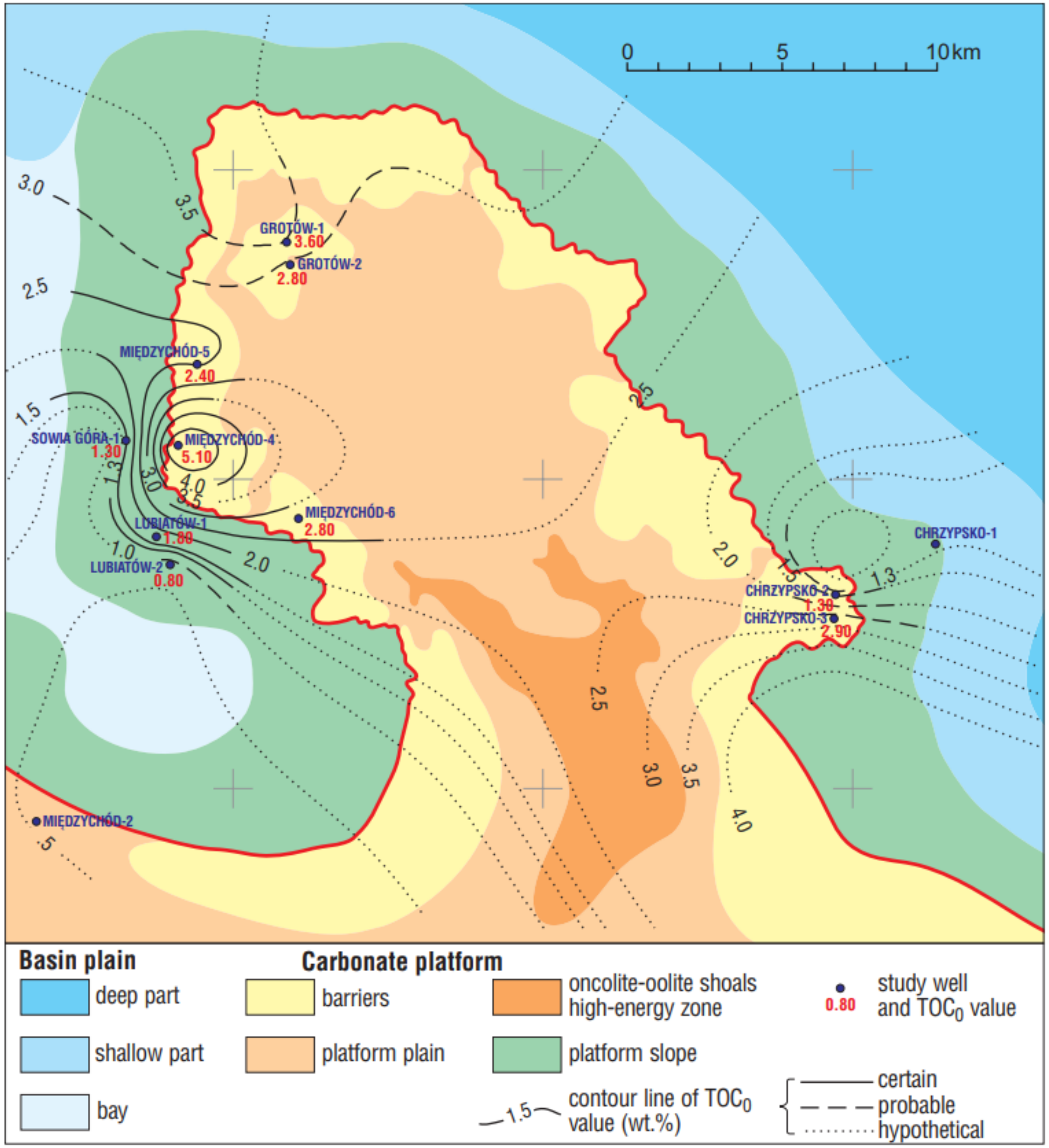

Fig. 10. Map of original total organic carbon (TOC_0) content in the Main Dolomite carbonates from the Grotów Peninsula

Source rocks of microbial-algal origin

Source rocks of microbial-algal origin commonly occur in the Main Dolomite strata in the Gorzów Wielkopolski–Międzychód–Lubiatów area on carbonate platform slopes and on carbonate platforms. Total organic carbon **(TOC) content varies from 0.01 wt.% to 1.0 wt.% (sporadically to 4 wt.%)**, and calculated original total organic carbon (TOC0) content from 1.0 wt.% to about 5.0 wt.%.**Oil-prone type II kerogen dominates** with occasional amounts of type III or type I kerogens. Hydrocarbon generation processes followed two pathways. In the first pathway, generation was a single-stage process with full generation of hydrocarbon mass in a continuous progression of organic matter transformation, in late Triassic time. In the second pathway, the generation took place in two stages. Eighty to ninety percent of hydrocarbon mass was generated from kerogen by the end of the Jurassic period and the remaining generation was completed during post-Cretaceous time. As a consequence, oil accumulated in traps at the turn of the Triassic-Jurassic periods, and gas saturation of oil accumulations took place by late Jurassic time, with the final gas generation in the Paleogene or Neogene time. Hydrocarbons migrated only a few kilometres from source rocks to reservoir rocks within the Main Dolomite strata.
Kotarba & Wagner 2007

Microbialite lithofacies are represented by columnar, planar and domal stromatolites, clotted thrombolites and biolaminites developed in high-to-low energy environments within the upper slope, lower parts of oolitic barrier/shoal, restricted lagoon, and tidal flat and tidal channel zones.
Słowakiewicz & Mikołajewski 2011

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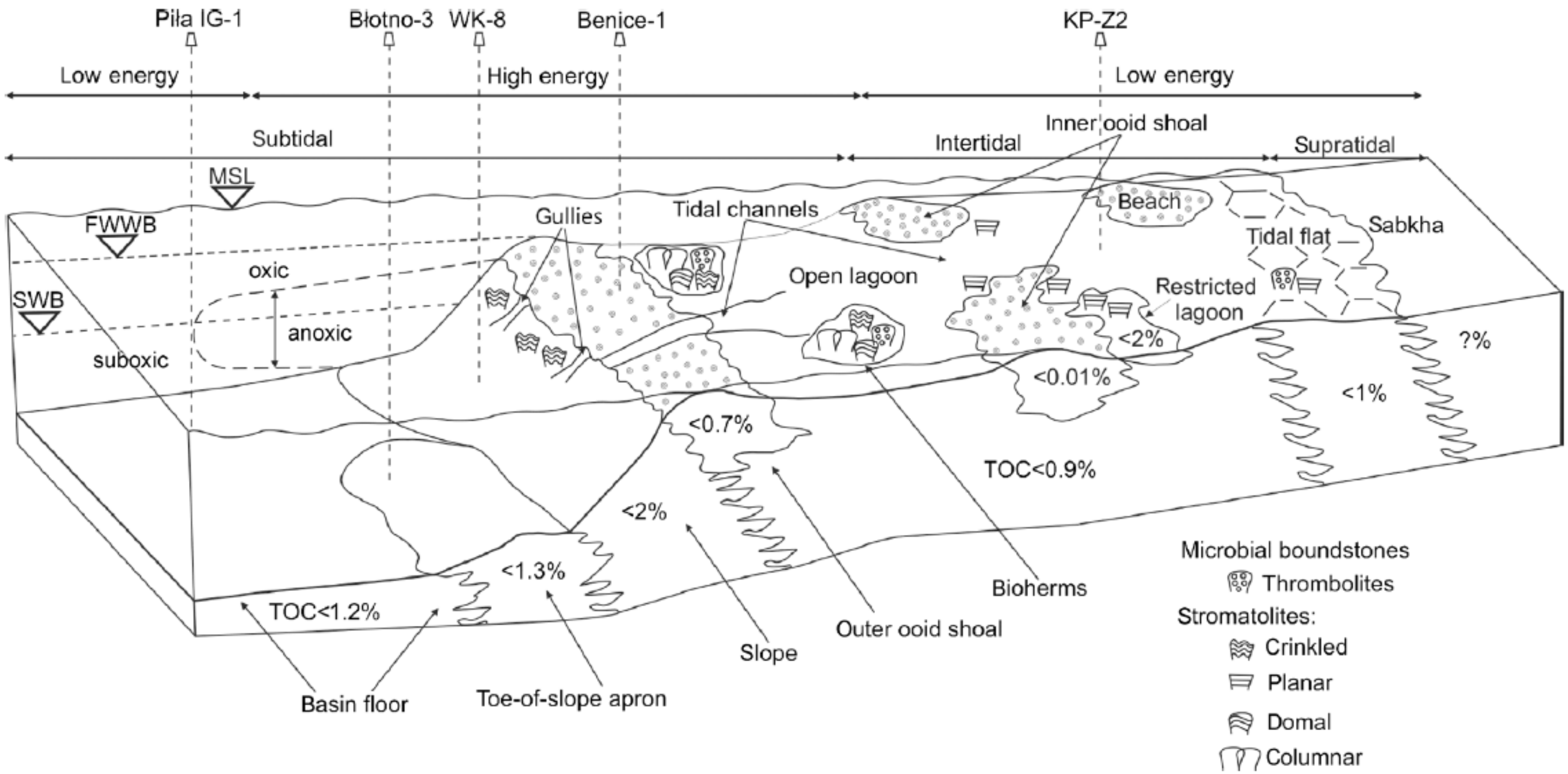

Figure 5. Depositional model of the Z2 carbonate in the southern Permian Basin in Europe, with boreholes projected from northwest Poland. MSL = mean sea level; FWWB = fair-weather wave base; SWB = storm wave base (modified from Słowakiewicz and Mikołajewski, 2011; reproduced with permission from Elsevier). Total organic carbon (TOC) values represent the highest values per Z2C succession. Note that, for the Z2C basinal facies, the maximum values of 1.2% TOC are rare and do not reflect high organic productivity because average TOC values are less than 0.3% and values in the range of 0% to 0.2% are most common (see Słowakiewicz and Gąsiewicz, 2013).

Słowakiewicz et al. 2013

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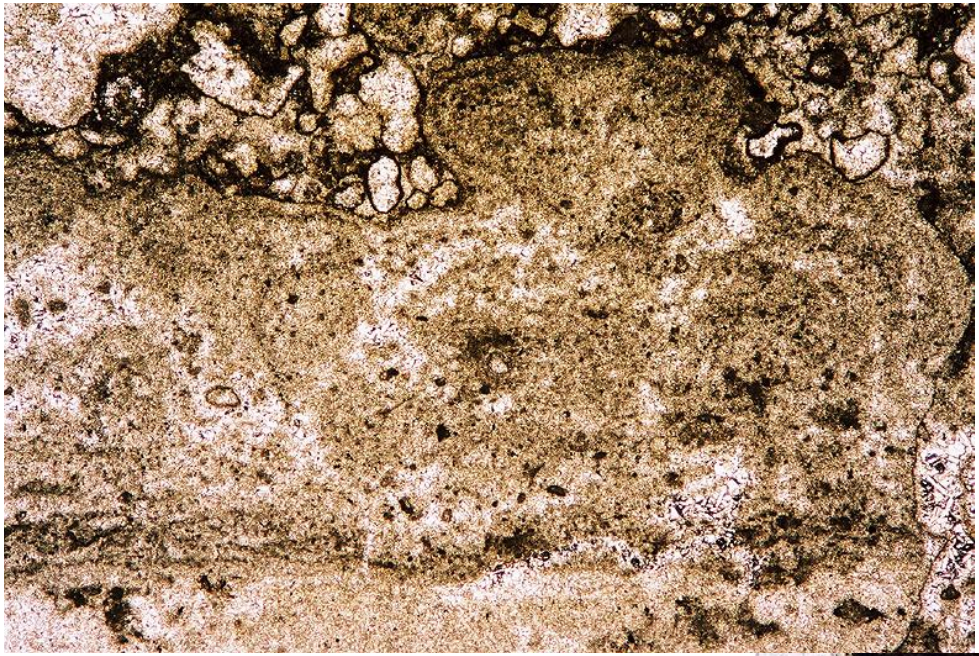
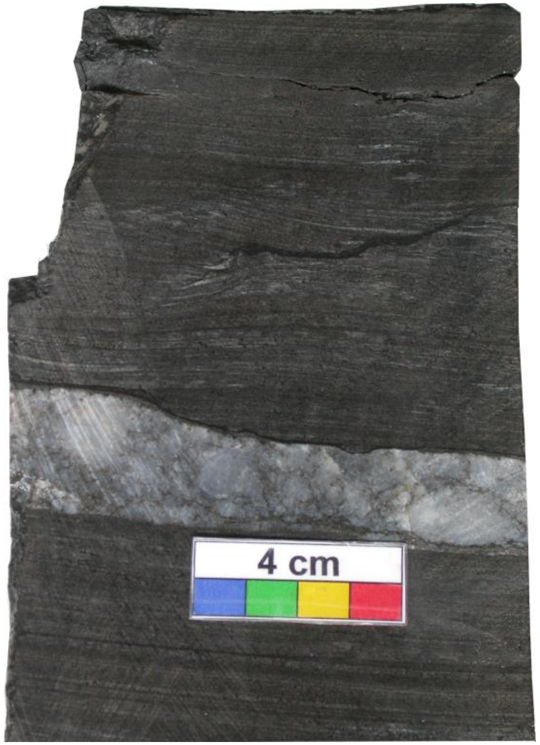
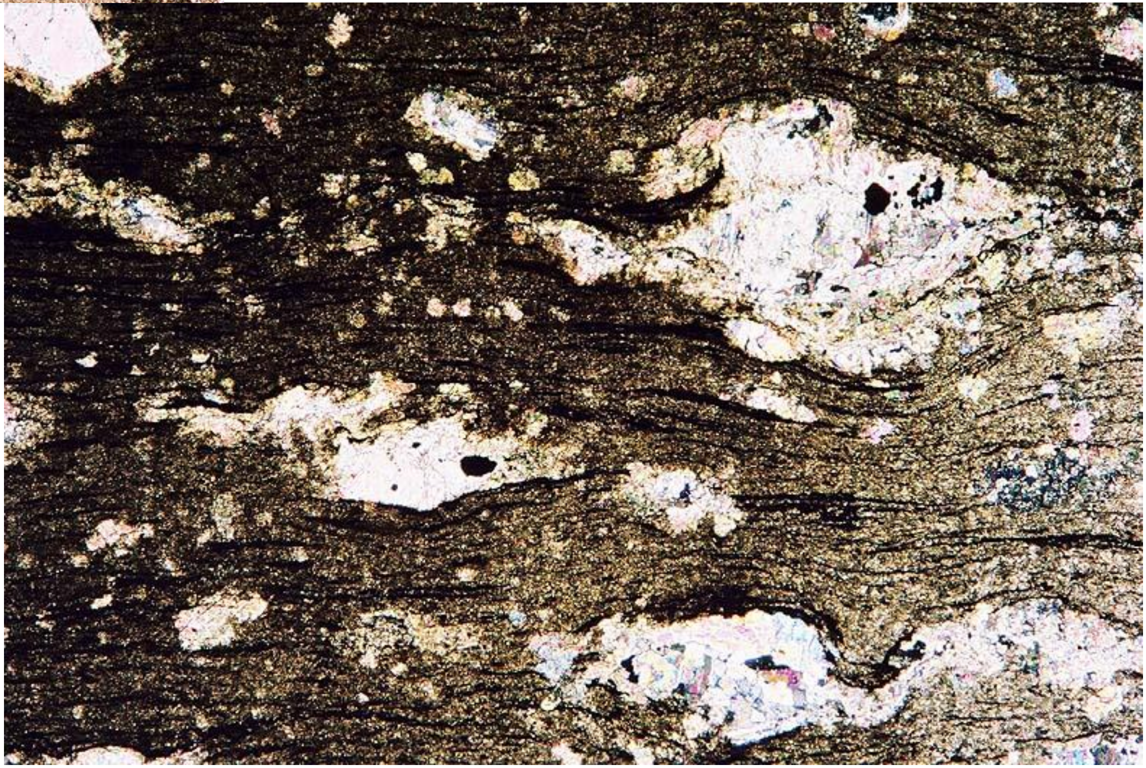
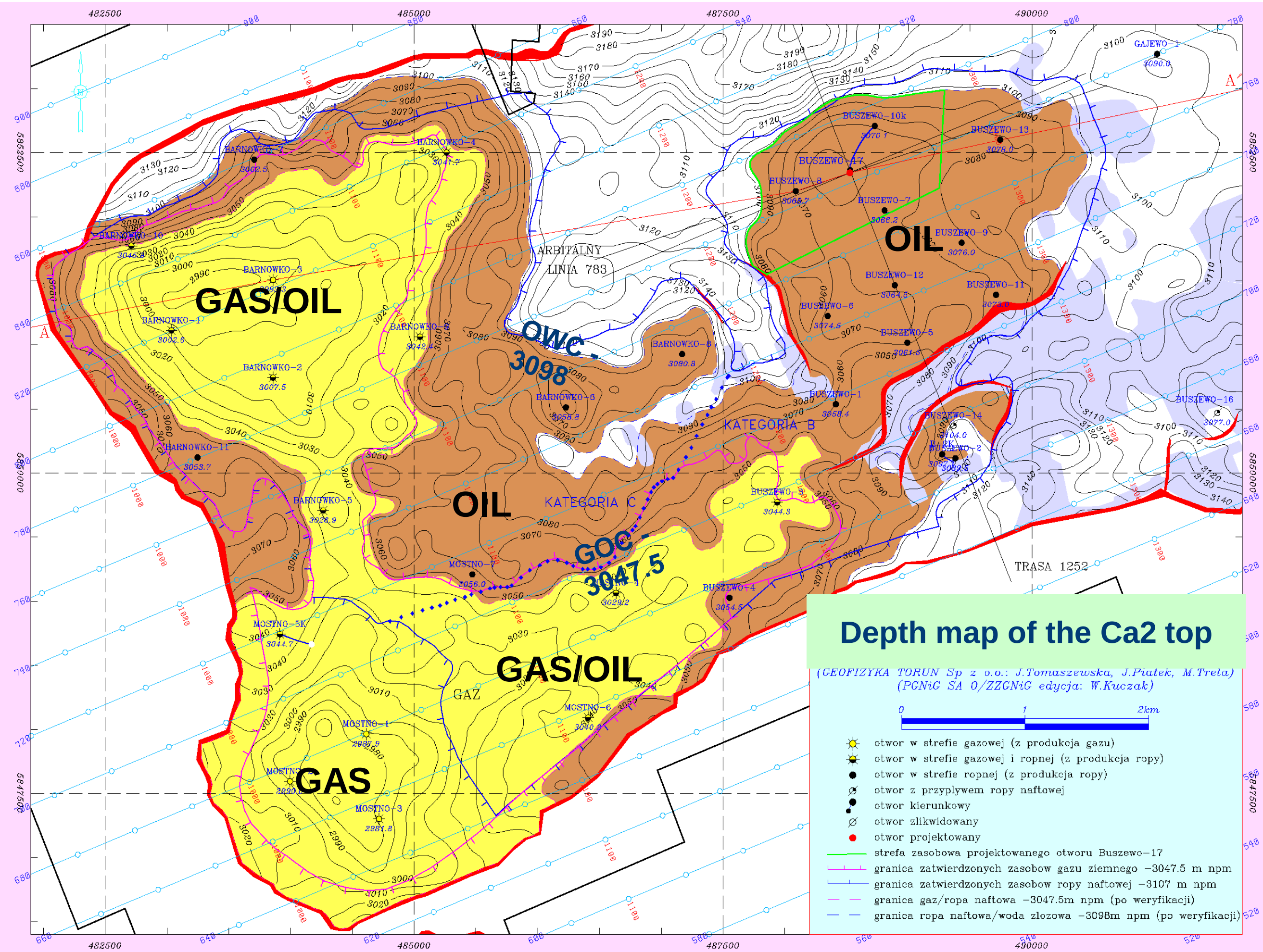



