Hydrocarbon Exploration in a Multiply Overprinted Caledonian Continental Collision Zone in the German Baltic Sea: Current Status

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Outline

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Purpose of Work and This Presentation

Exploration History

Geological Setting

Basin Development

Wells Wells Wells (4 German and 3 Polish offshore, 7 on Rügen…compact)

Results of Seismic Interpretation

Concluding Remarks

Purpose of Work and This Presentation

Franconia Geoscience Ltd.

Work performed:

…to better understand the geology and therefore the prospectivity of the block and the surrounding areas

This presentation:

…aims to present the current status of hydrocarbon exploration on the German shelf east of Rügen island

Exploration History

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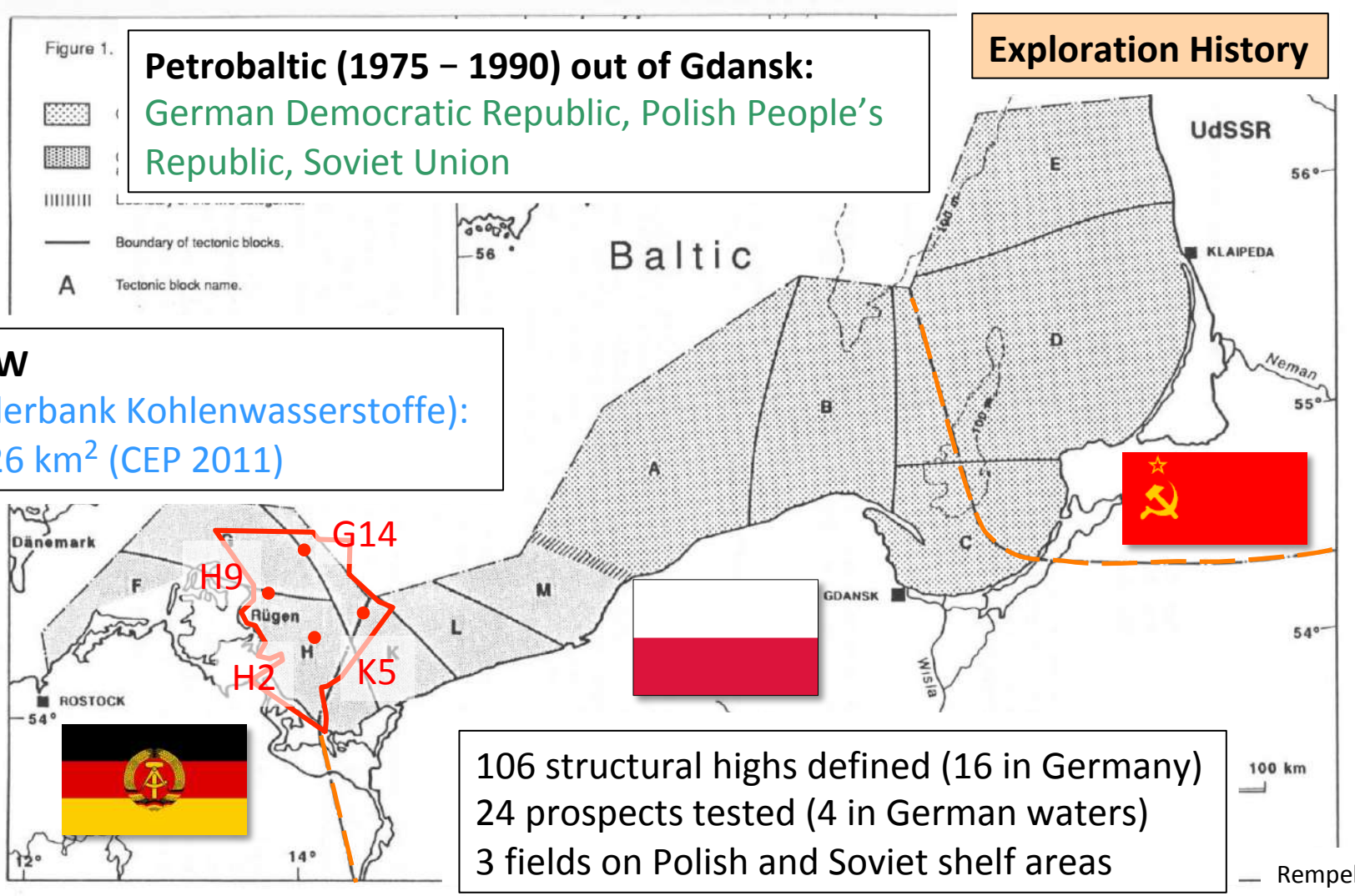
Petrobaltic (1975 – 1990) out of Gdansk:
German Democratic Republic, Polish People's Republic, Soviet Union

OKW
(Oderbank Kohlenwasserstoffe):
4626 km^2 (CEP 2011)



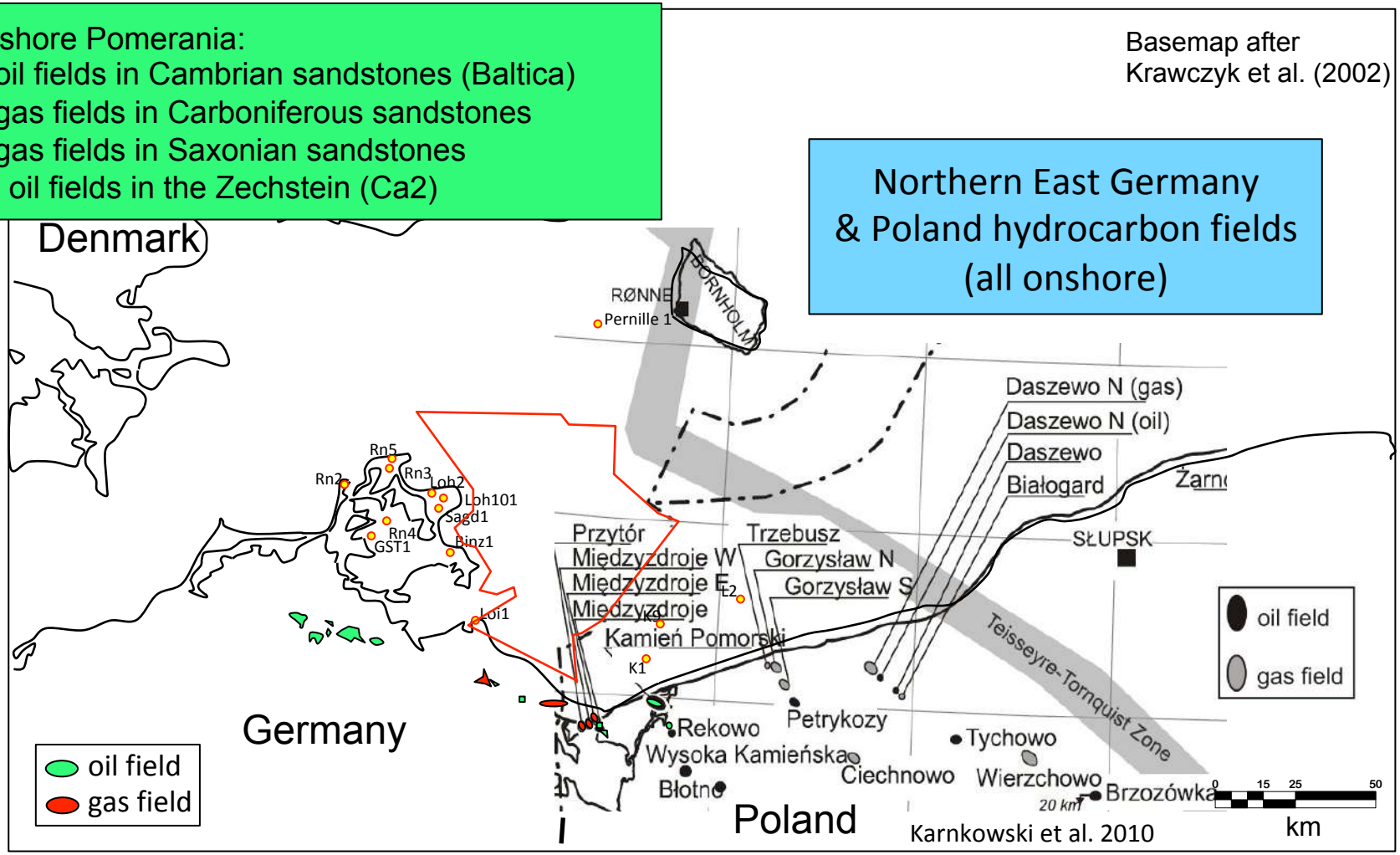
106 structural highs defined (16 in Germany)
24 prospects tested (4 in German waters)
3 fields on Polish and Soviet shelf areas