4 cm


4 cm



BARNÓWKO-MOSTNO-BUSZEWO (BMB)
OIL AND GAS FIELD – the Main dolomite – Ca2



Discovery – 1993 (Mostno-1)
Start of production - 1998
Area – 30 km^2

Oil in place: 60 MMt (73 MMcm)
Reserves: 12.6 MMt (15.4 MMc)
RF: 0.21
Gas in place: 28 Bcm
Reserves of sulphur – 740 Mt

Annual prod. 2017: 302.5 Mt
HC column height – 120m

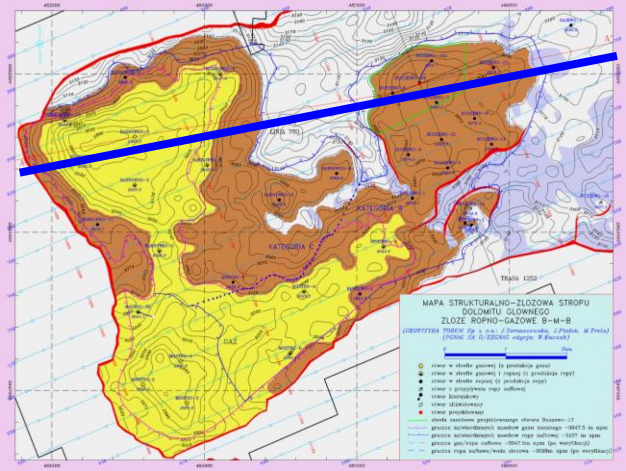
Gas composition [%vol]:
C1 – 35%
…
C1-n – 43.5 - 49.7%
N2 – 52%
H_2S – 4.35%

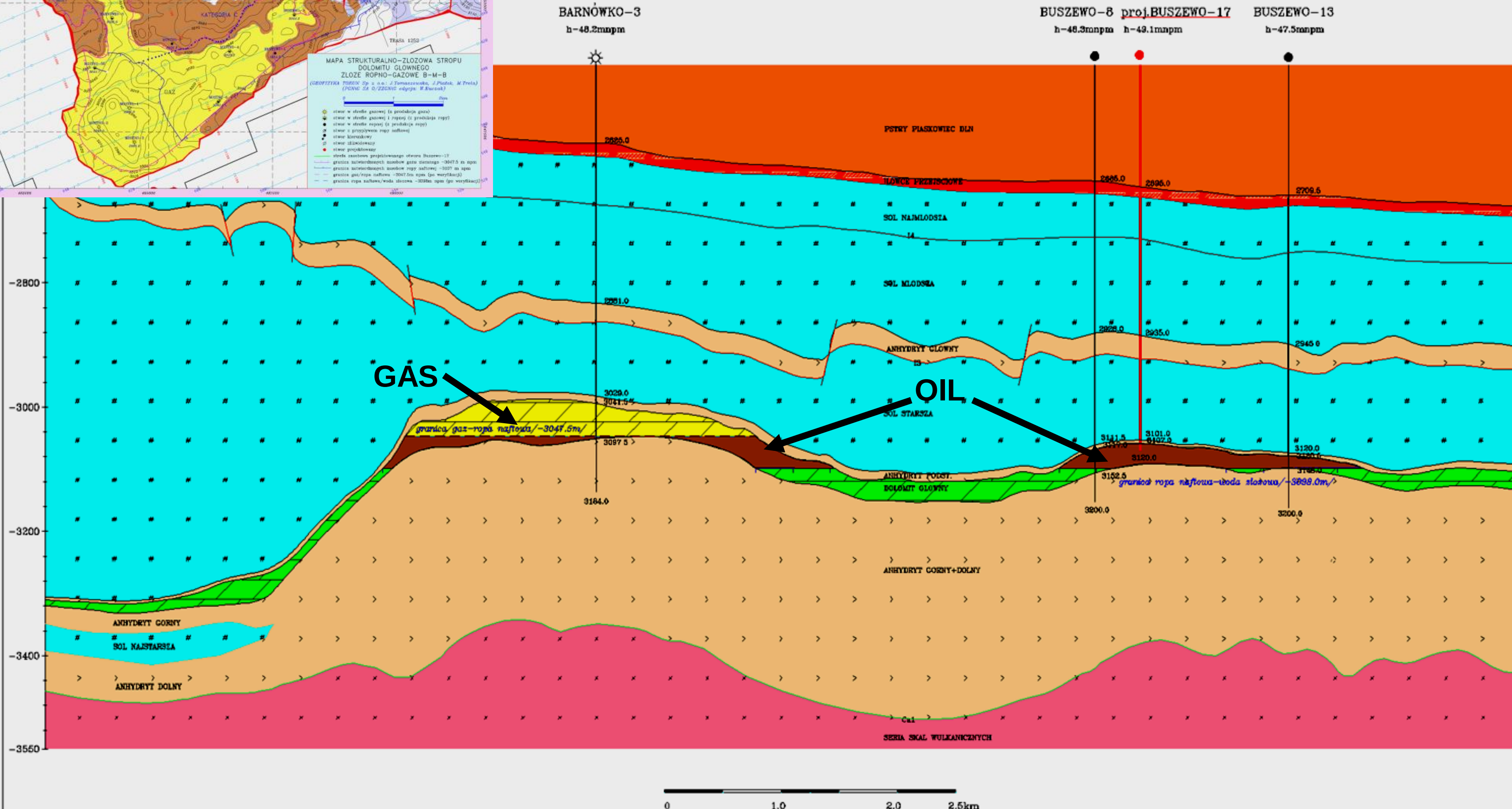
Oil – 0.818g/cm^3

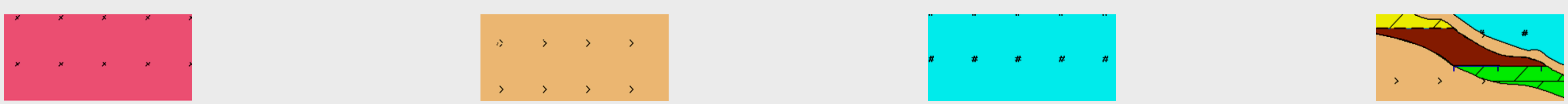
Ca2
Porosity: 17%
Permability: av. 10-12mD

Reservoir pressure – 56 MPa.

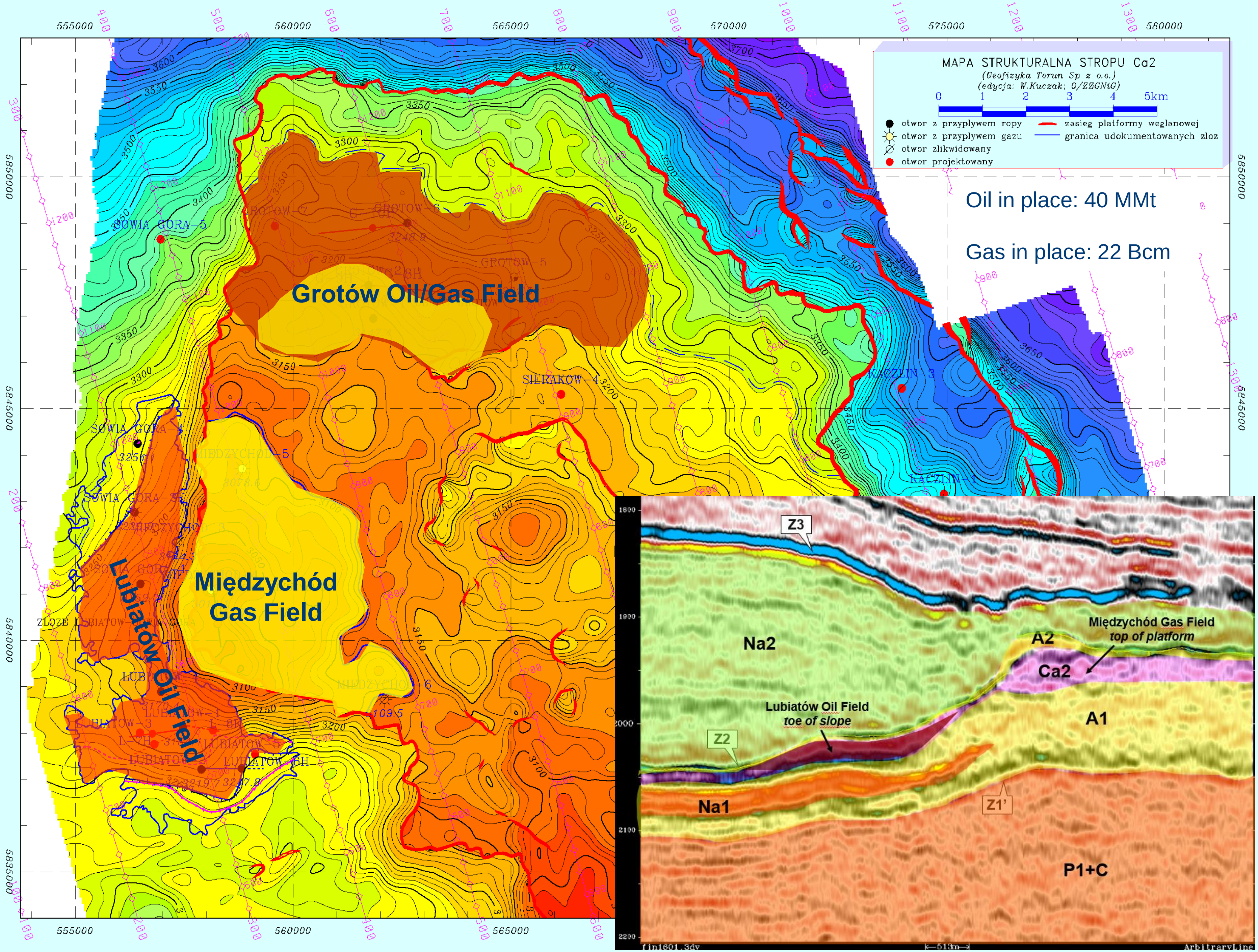
BMB field cross section





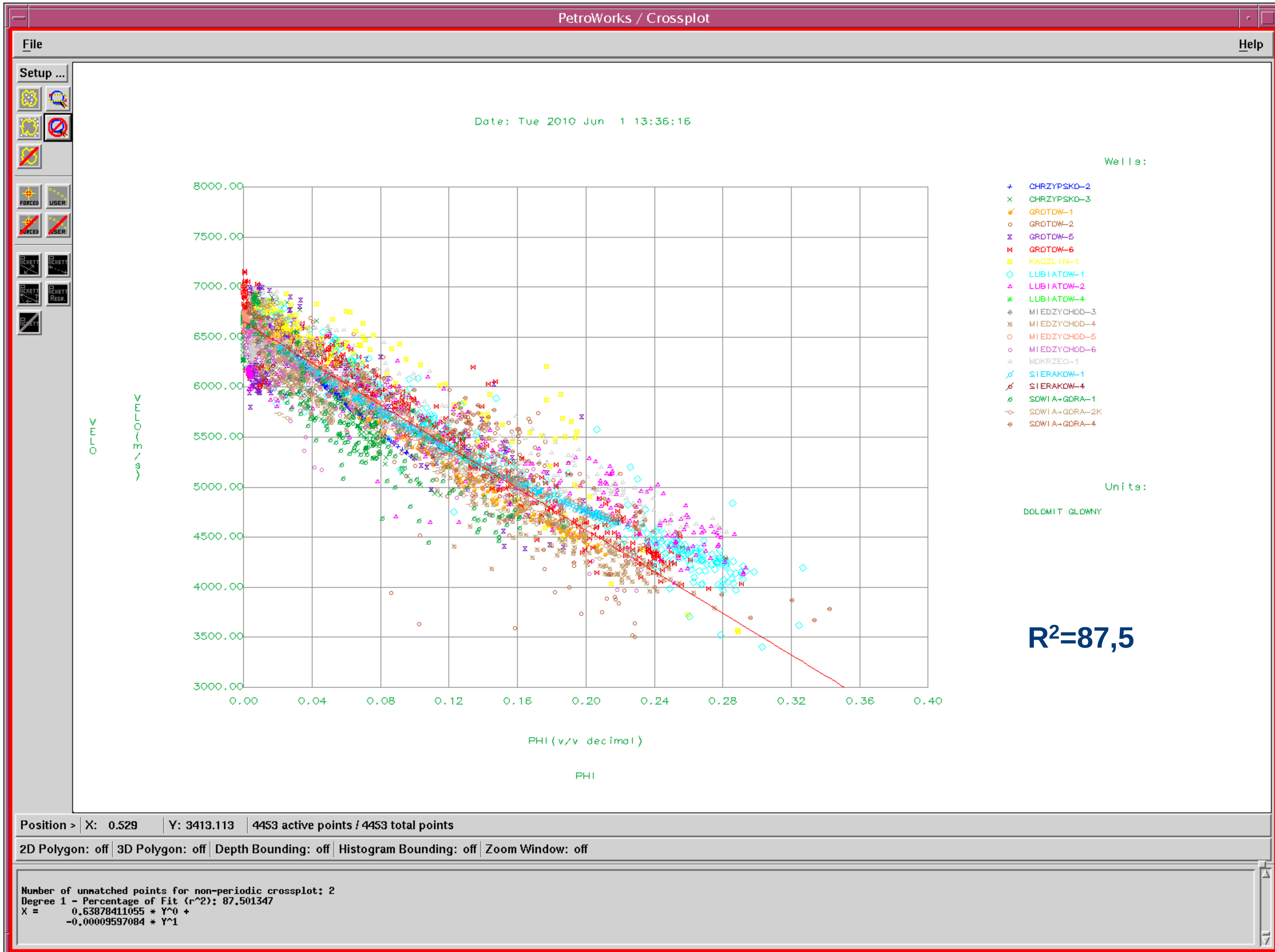


Rotligend | Anhydrite (A1,A2,A3) | Salt (Na1,Na2,Na3, Na4) | Main Dolomite – gas/oil/water

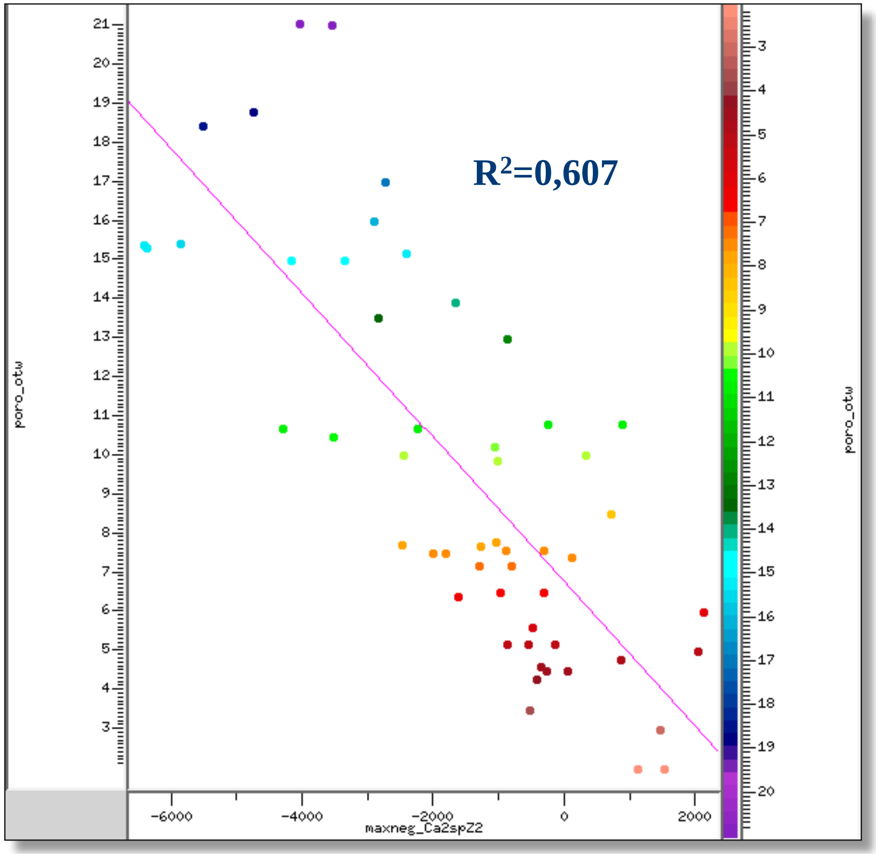


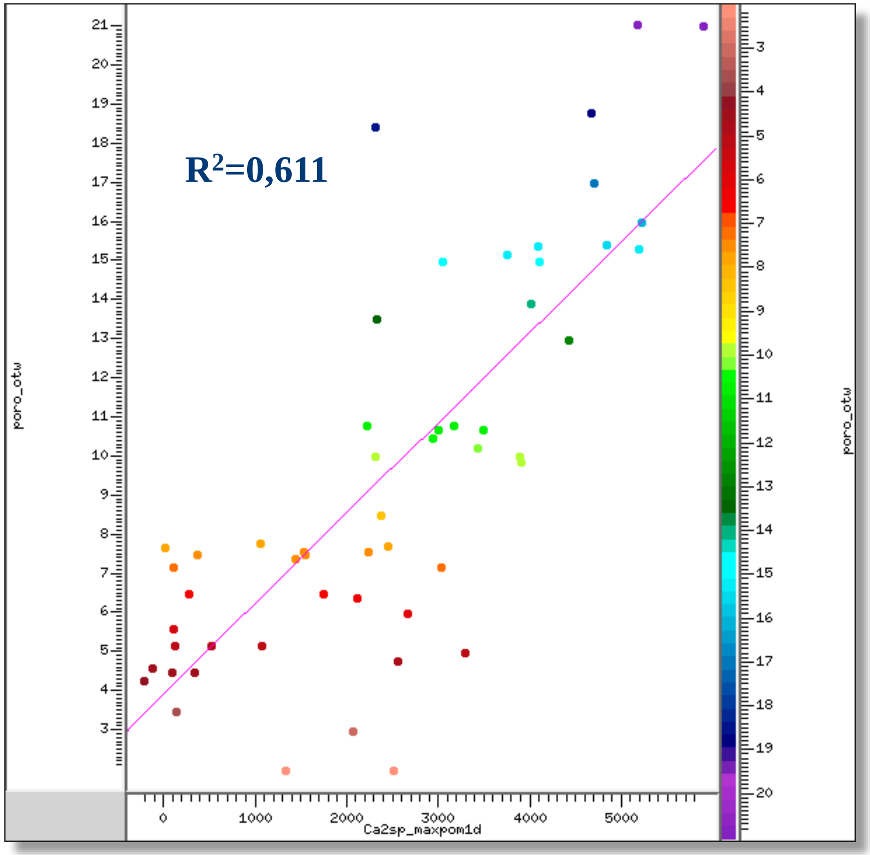
MAPA STRUKTURALNA STROPU Ca2
(Geofizyka Torun Sp z o.o.)
(edycja: W.Kuczak; O/ZZGNiG)
0 1 2 3 4 5km
otwor z przyplywem ropy
otwor z przyplywem gazu
otwor zlikwidowany
otwor projektowany
zasieg platformy weglanowej
granica udokumentowanych zloz
Oil in place: 40 MMt
Gas in place: 22 Bcm
Grotów Oil/Gas Field
Międzychód Gas Field
Lubiatów Oil Field
Z3
Na2
A2
Ca2
Międzychód Gas Field
top of platform
Lubiatów Oil Field
toe of slope
A1
Z2
Na1
Z1'
P1+C

P-velocity versus porosity
(based on the logs from 20 wells in Międzychód-Sieraków area)



Relationship between porosity and seismic amplitudes





Ca2$_{top}$ Ca2$_{base}$

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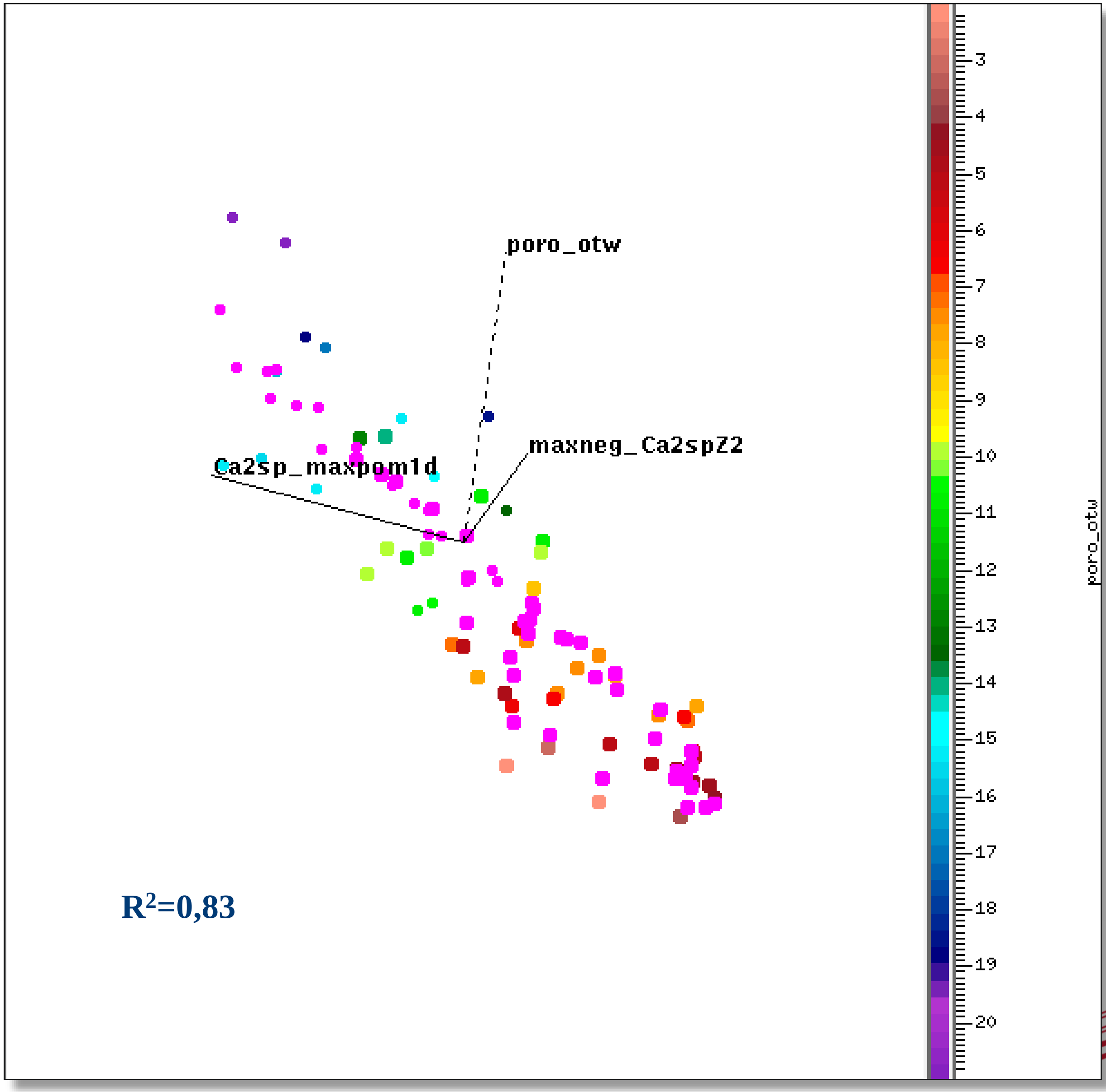
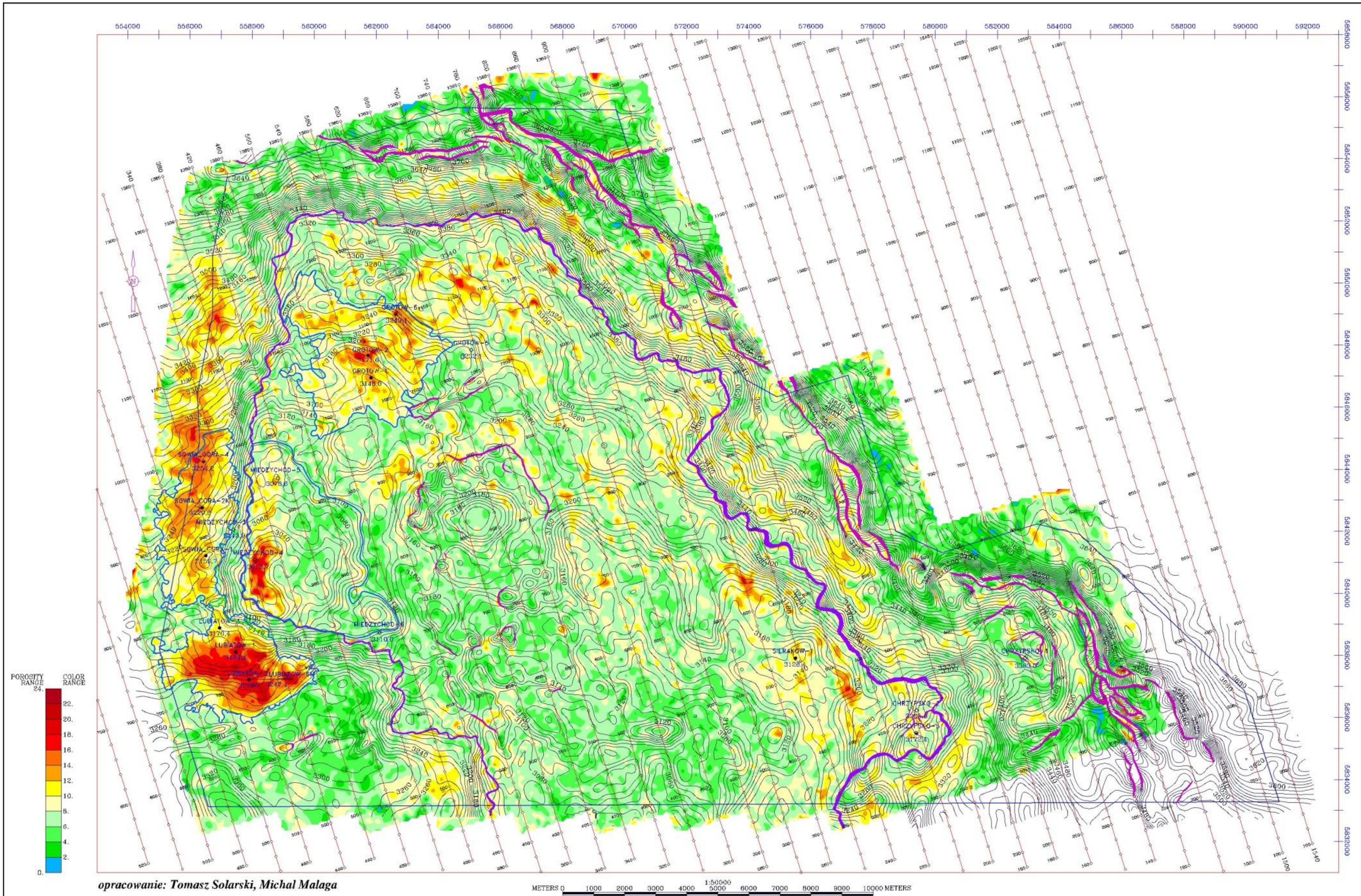
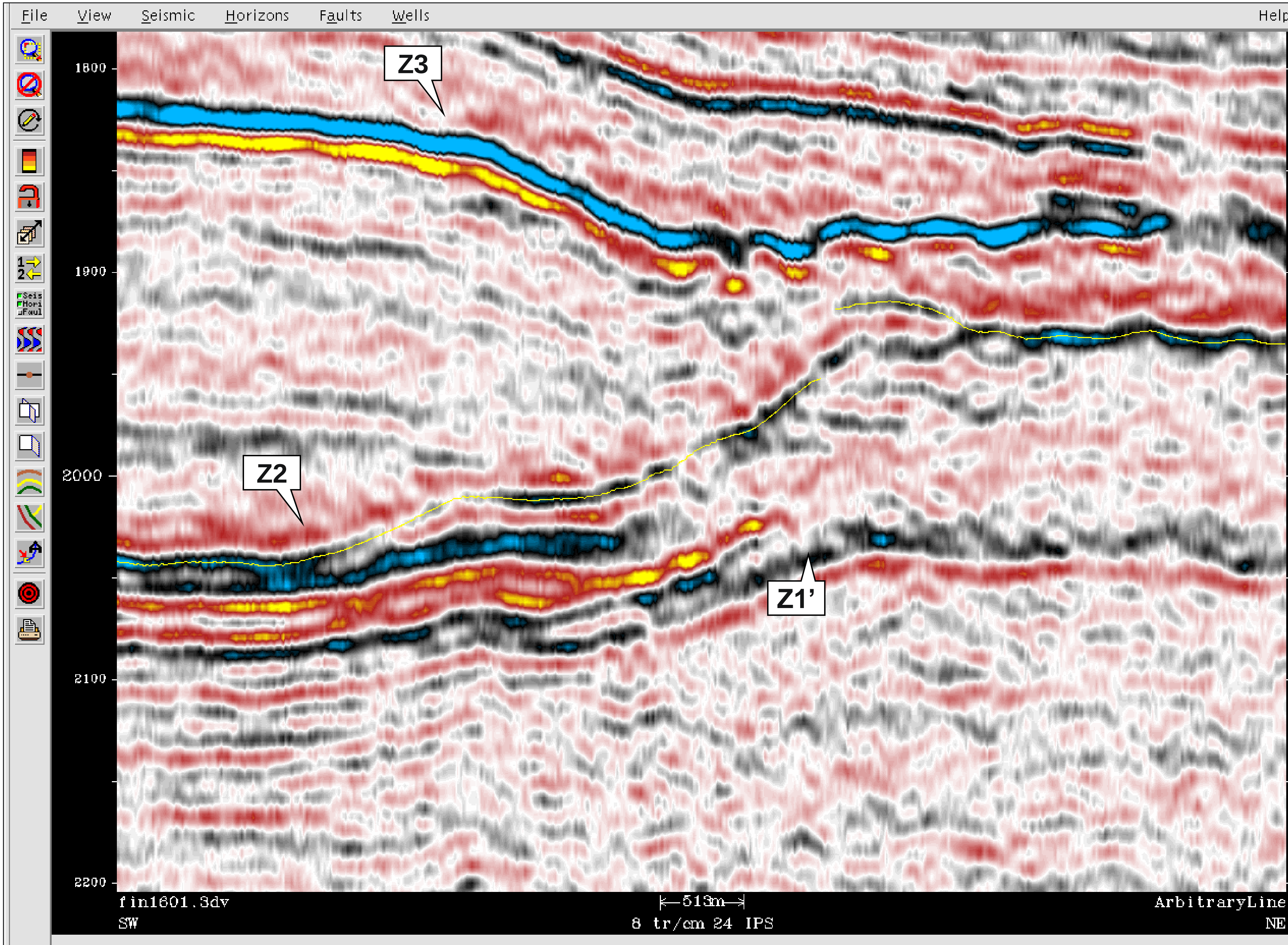
Relationship between porosity and group of 3 seismic attributes ($ampCa2_{top}$, $ampCa2_{base}$,rfls4d12)