Rempel 1991

Onshore Pomerania:
-4 oil fields in Cambrian sandstones (Baltica)
-7 gas fields in Carboniferous sandstones
-6 gas fields in Saxonian sandstones
-11 oil fields in the Zechstein (Ca2)

Basemap after
Krawczyk et al. (2002)

Northern East Germany & Poland hydrocarbon fields (all onshore)



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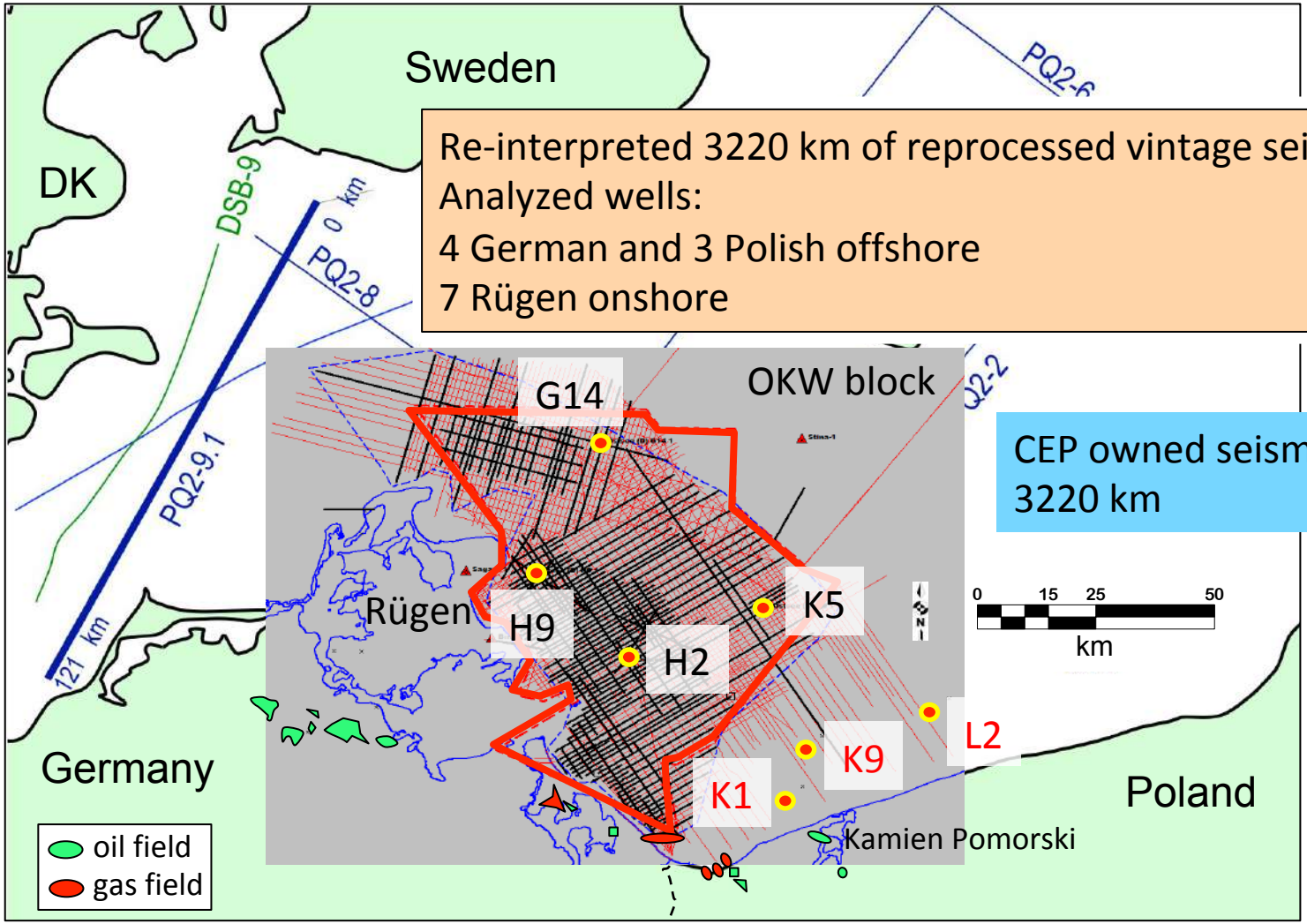
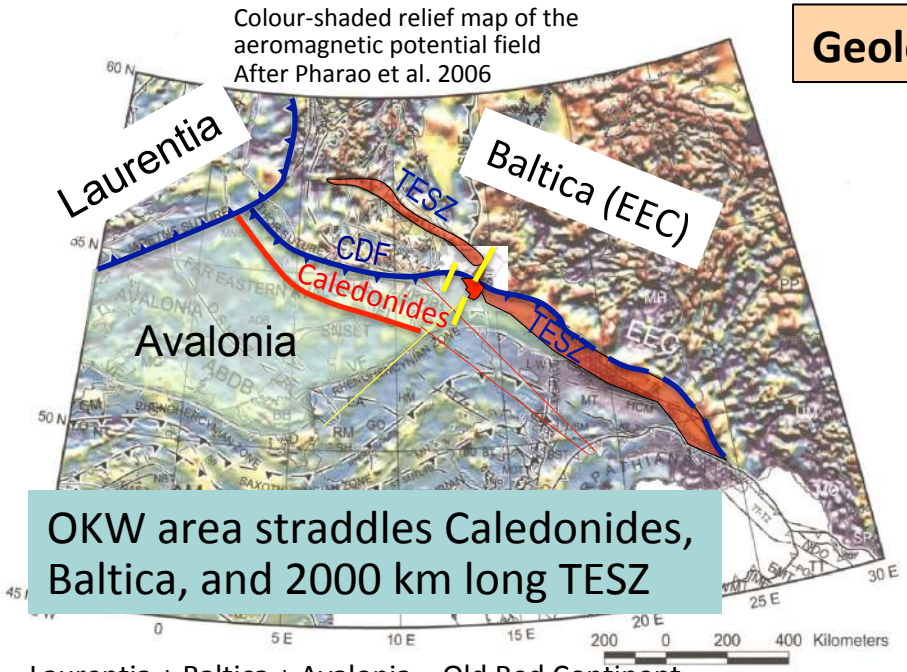


Re-interpreted 3220 km of reprocessed vintage seismic
Analyzed wells:
4 German and 3 Polish offshore
7 Rügen onshore

CEP owned seismic (black):
3220 km

Geological Setting

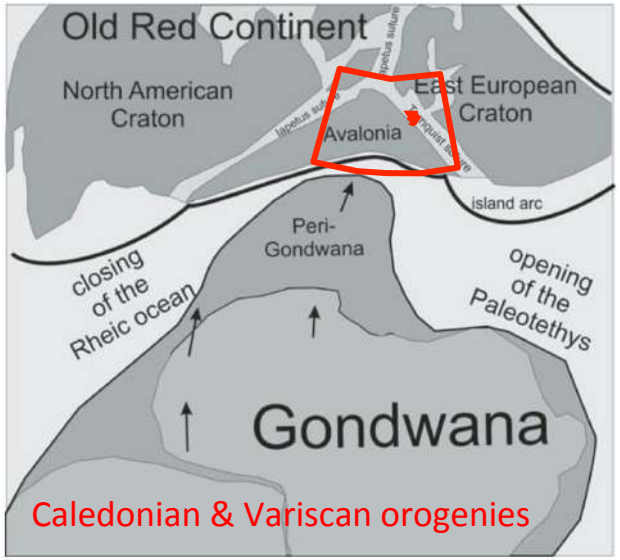


Colour-shaded relief map of the aeromagnetic potential field
After Pharao et al. 2006