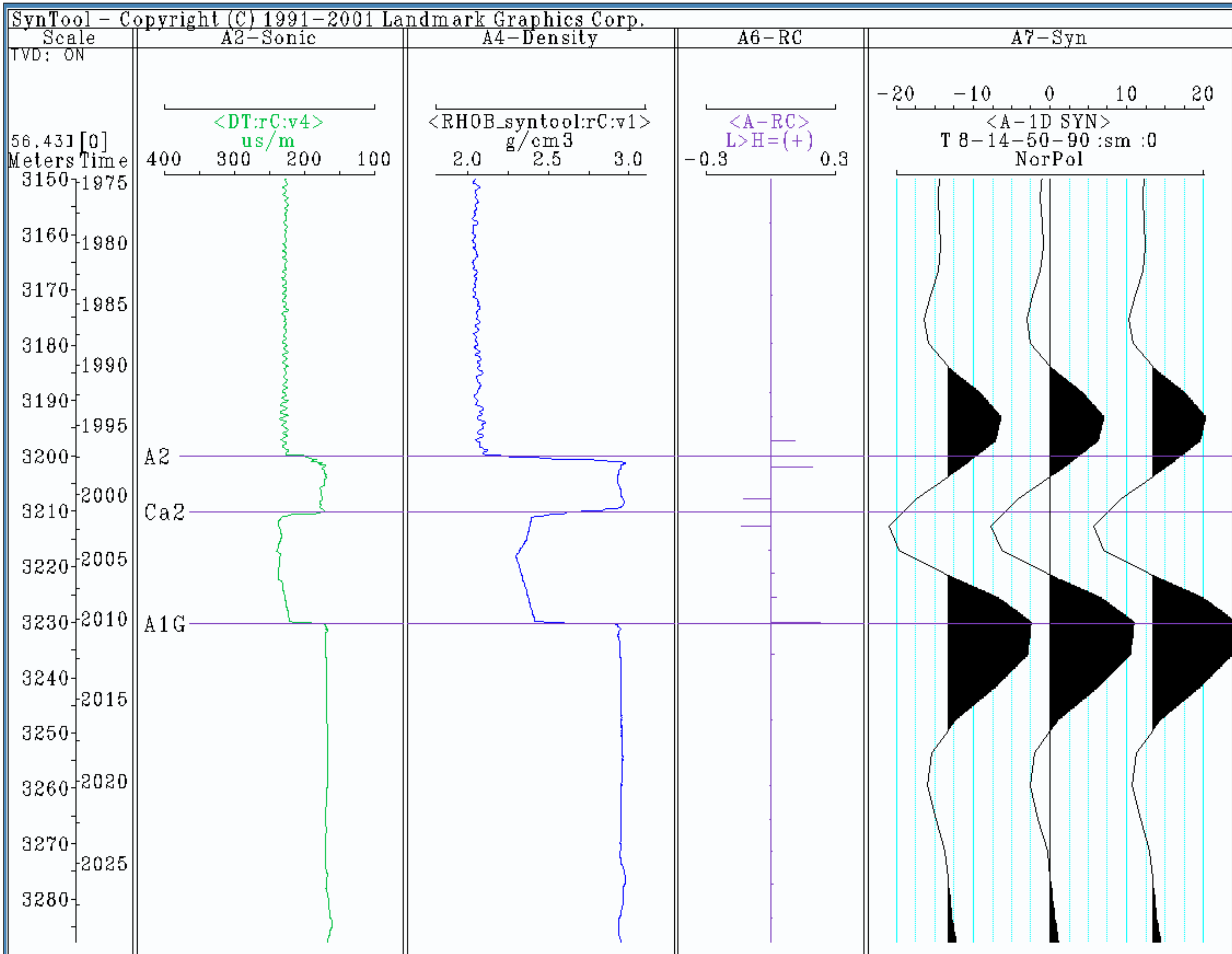
Lubiatow Oil Field – porosity map derived from seismic attributes



LMG - 3D seismic line

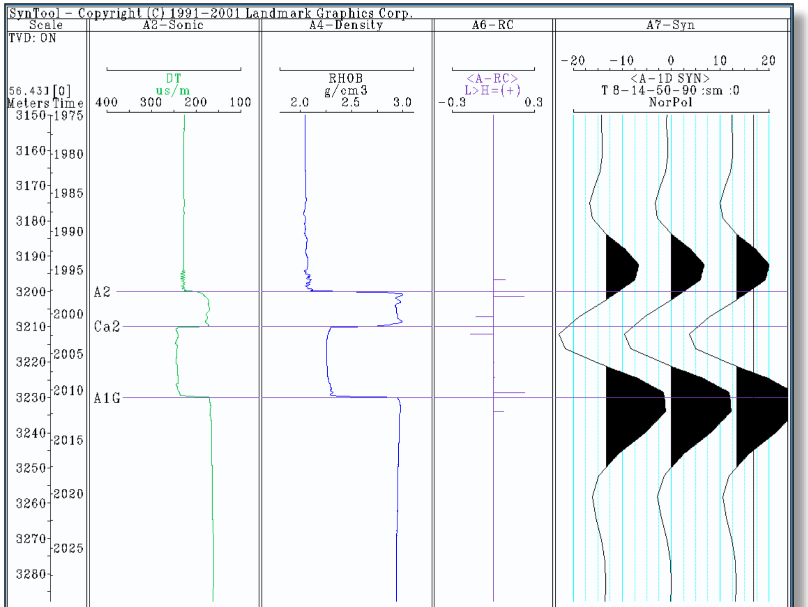


1D modeling - 20 m of porous dolomite below 10 m of anhydrite

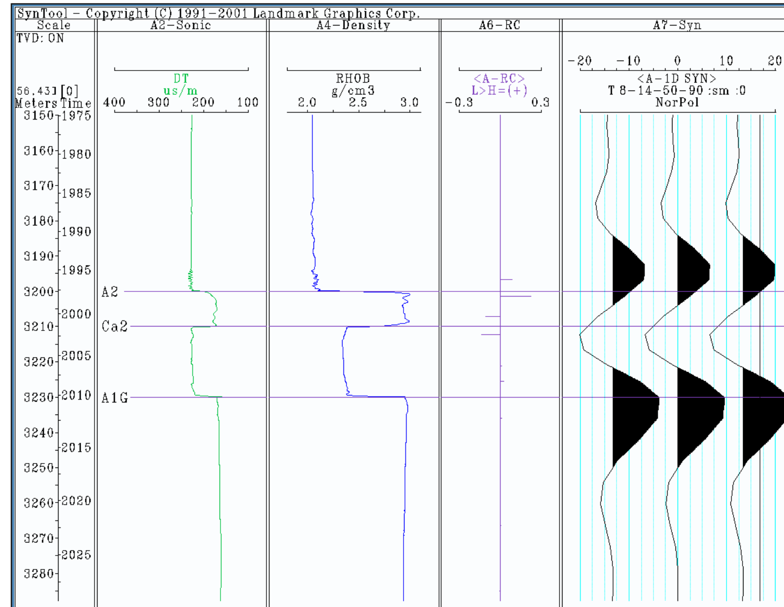


1D modeling - 20 m of porous dolomite below 10 m of anhydrite.
Effect of porosity variation

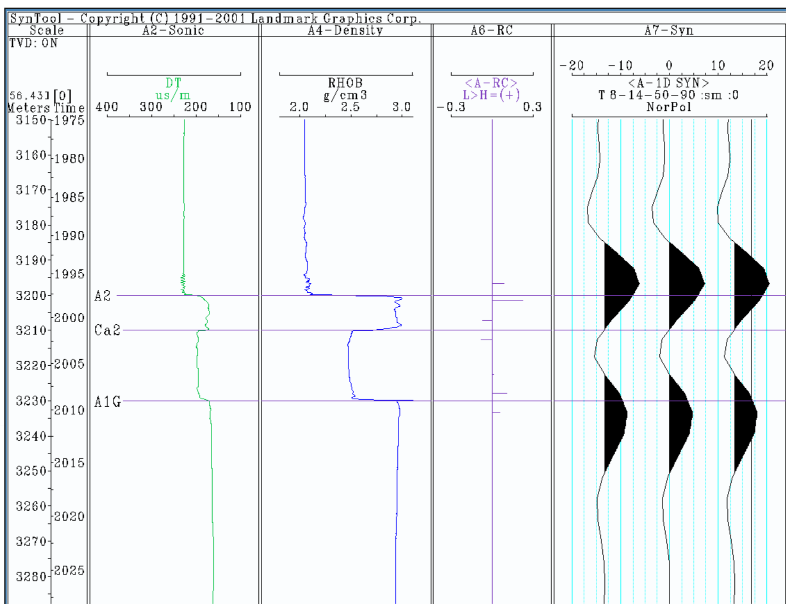
High



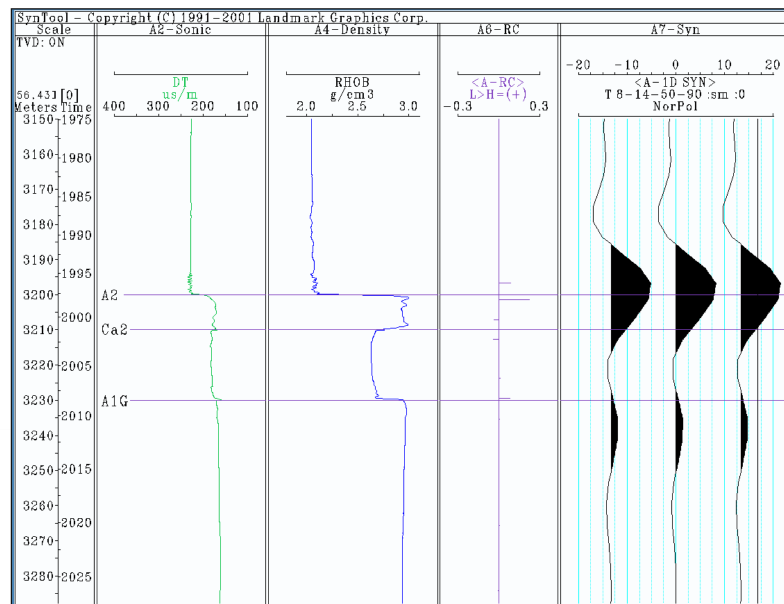
Medium



Low

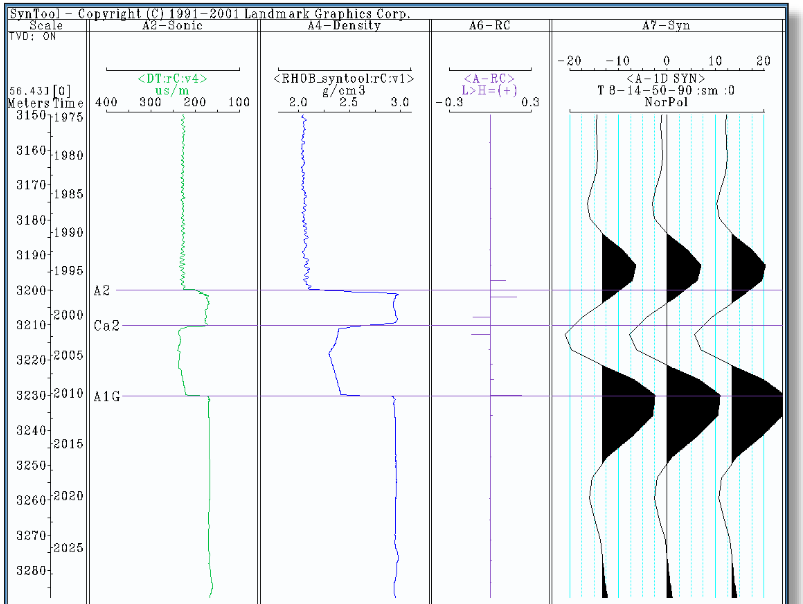


Very low

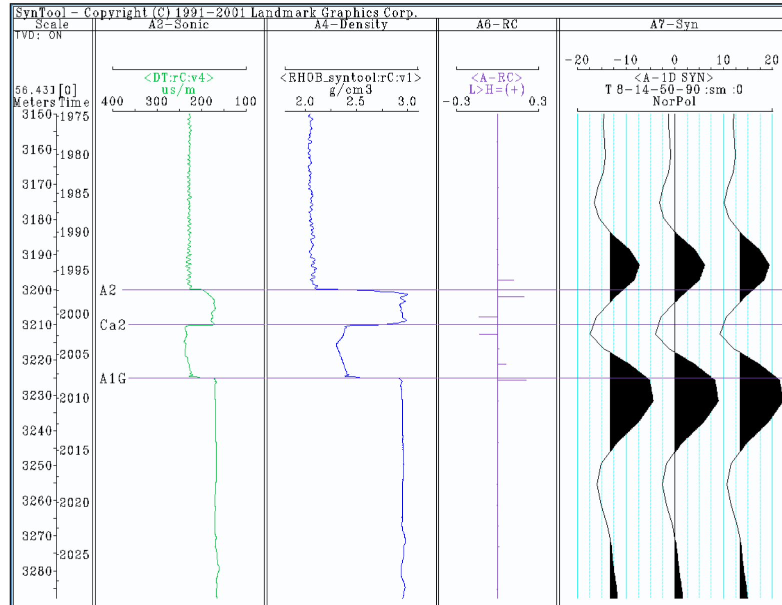


1D modeling - porous dolomite below 10 m of anhydrite
Effect of thickness variation

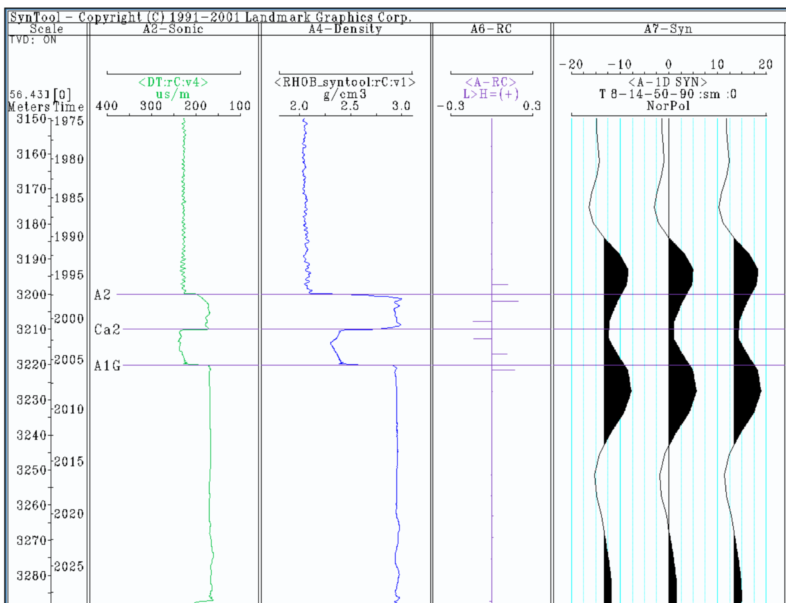
20 m



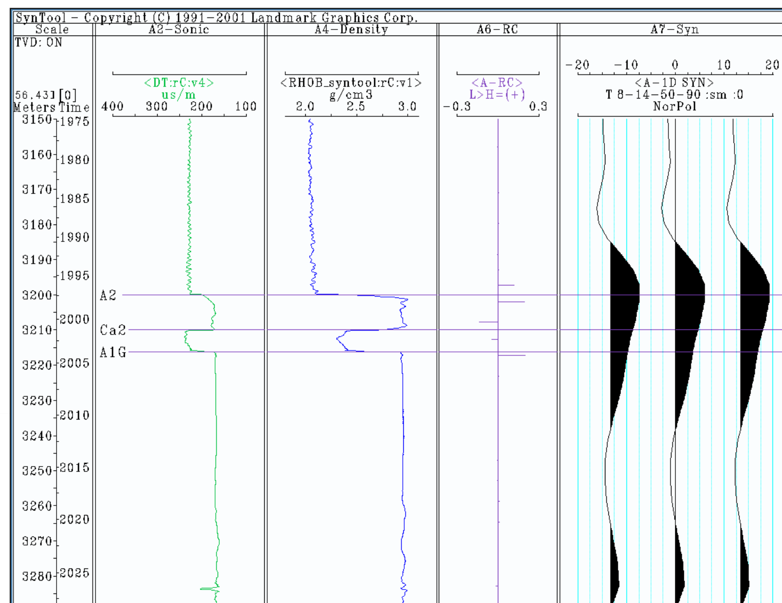
15 m



10 m

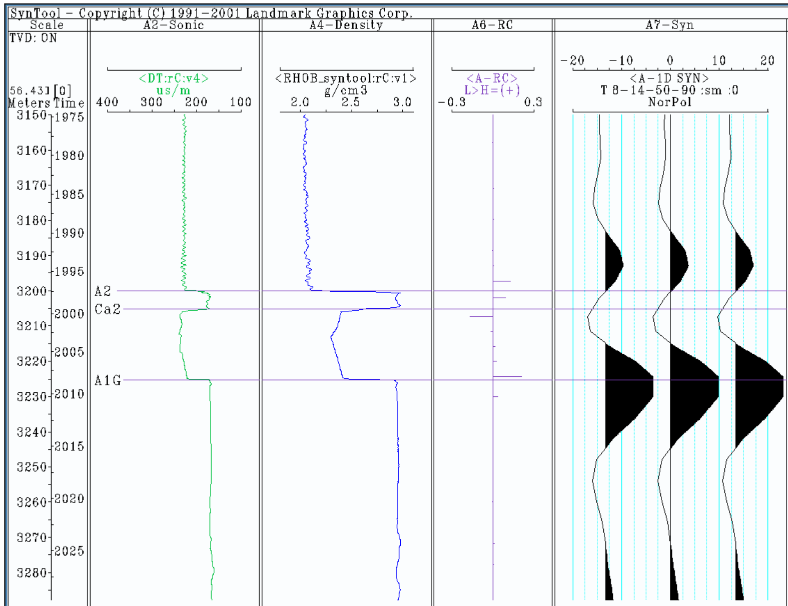


6 m

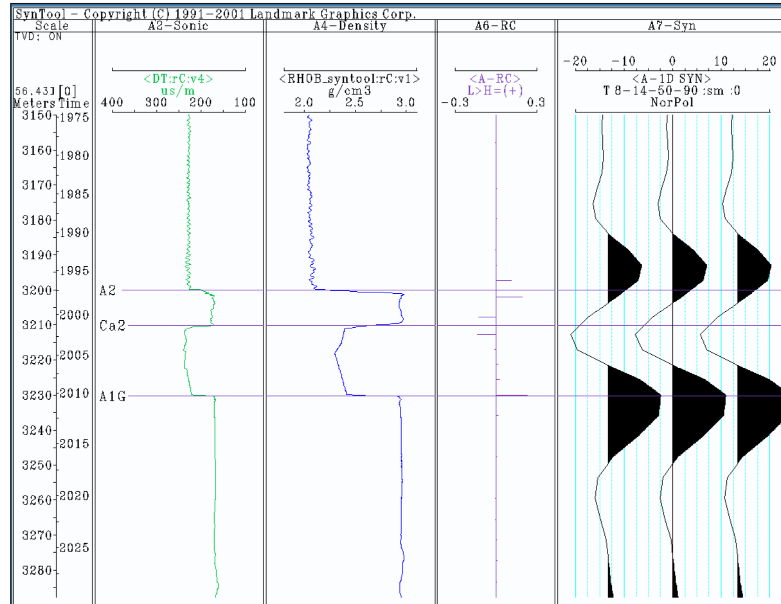


1D modeling - 20 m of porous dolomite below anhydrite
Effect of the anhydrite thickness variation

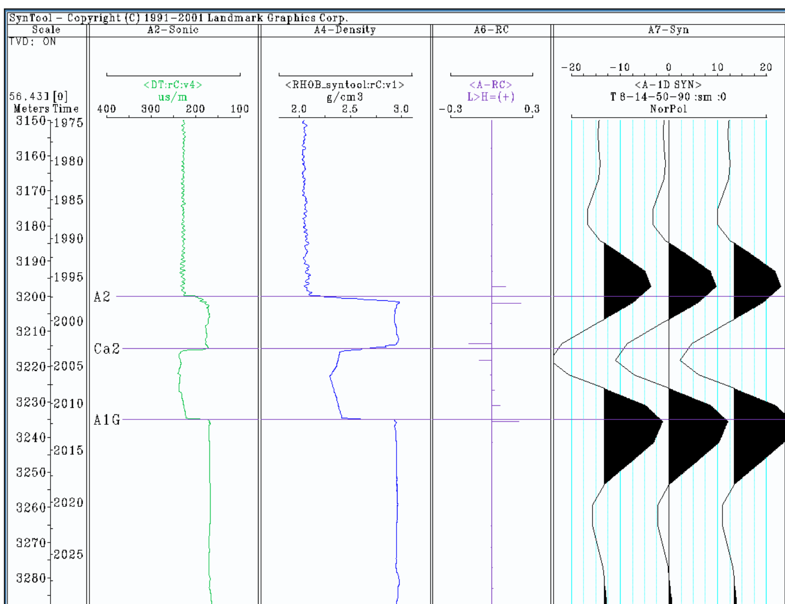
5 m



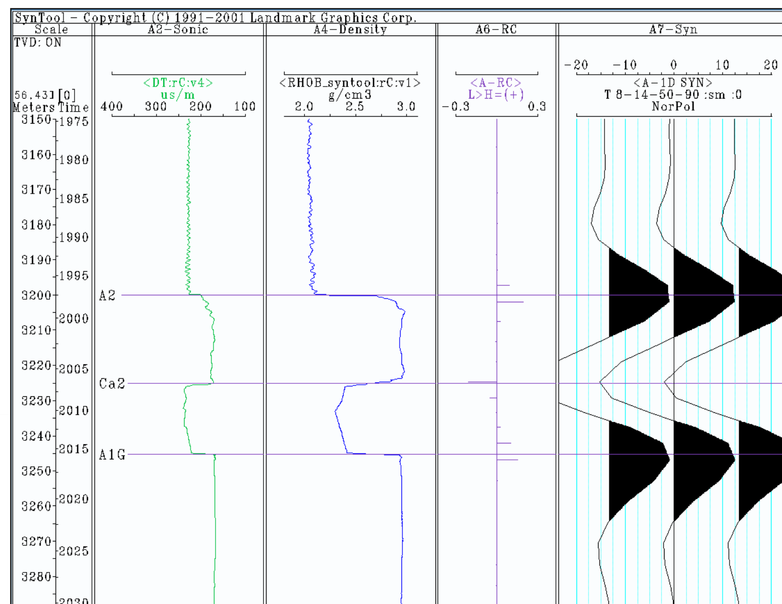
10 m

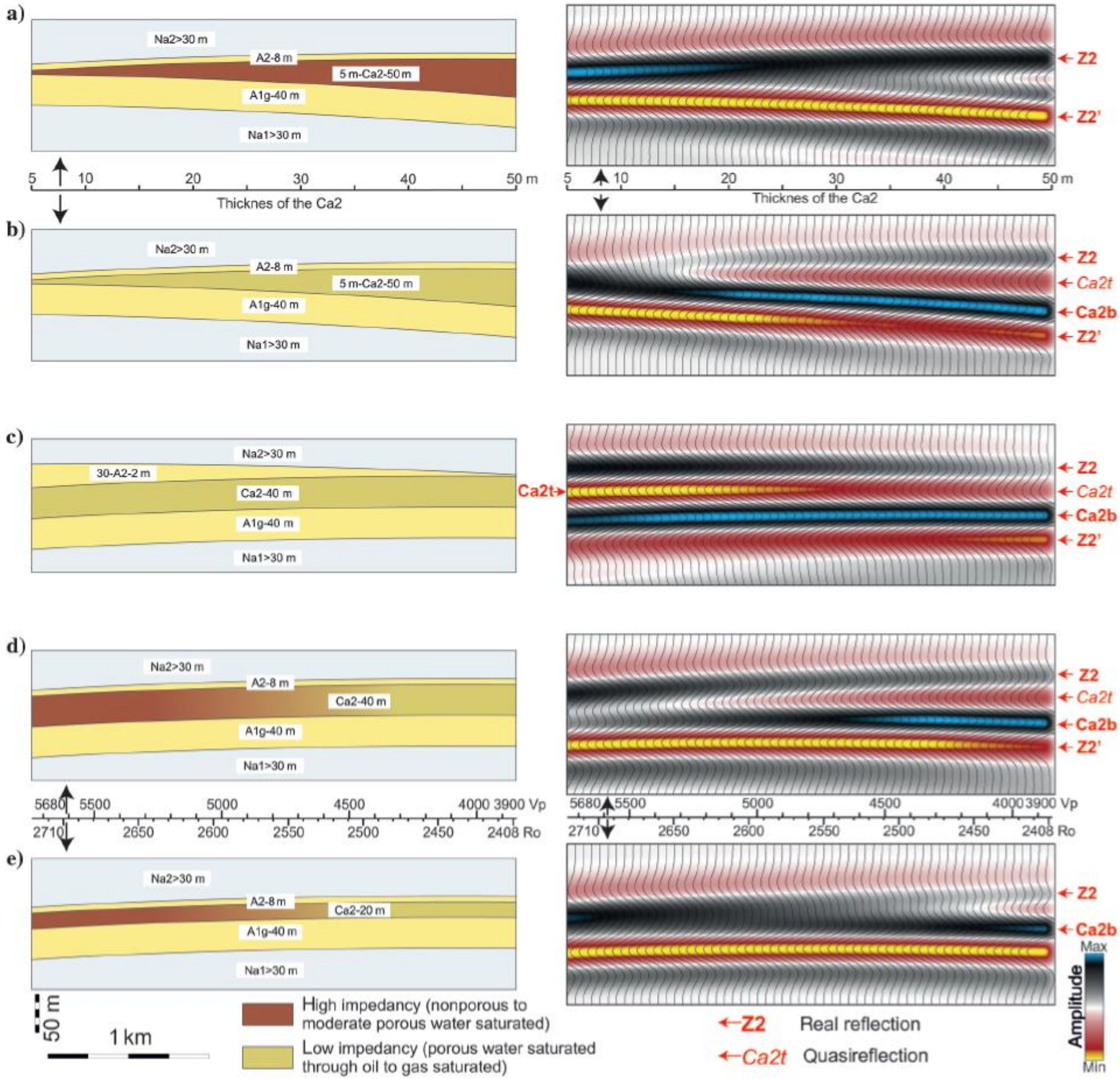


15 m



25 m



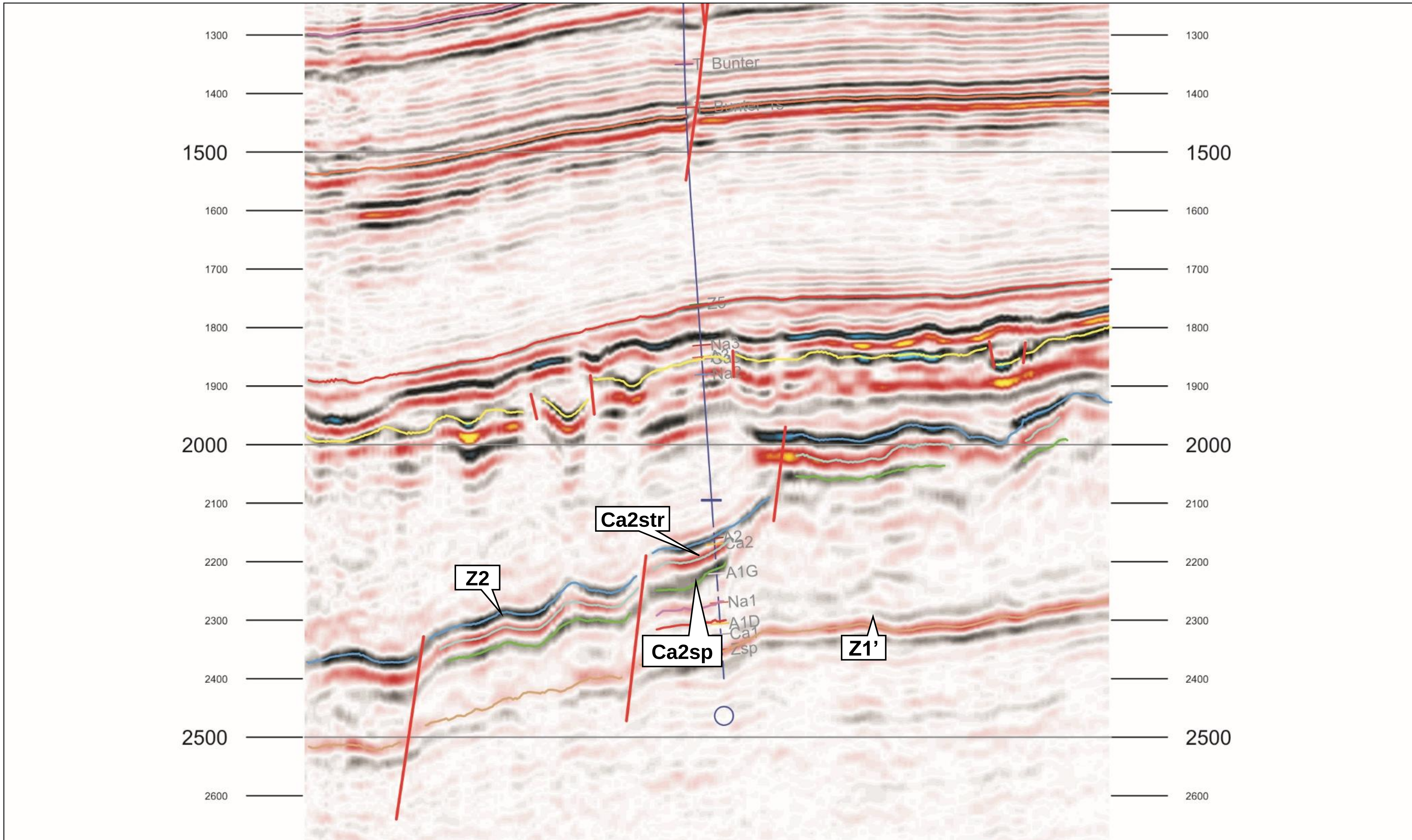


Theoretical models with thickness and physical parameters of units typical for toe-of-slope of sulfate-carbonate platforms in the Gorzów Wielkopolski area.