OKW area straddles Caledonides, Baltica, and 2000 km long TESZ

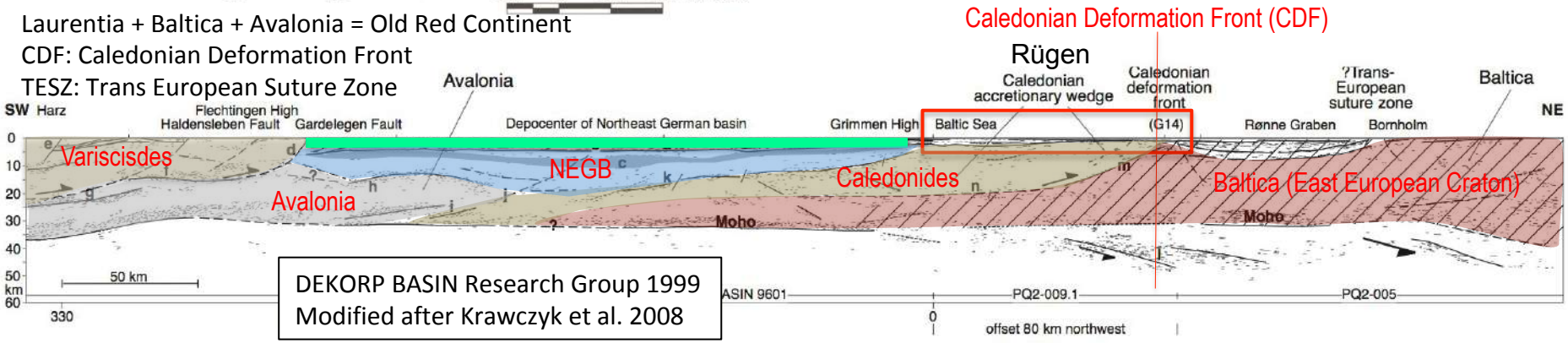
2 Caledonian sutures:
Tornquist: Upper Ord.
→ Baltica
Iapetus: Silurian
→ Old Red

"N. German – Polish Caledonides"



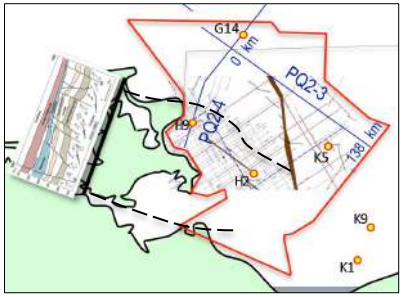
Kroner et al. 2007

Laurentia + Baltica + Avalonia = Old Red Continent
CDF: Caledonian Deformation Front
TESZ: Trans European Suture Zone

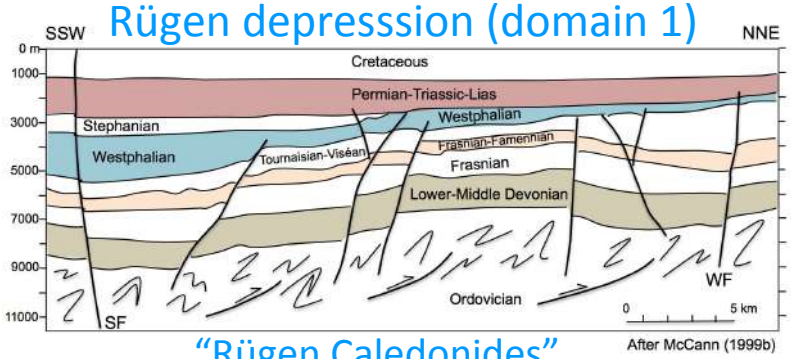


DEKORP BASIN Research Group 1999
Modified after Krawczyk et al. 2008

Basin Development



Rügen depresssion (domain 1)



"Rügen Caledonides"

Main Devonian reservoirs:
Middle Devonian marine sandstones (Old Red facies)
Upper Devonian shallow marine carbonates

open shelf

deeper marine Frasnian carbonates

continental to shallow marine

Middle Devonian qtz-sandstones

System	Subsystem/ Series	Stage	Age (Ma)
Carboniferous	Mississippian	Tournaisian	recent
Devonian	Upper	Famennian	372,2–358,9
		Frasnian	382,7–372,2
	Middle	Givetian	387,7–382,7
		Eifelian	393,3–387,7
	Lower	Emsian	407,6–393,3
		Pragian	410,8–407,6
		Lochkovian	419,2–410,8
Silurian	Pridoli	no faunal stages defined	older

Subdivision of the Devonian system according to the ICS.[1]

Seal
Res.
Res.

convergence:
compression, uplift

extension:
rifting,
subsidence

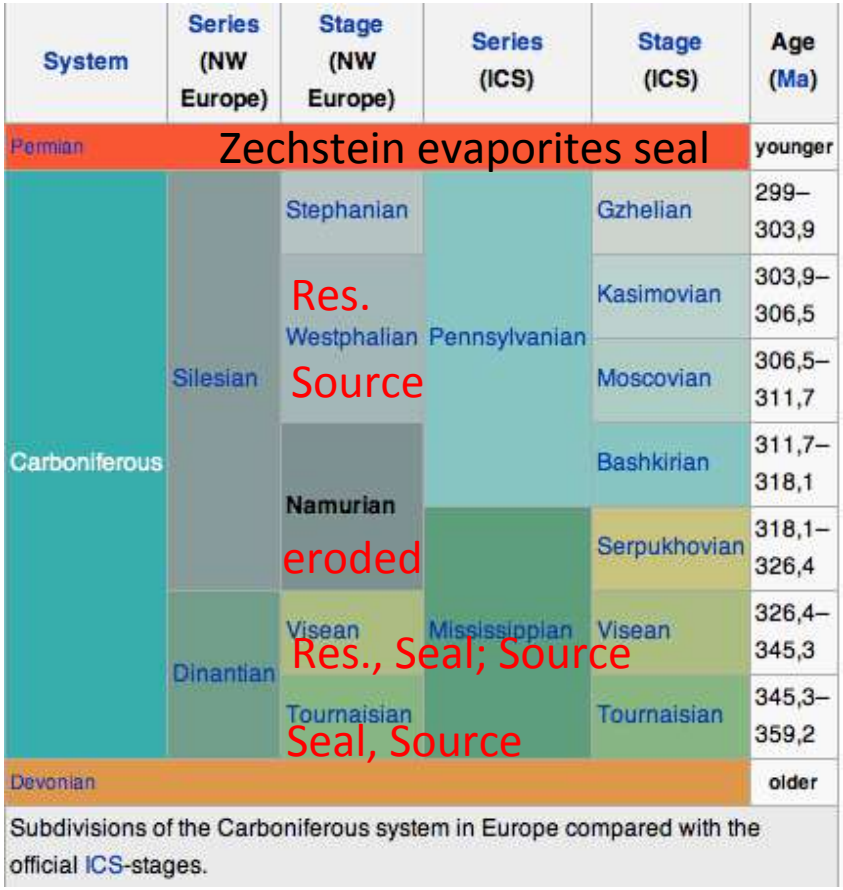
Variscan basin initiation in the early Devonian: continental deposition (Old Red Sandstone)

Main Carboniferous reservoirs:
Westphalian continental sandstones
Viséan carbonates (flowed oil in Hiddensee 3 test)

Main Zechstein reservoir:
Ca2 (Stassfurt carbonate)
→ Kamien Pomorski, Lütow

continental:
molasse sandstones
(fluvial, lacustrine)

shallow marine:
carbonates w. minor
clastic rocks

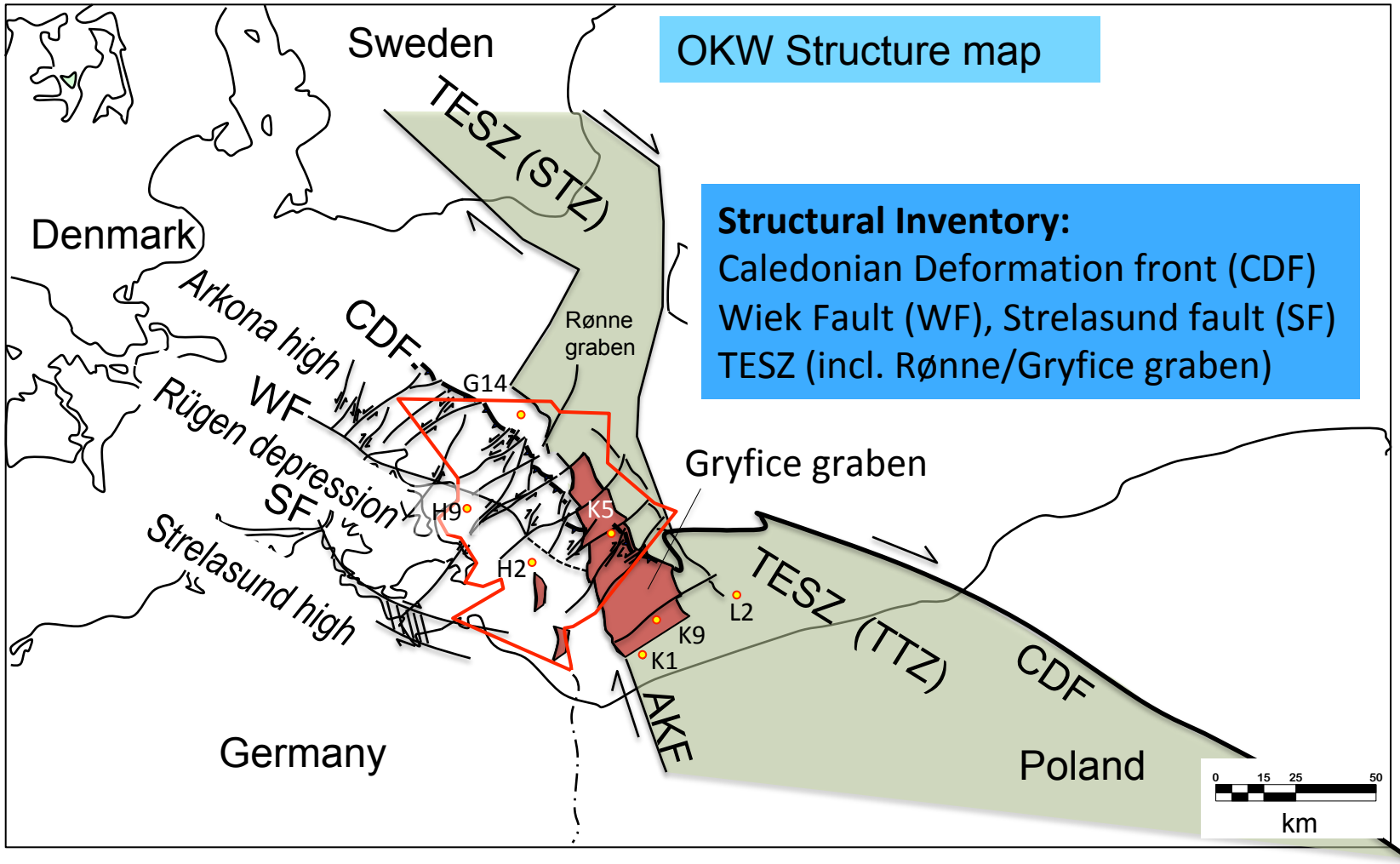


Subdivisions of the Carboniferous system in Europe compared with the official ICS-stages.

dextrally transtensional

early terminal collision:
post-Viséan uplift
("Sudetic discordance")

compression:
Variscan orogeny


OKW Structure map
Sweden
Denmark
Germany
Poland
TESZ (STZ)
TESZ (TTZ)
CDF
CDF
AKF
Arkona high
WF
Rügen depression
SF
Strelasund high
Rønne graben
Gryfice graben
G14
H9
H2
K5
K9
K1
L2
Structural Inventory:
Caledonian Deformation front (CDF)
Wiek Fault (WF), Strelasund fault (SF)
TESZ (incl. Rønne/Gryfice graben)
0 15 25 50
km

4 German Offshore Wells (1986-1990): H2, H9, K5…G14

Paleozoic targets

No hydrocarbon shows, only indications

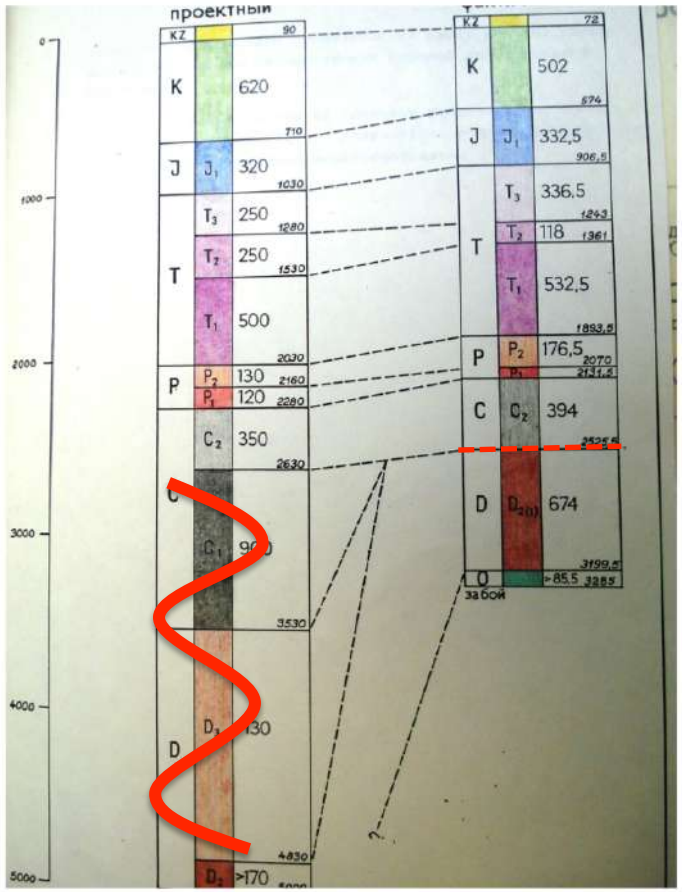
Prognosis vs. reality: huge discrepancies