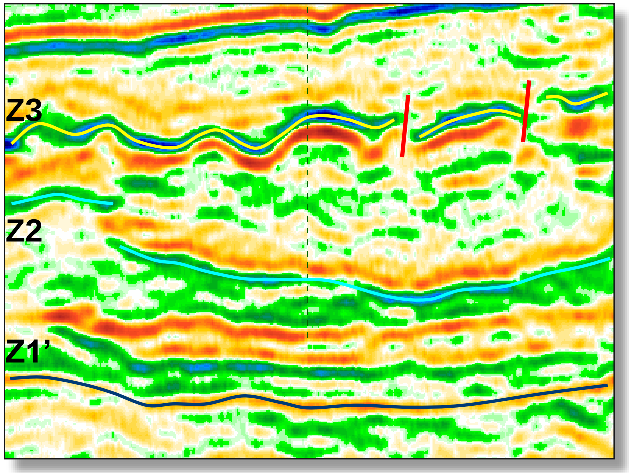
Zdanowski & Górniak, 2014

PGNiG

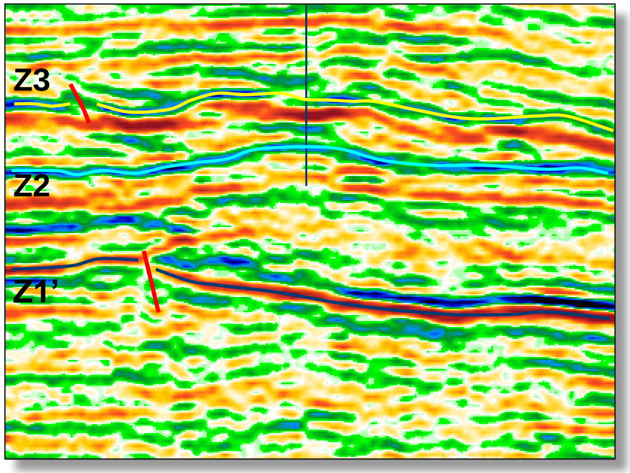
South Jutland, Denmark



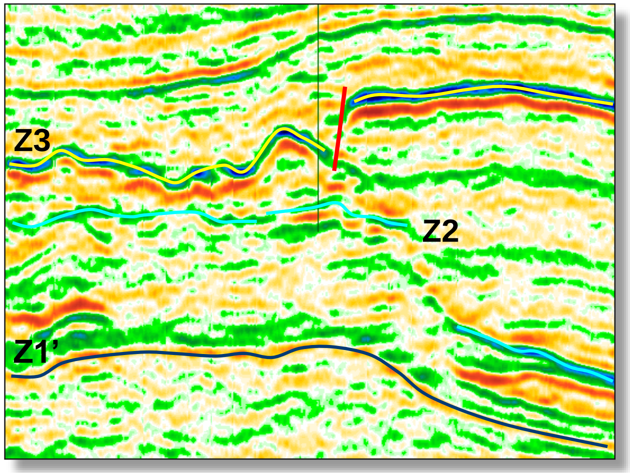
Variety of main dolomite seismic images



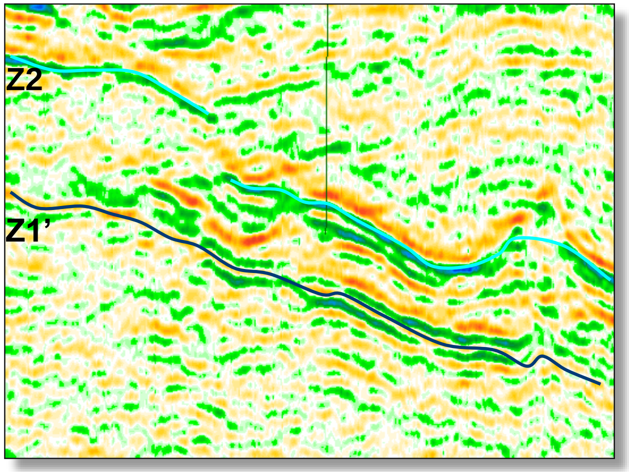
Mokrzec-1



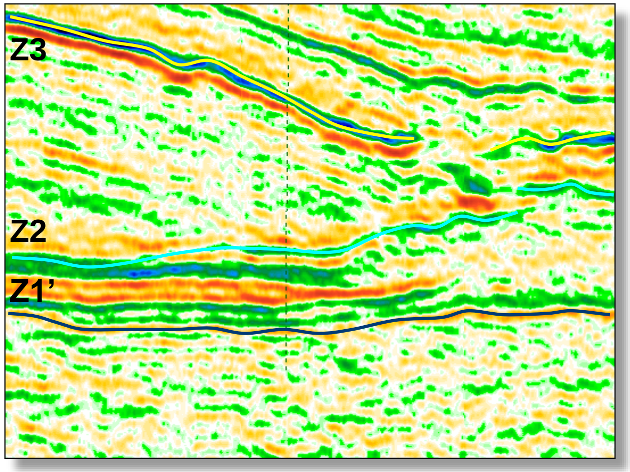
Opalenica-1



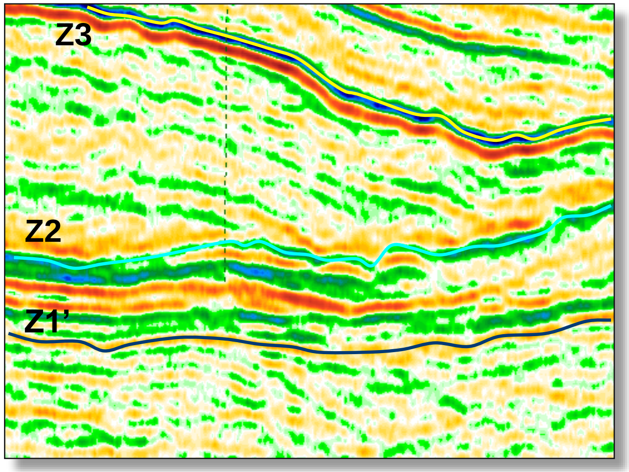
Krobielewko-5



Kaczlin-1



Lubiatów-1

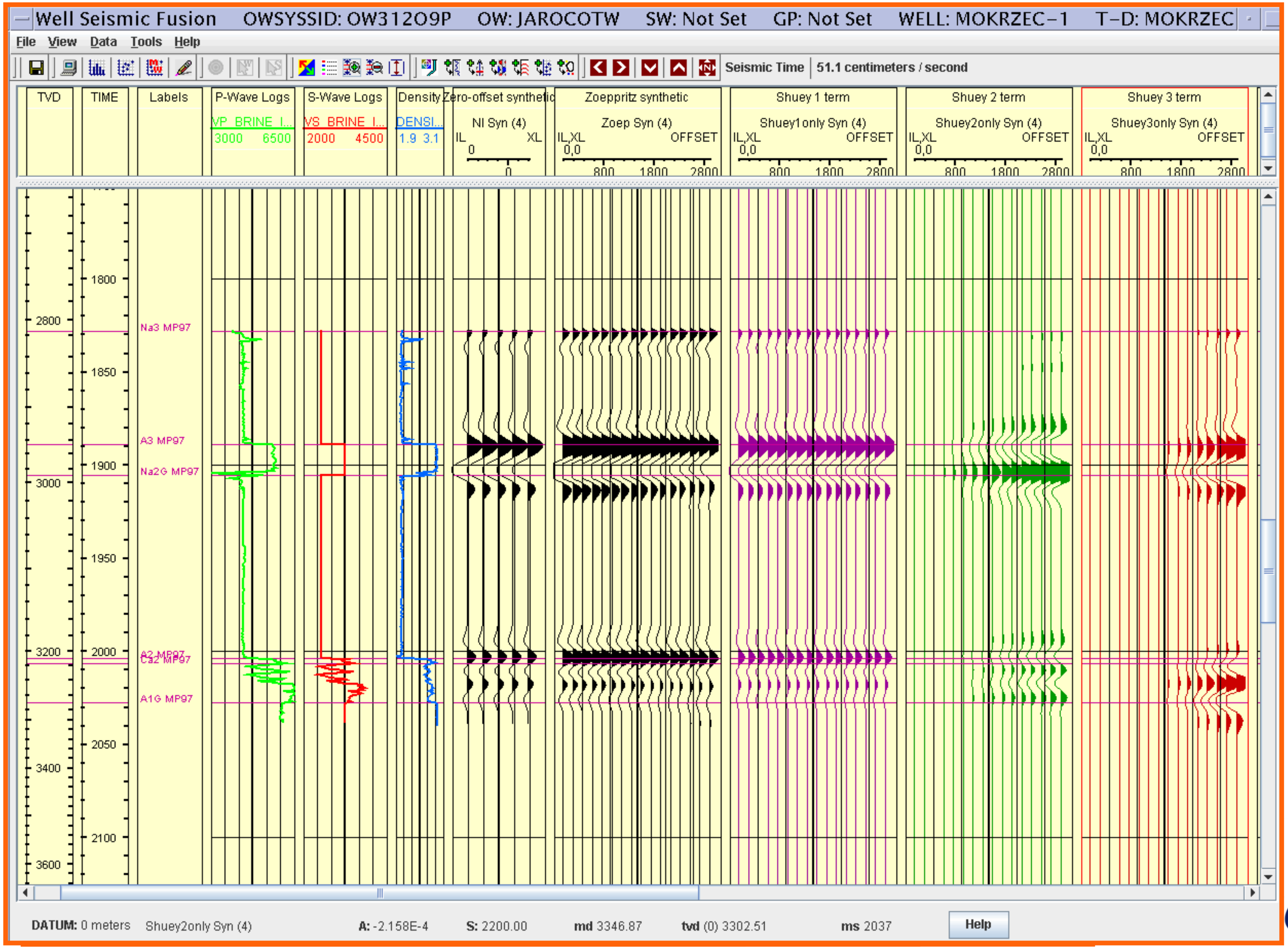


Lubiatów-2

PGNiG

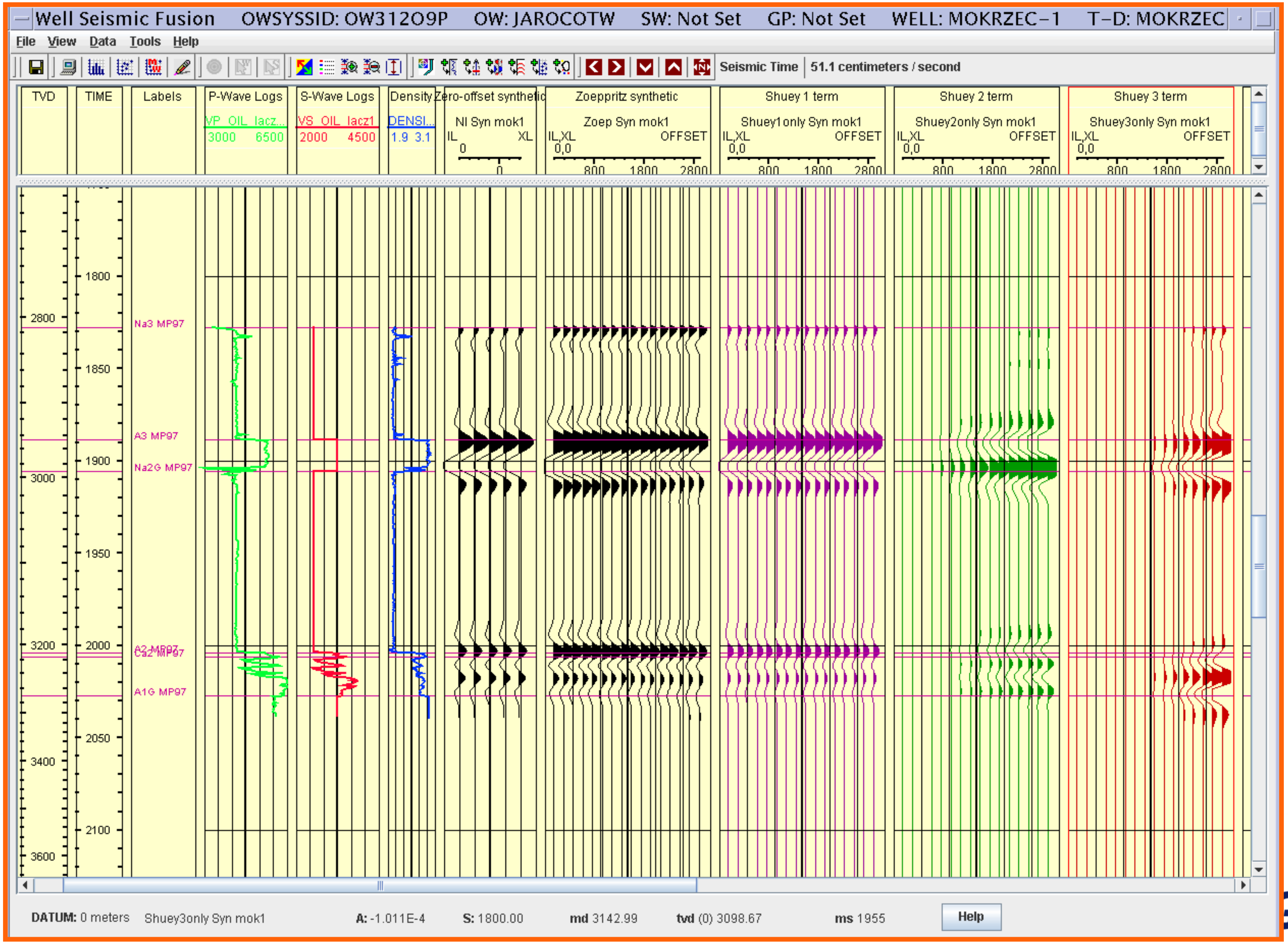