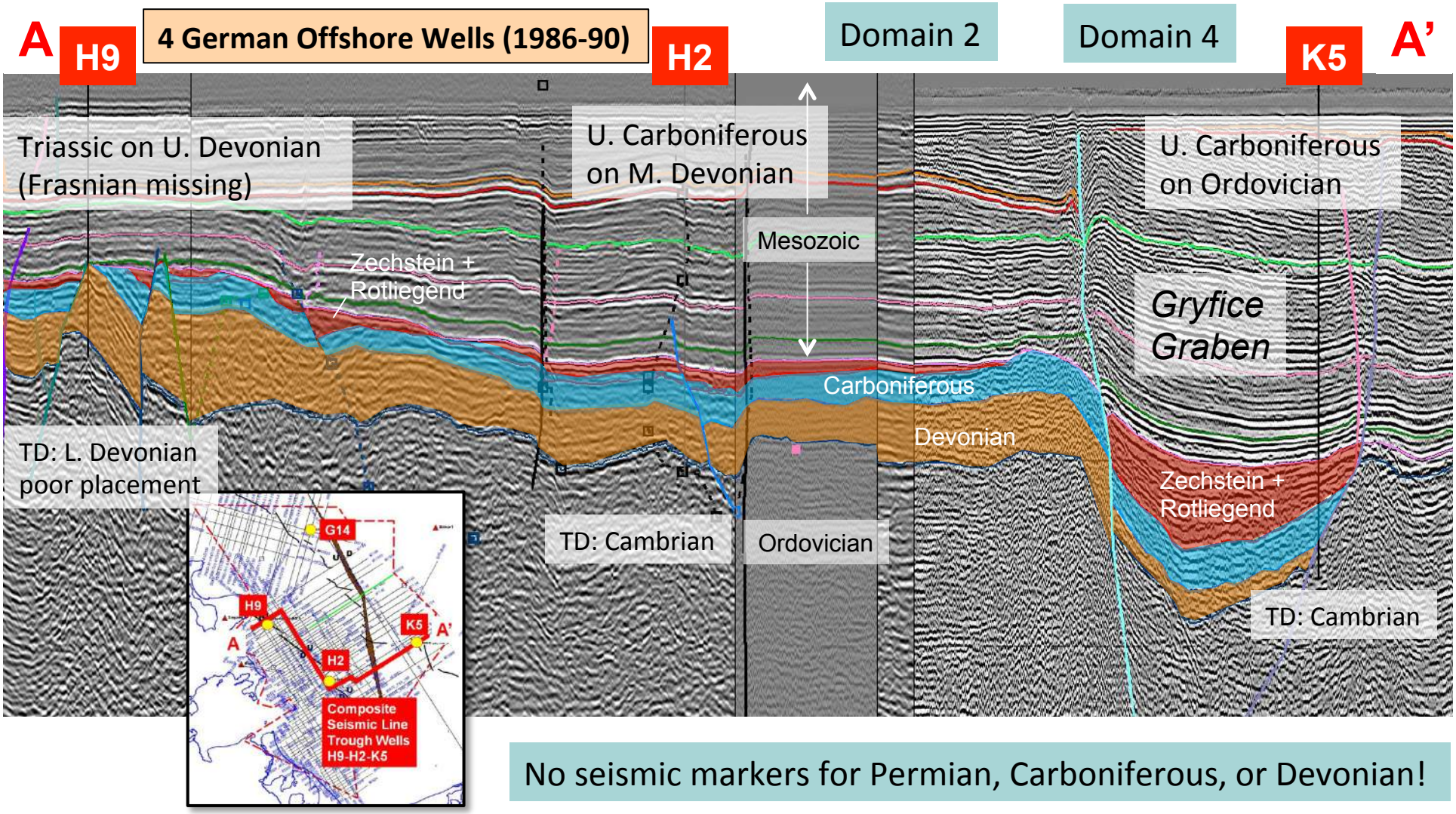
- G14: Triassic on overcooked platform Silurian (starved passive continental margin sequence)
- H2: Lower Carboniferous and Upper Devonian (Frasnian Res.) missing
- H9: Triassic on Upper Devonian (Frasnian missing)
- K5: Upper Carboniferous on top of Ordovician

Poor well placements→ effects of Variscan orogeny (post-Viséan uplift/erosion of Namurian to Devonian section) not considered in four consecutive wells

H2 prognosis

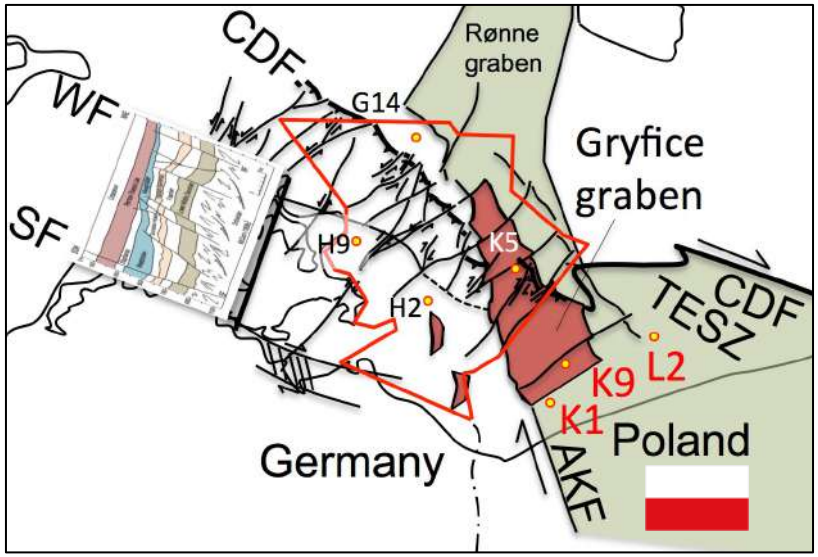
H2 log





No seismic markers for Permian, Carboniferous, or Devonian!

3 Polish Offshore Wells (1986-1989): K1, K9, L2



K1 and K9 in similar setting as K5 (Gryfice graben)

Paleozoic targets

No hydrocarbon shows, only indications

Ca2 without reservoir quality (K1, K9)

7 Rügen Onshore Wells (1964 -1973) …out of 32 between 1962 and 1986

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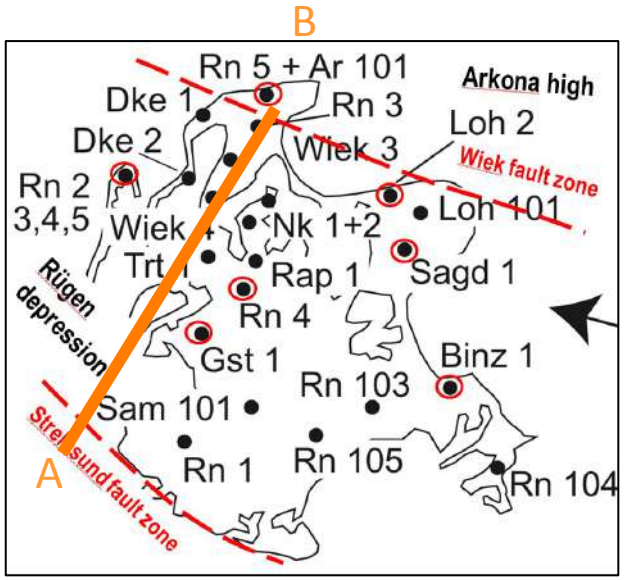
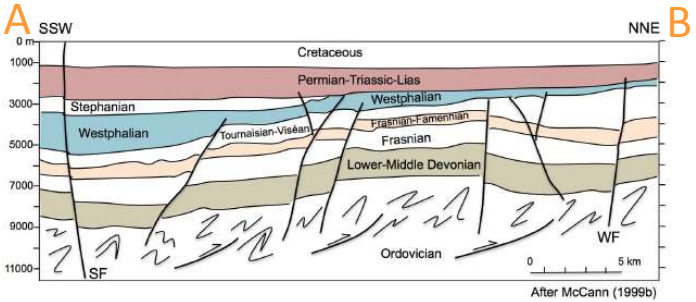




7 wells examined (6 within Rügen depression cf. H2 & H9); all drilled on local highs!

Paleozoic targets

No hydrocarbon shows, only indications

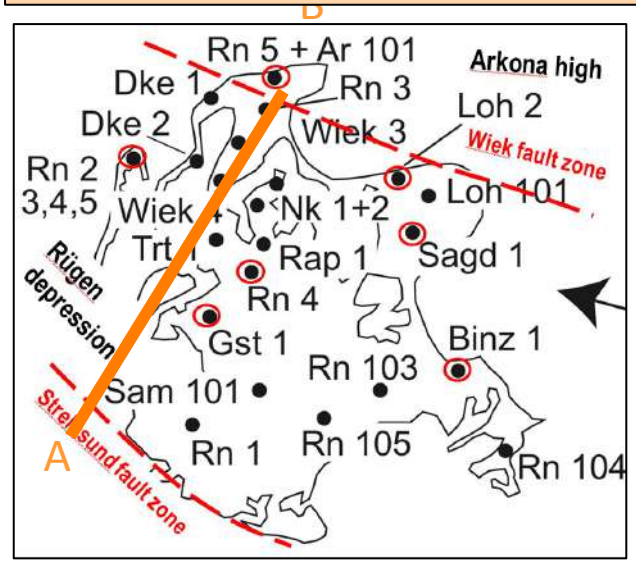
Prognosed stratigraphic section missing: e.g. 70% of U. Devonian in Binz 1/73