Brine saturation

Mokrzec-1



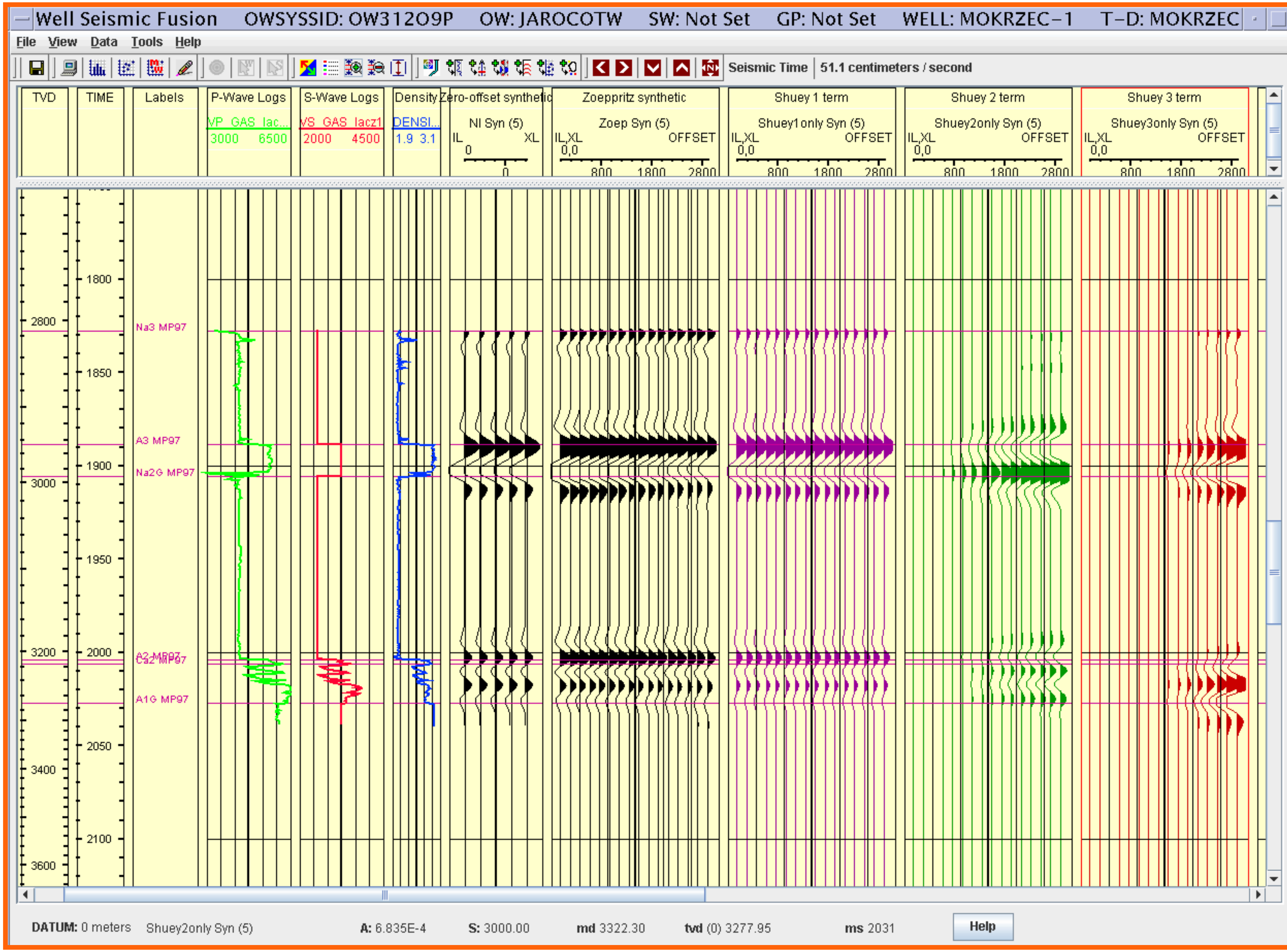
Oil saturation

Mokrzec-1



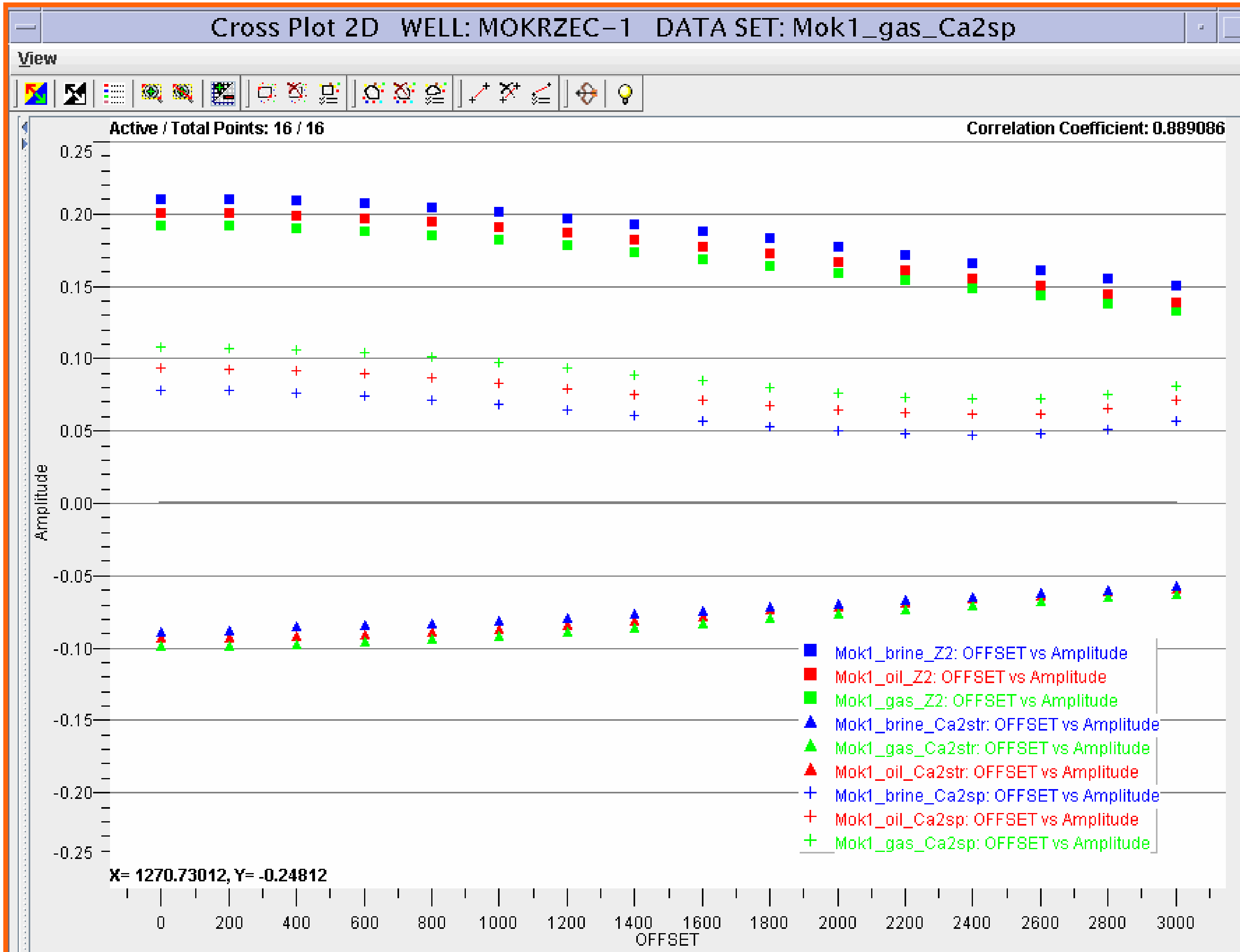
Gas saturation

Mokrzec-1



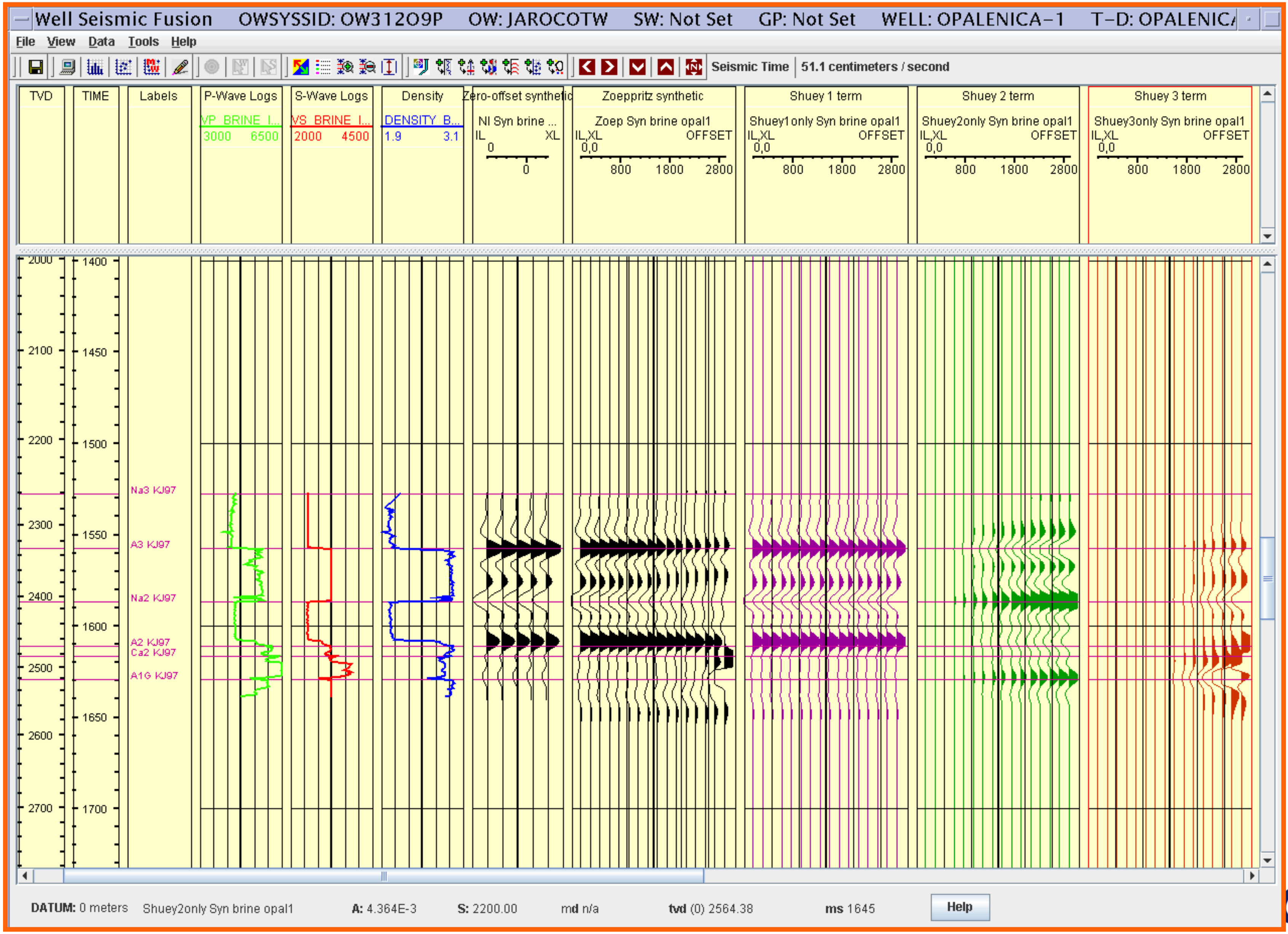
Changes of amplitudes with offset

Mokrzec-1



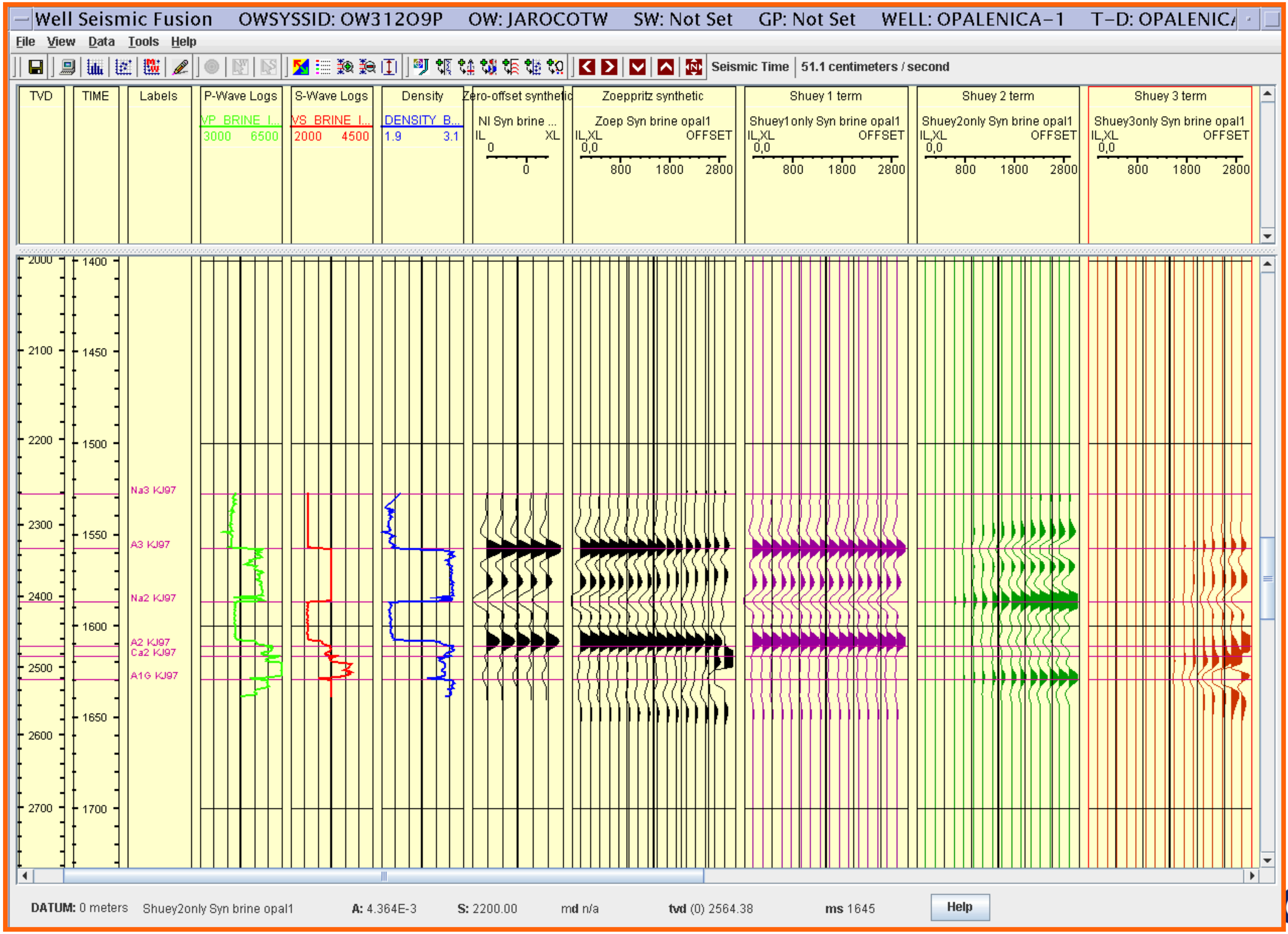
Brine saturation

Opalenica-1



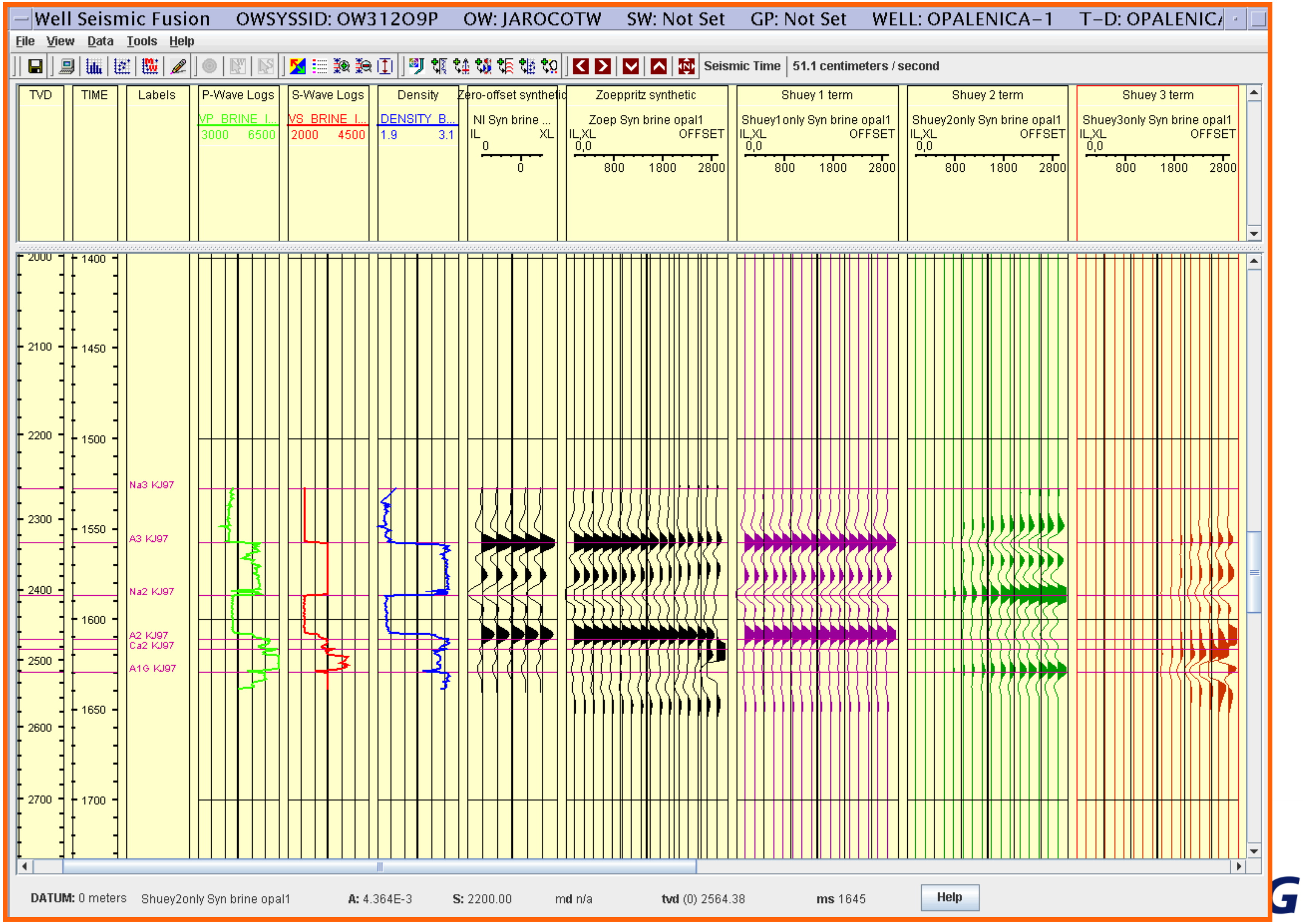
Oil saturation

Opalenica-1

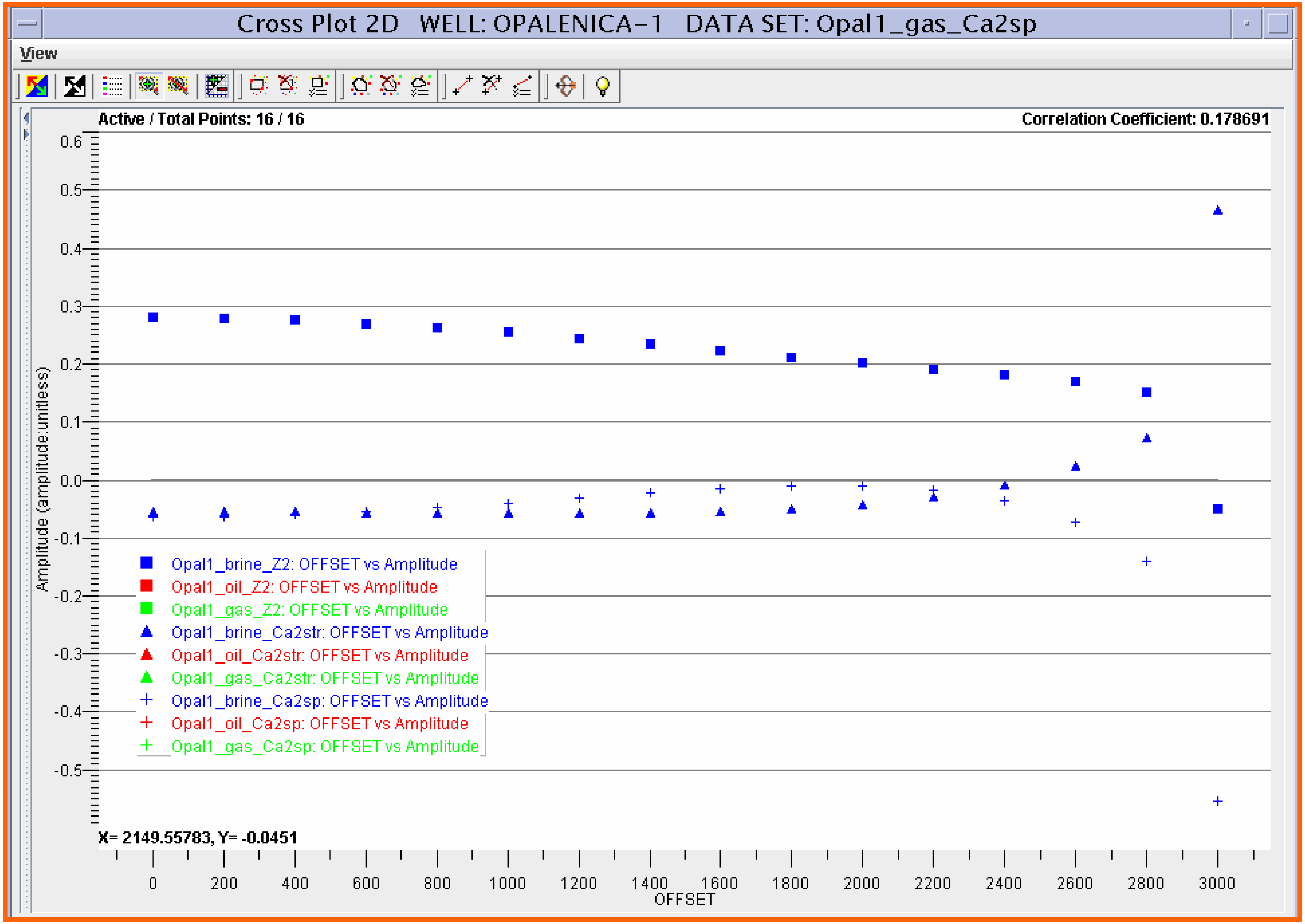


Gas saturation

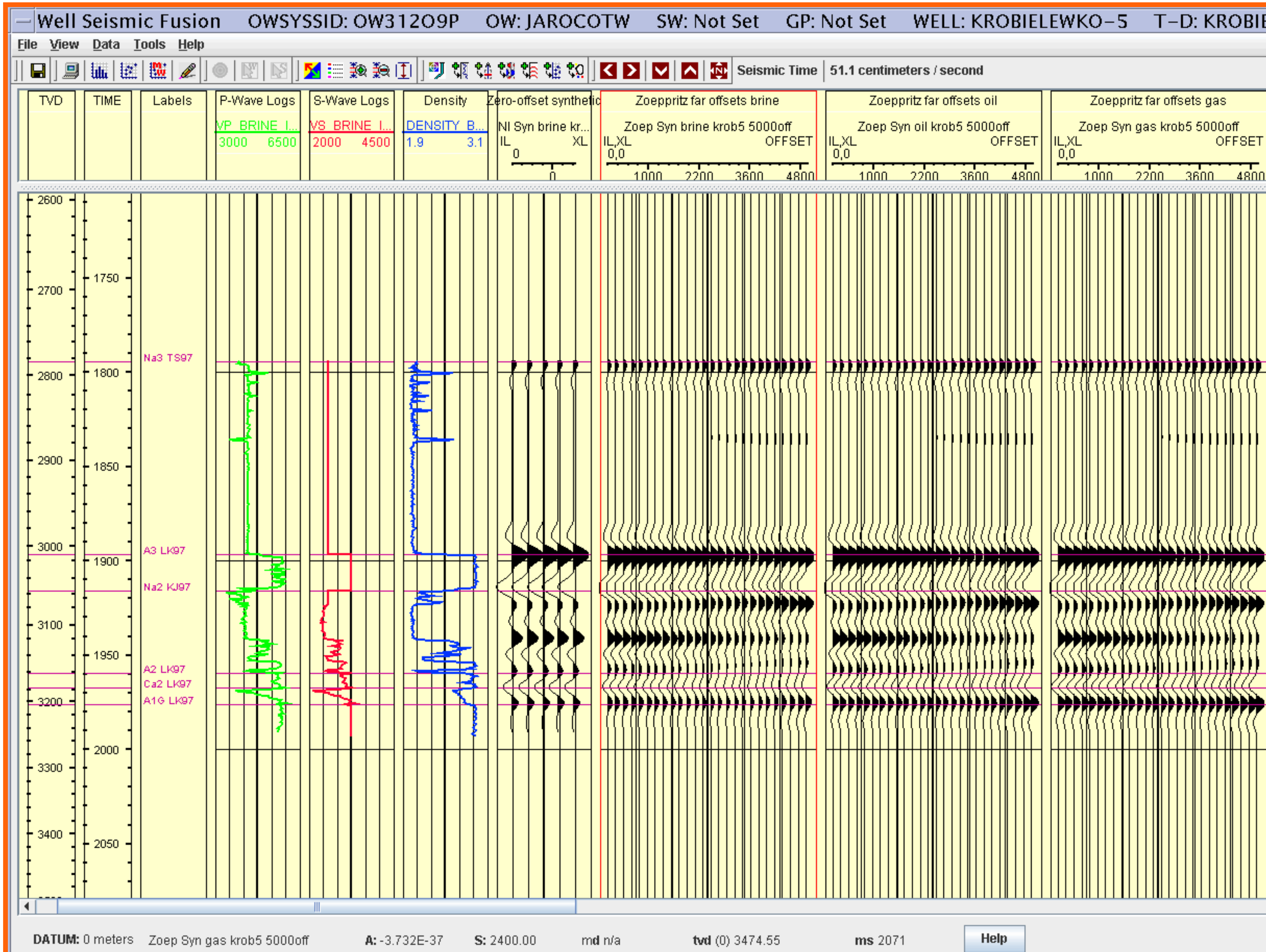
Opalenica-1



Changes of amplitudes with offset *Opalenica-1*

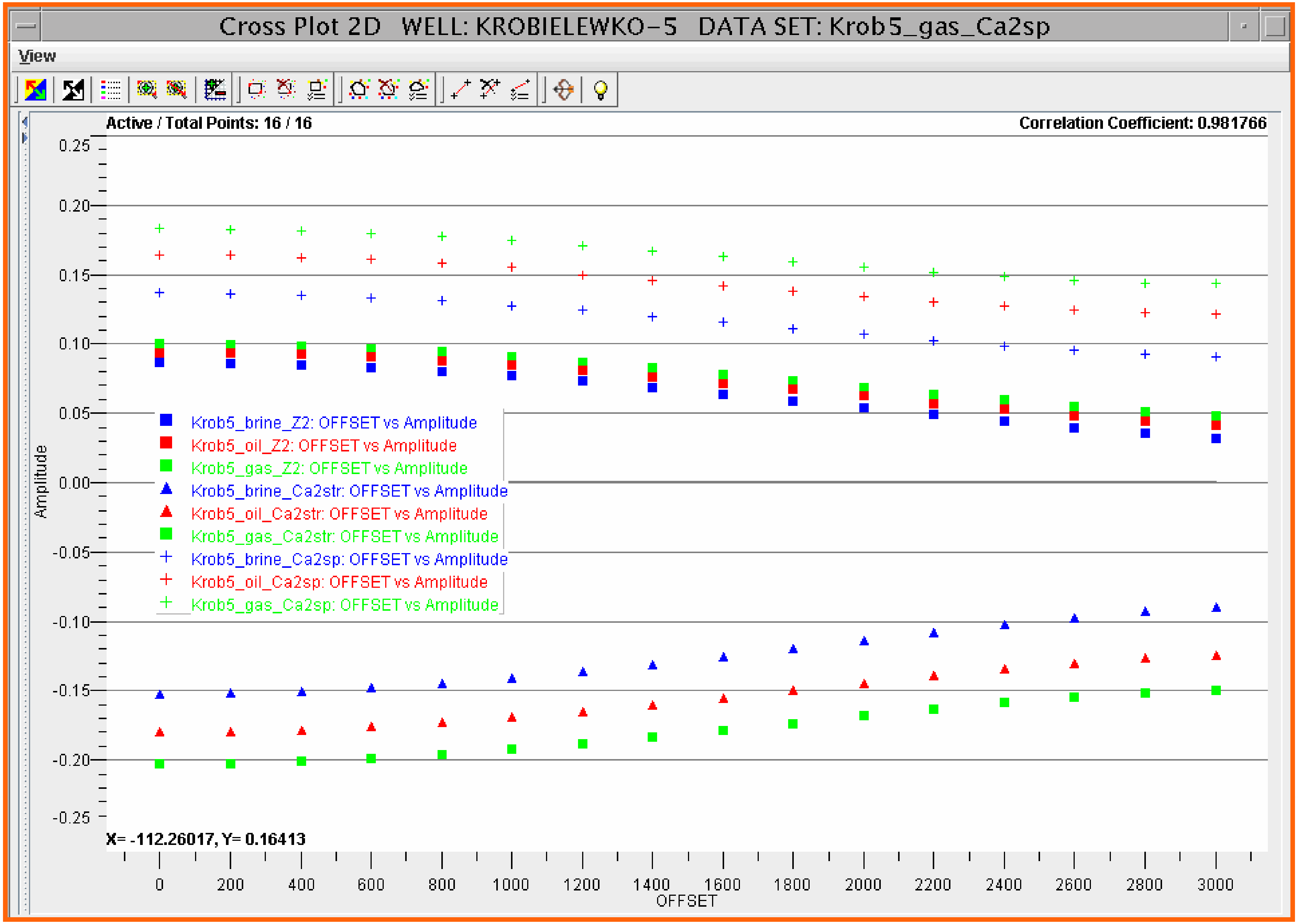


Krobielewko-5



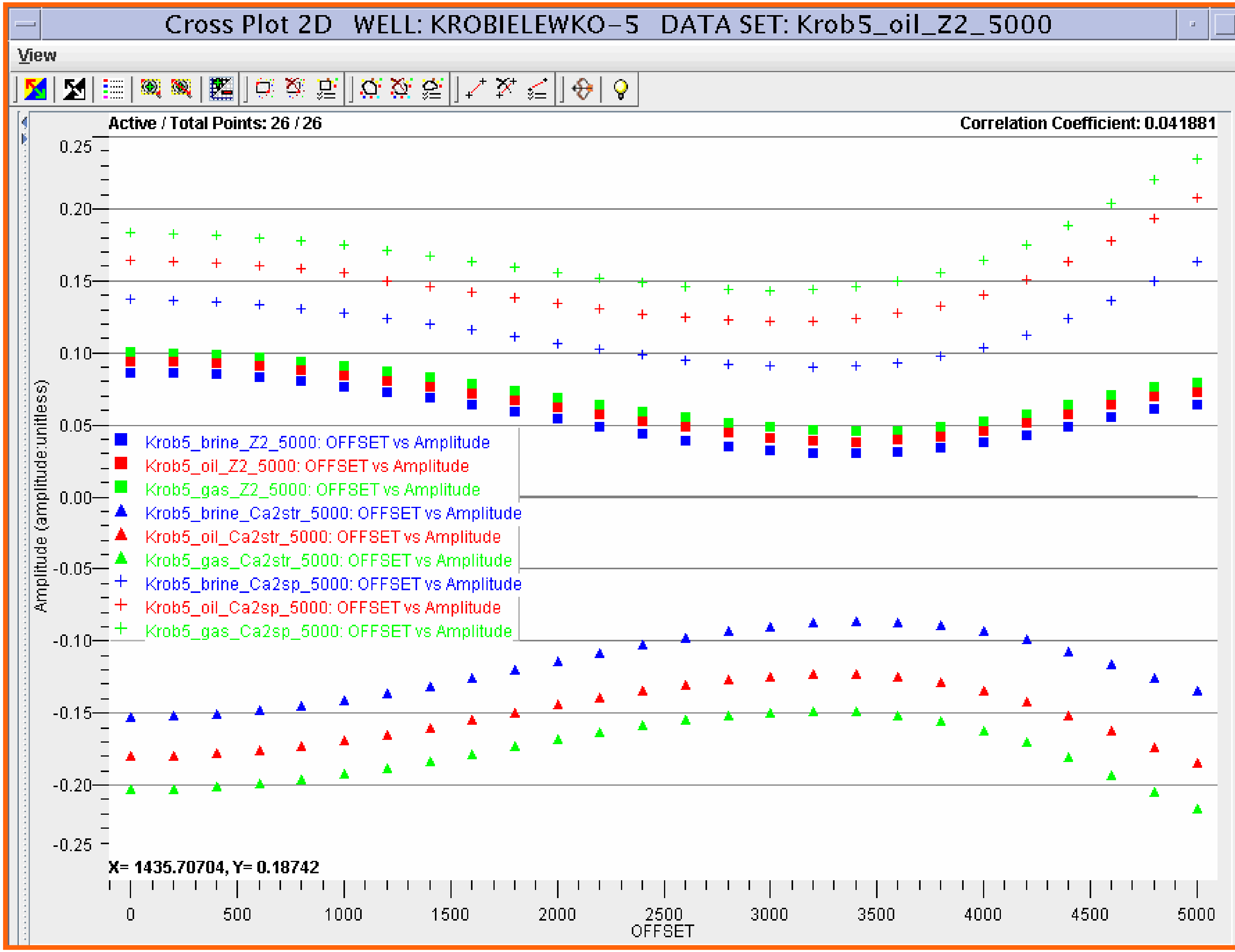
Changes of amplitudes with offset

Krobielewko-5



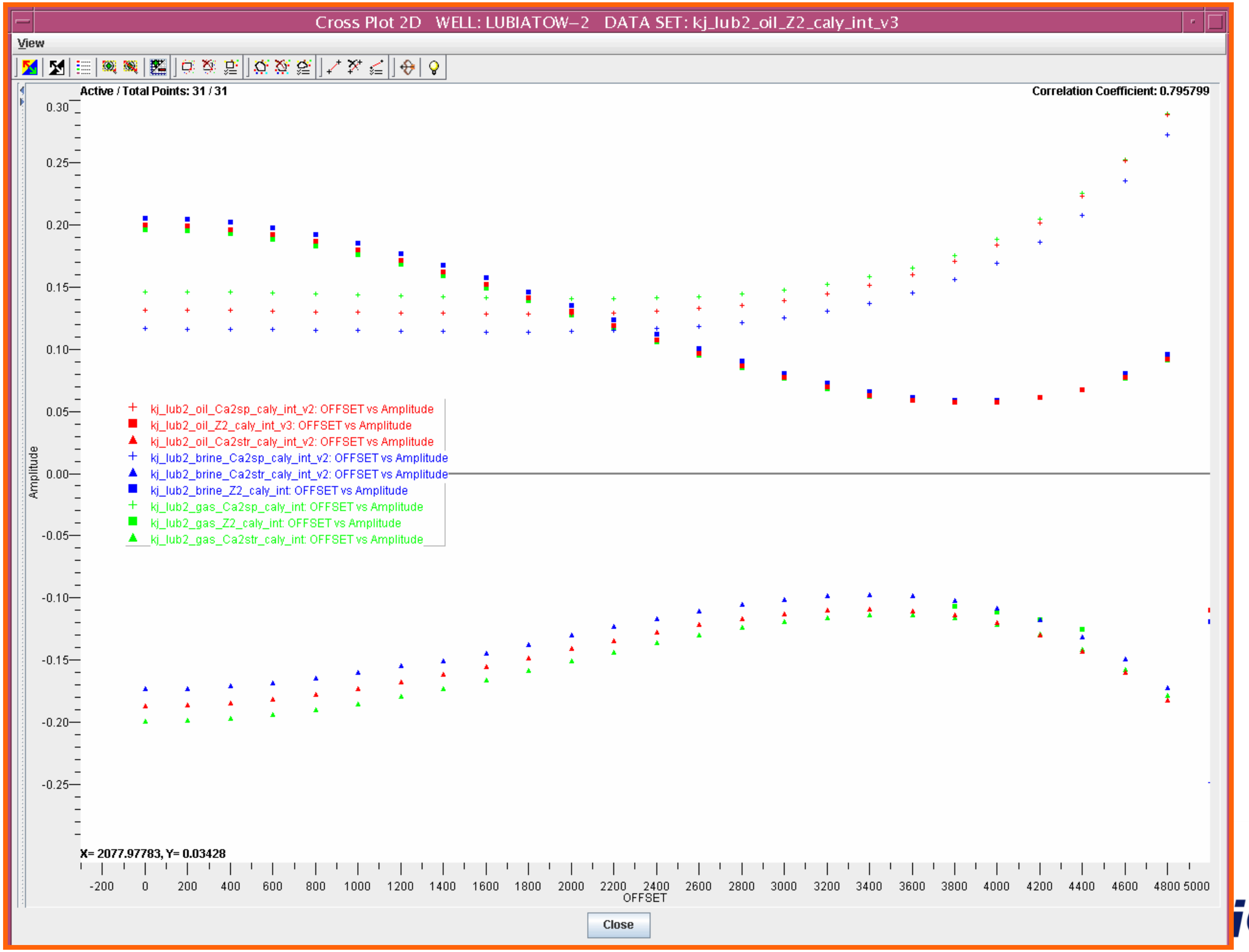
Changes of amplitudes with offset

Krobielewko-5

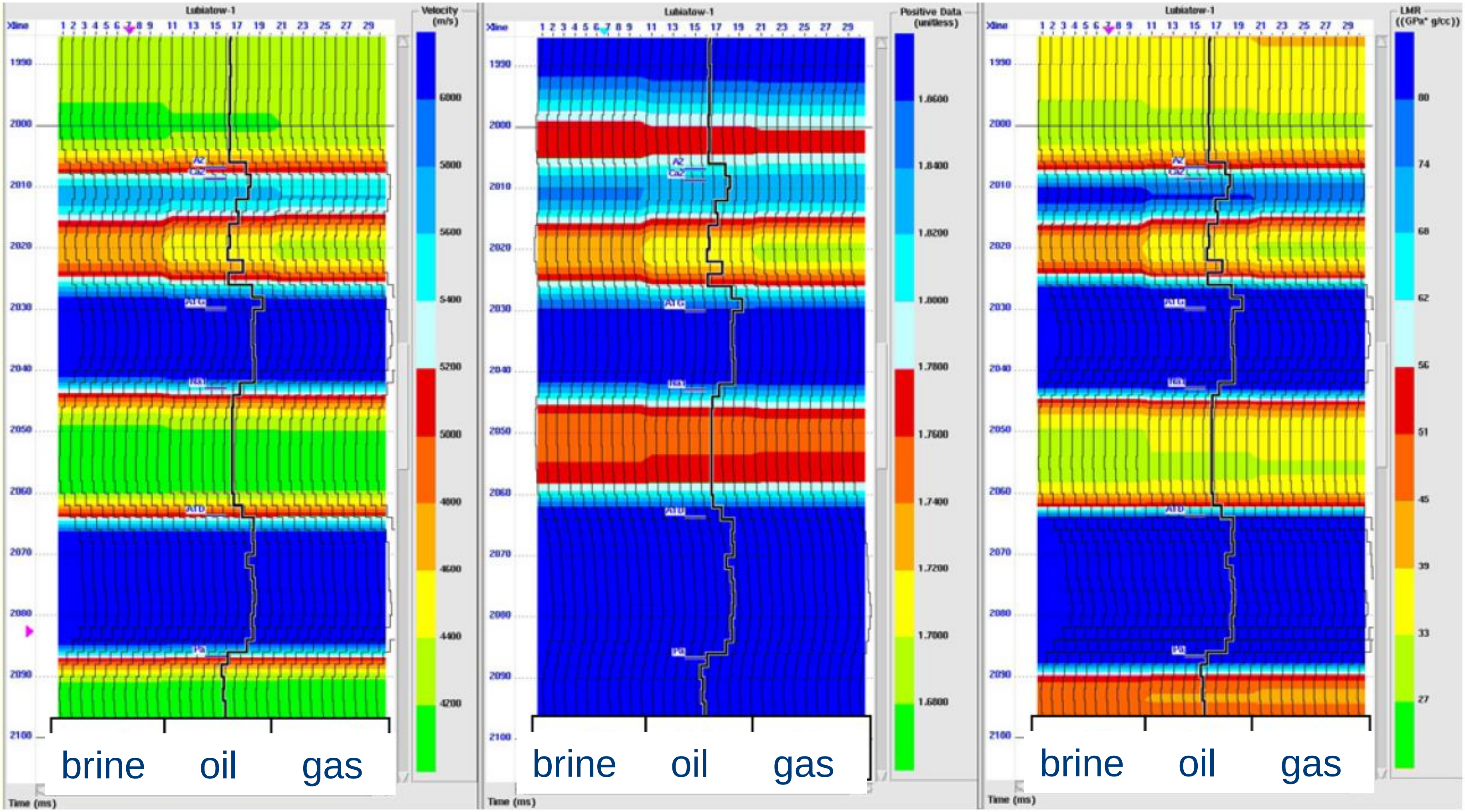


Changes of amplitudes with offset

Lubiatów-2



Simultaneous inversion of synthetic data *Lubiatów-1*



Vp **Vp/Vs** λρ

PGNiG

Thank you for your attention