Rn 5 on Arkona horst: top Ordocivian at 720 m (4000 m prognosed)

U. Devonian reefs on local highs (2ndary horsts)
→ eroded during Variscan uplift

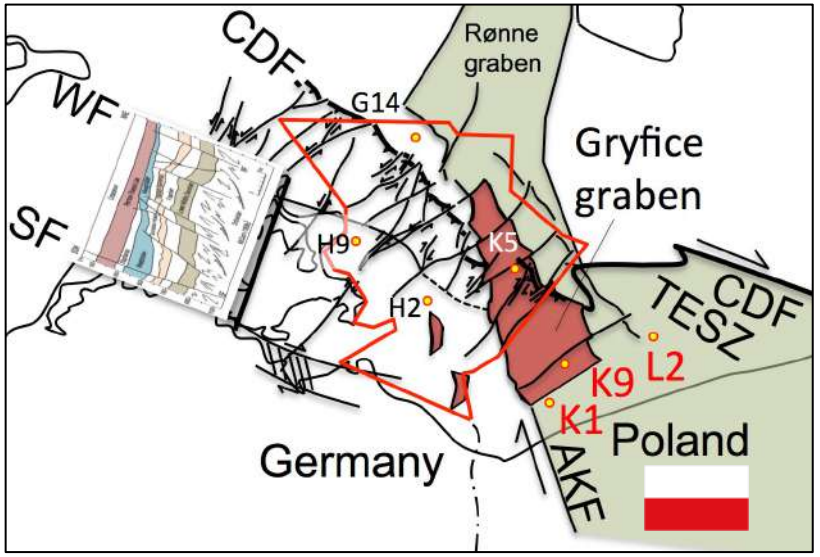
Eff. por. of M. Dev. sandstones is entirely depth dependent

7 Rügen Onshore Wells (1964–1973)
…out of 32 between 1962 and 1986



Paleozoic targets
No hc shows,
only indications

3 Polish Offshore Wells (1986–1989): K1, K9, L2



7 wells examined (6 within Rügen depression cf. H2 & H9); all drilled on local highs!
Prognosed stratigraphic section missing:
e.g. 70% of U. Devonian in Binz 1/73
Effective porosity of M. Dev. sandstones is entirely depth dependent

K1 and K9 in similar setting as K5 (Gryfice graben)

Ca2 without reservoir quality (K1, K9))

Where do we have production onshore?
→ Composite Polish onshore gas and/or oil deposit

Pre-Permian:

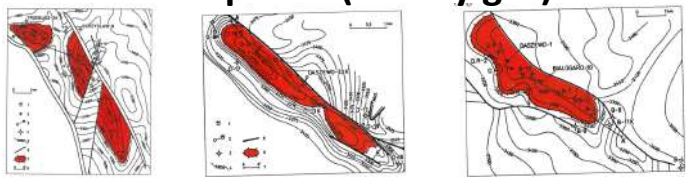
Geological Setting: TESZ; eastern extension of Rügen depression
Reservoir: mainly Westphalian sandstones; minor Viséan carb./ss
Trap: NNW to NW trending Alpine inversion anticlines against TESZ-related faults
Seal: mainly Zechstein salt and anhydrites; lesser intraformational
Source: mainly Tournaisian (Lower Carboniferous) shales

Late Alpine uplift vs. early Variscan uplift

Permian:

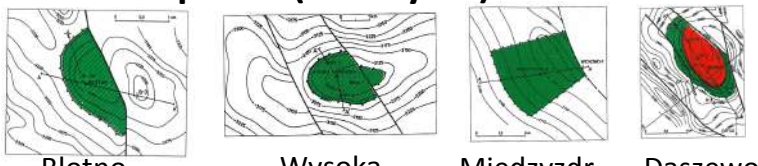
Geological Setting: same as above
Reservoir: Ca2 (Stassfurt carb.), Rotl. sandstone
Trap: same as above
Seal: same as above
Source: Ca2, Carboniferous

Pre-Permian deposits (mainly gas)



Goryslaw Daszewo North Bialogard

Permian deposits (mainly oil) Karnkowsky (1999)



Blotno Wysoka Miedzyzdr. Daszewo

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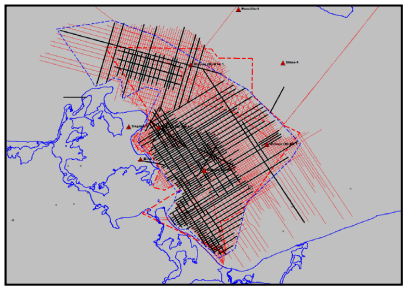
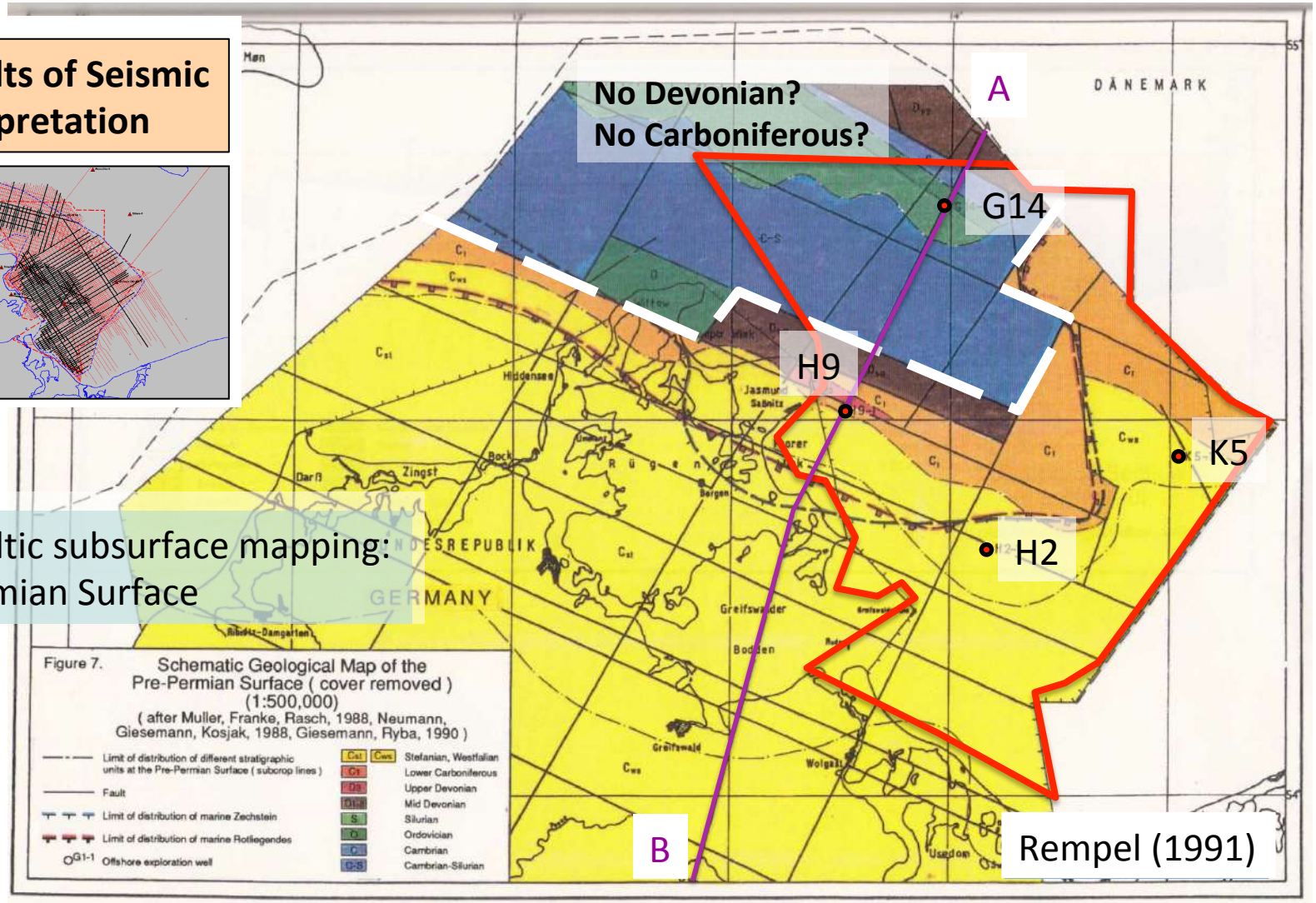
Results of Seismic Interpretation



Petrobaltic subsurface mapping:
Pre-Permian Surface



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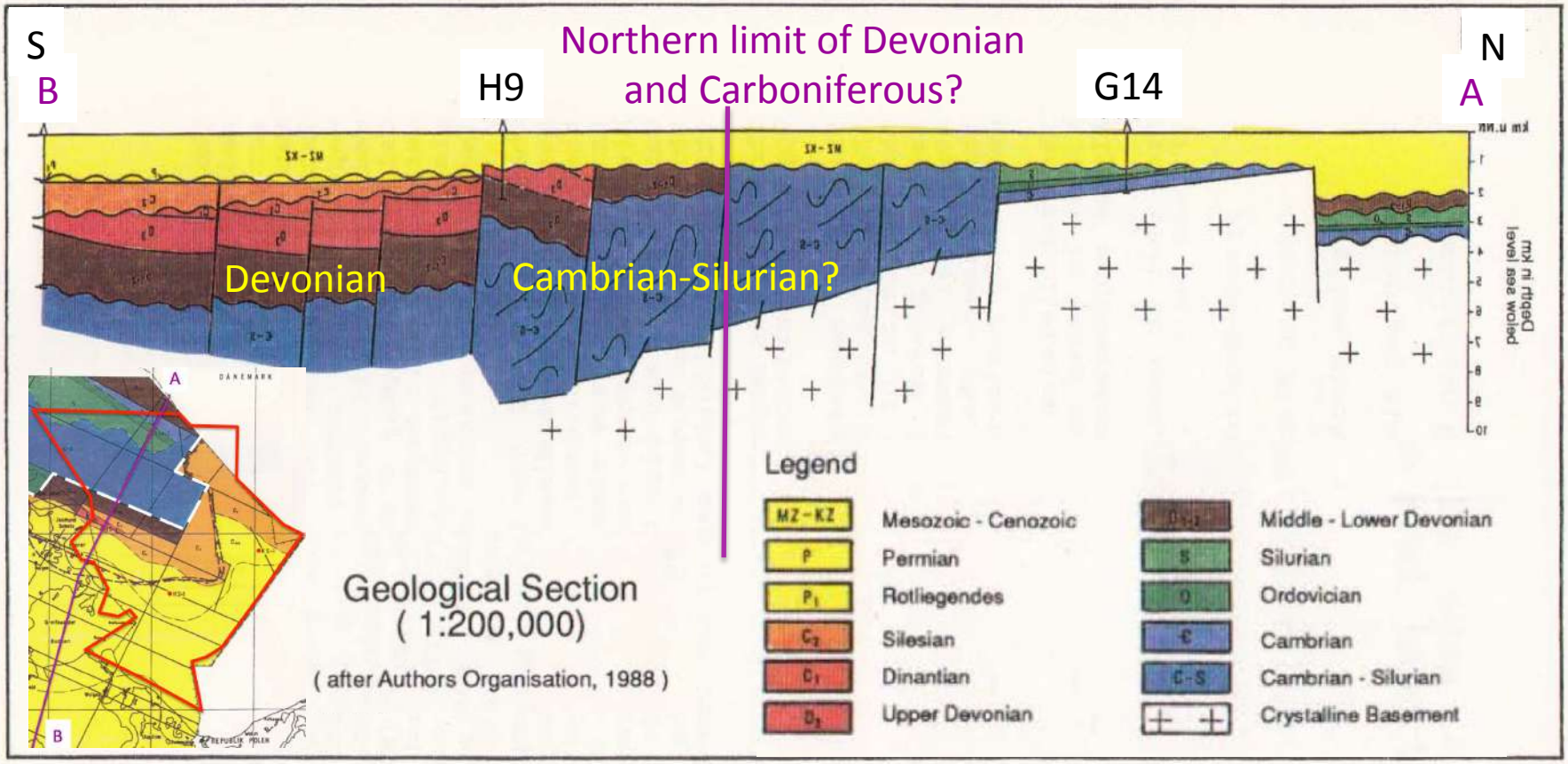
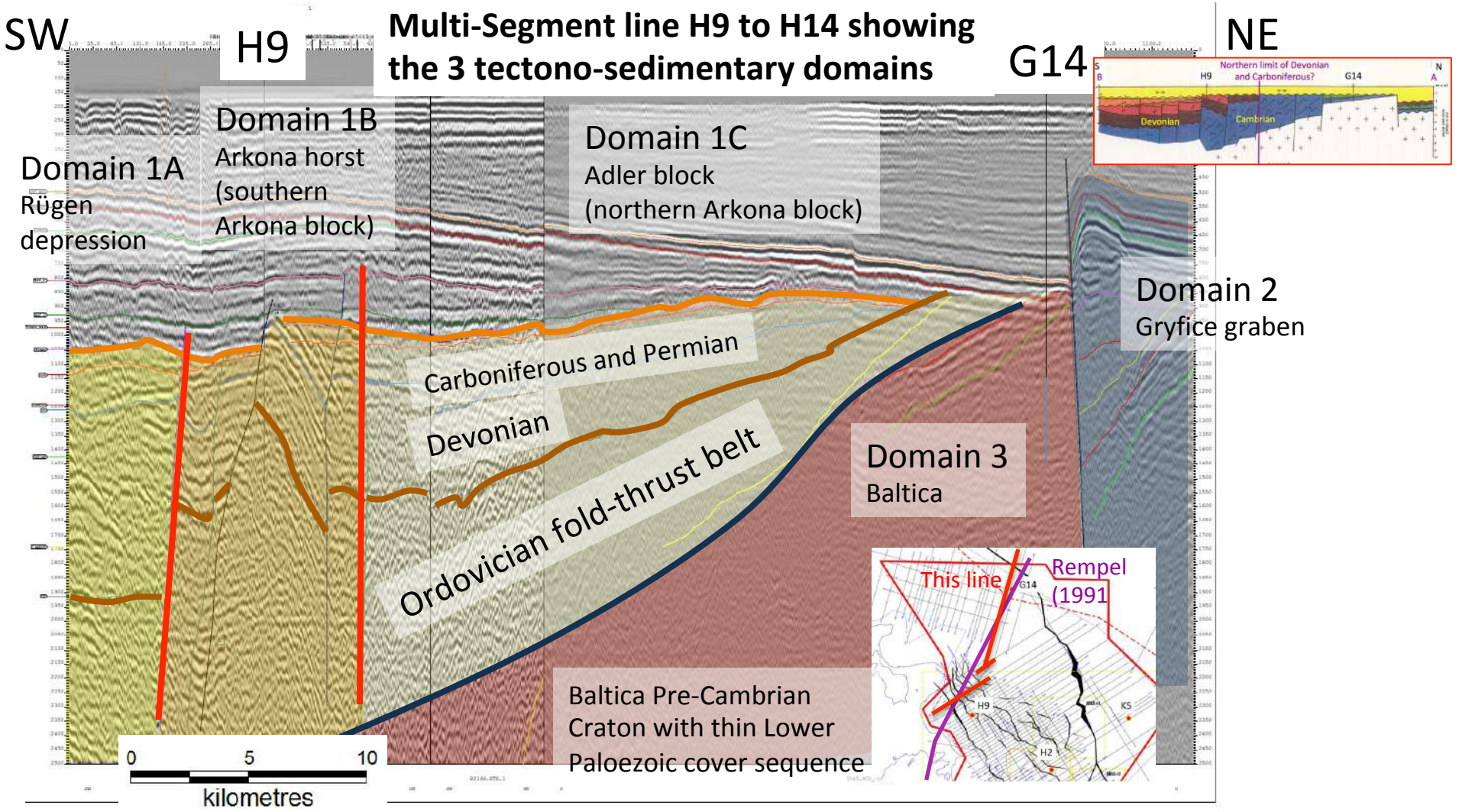


Actual section is side reversed!

Rempel (1991)


SW
H9
Multi-Segment line H9 to H14 showing the 3 tectono-sedimentary domains
G14
NE
Northern limit of Devonian and Carboniferous?
Devonian
Cambrian
Domain 1A
Rügen depression
Domain 1B
Arkona horst (southern Arkona block)
Domain 1C
Adler block (northern Arkona block)
Domain 2
Gryfice graben
Carboniferous and Permian
Devonian
Ordovician fold-thrust belt
Domain 3
Baltica
This line
Rempel (1991
Baltica Pre-Cambrian Craton with thin Lower Paloezoic cover sequence
0
5
10
kilometres

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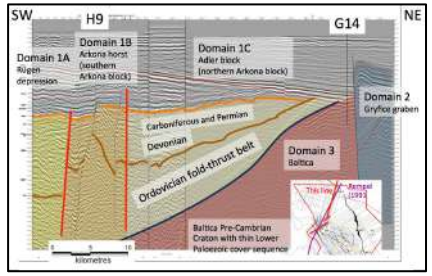
The 3 OKW tectono-sedimentary Domains

(based on Variscan and post-Variscan block faulting)



Domain 3
Baltica

G14

Domain 1C
Adler block
(northern Arkona block)

Domain 1B
Arkona horst
(southern Arkona block)

H9

Devonian extensional faults inverted in Namurian and Cretaceous

Domain 2
Gryfice graben (TTZ)

AREA #1

K5

Domain 1A
Rügen depression

H2

AREA #2

N

0 5 10
kilometres

Adler-Kamien fault:
Silurian initiation?
Namurian inversion
Permian to Jurassic growth
Cretaceous inversion

TIME STRUCTURE MAPS

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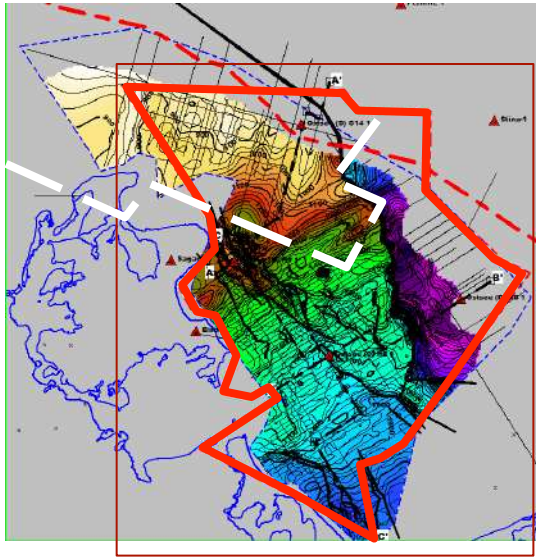
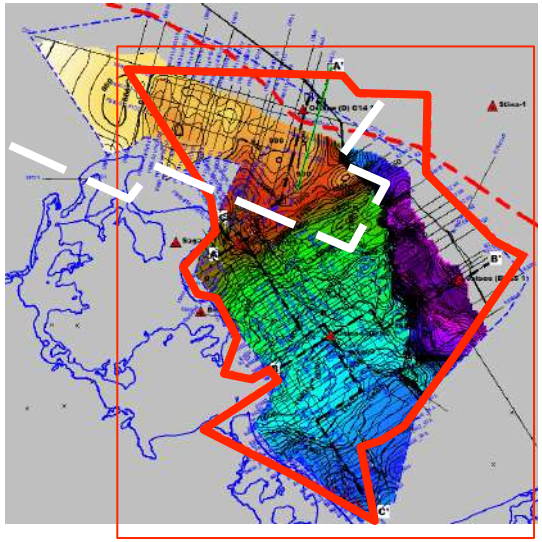
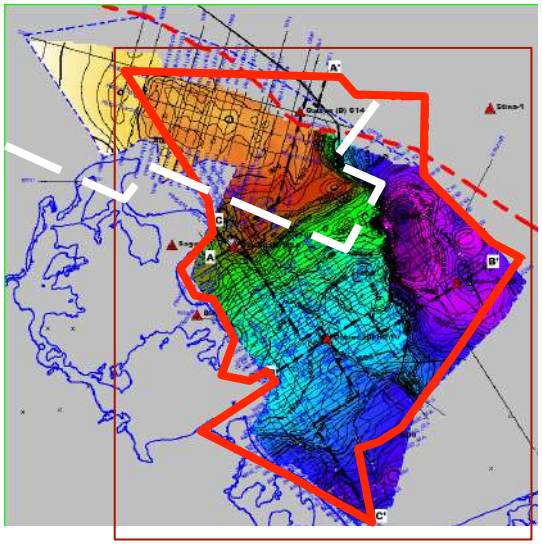


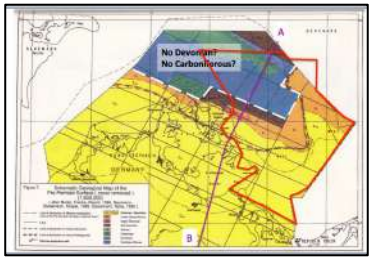
Top Devonian



Top Carboniferous



Top Permian



Devonian and Carboniferous extend more outboard than mapped by Petrobaltic. The packages are above the 2500 m porosity cutoff (for the M. Devonian)

OKW Prospectivity: Seismic

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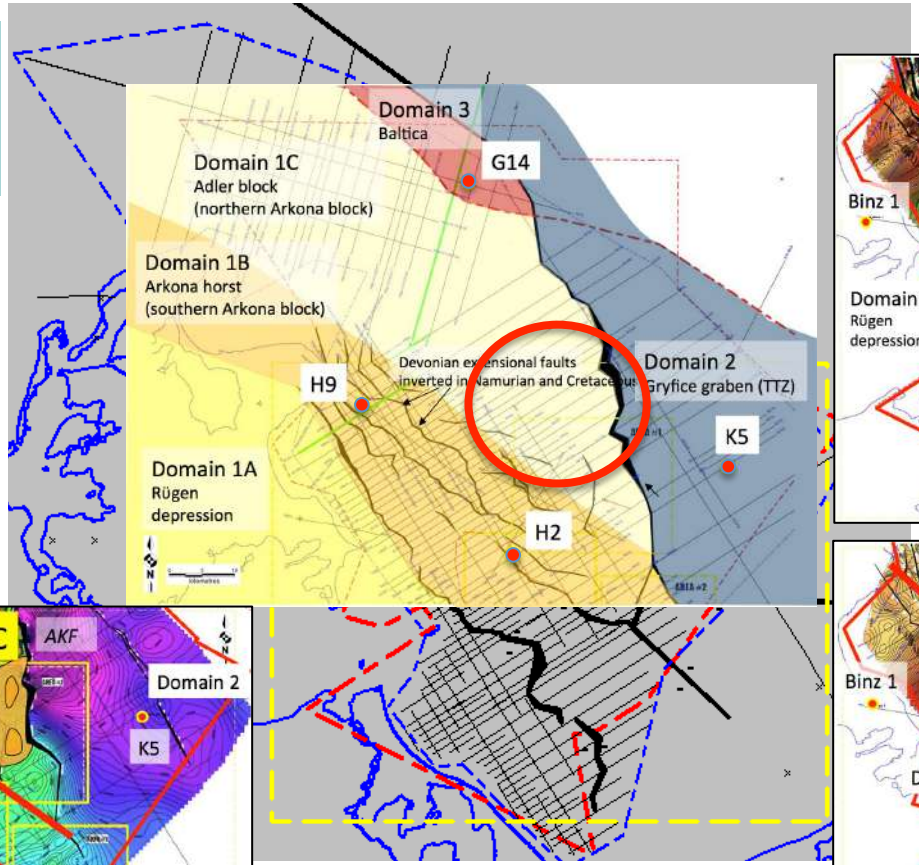
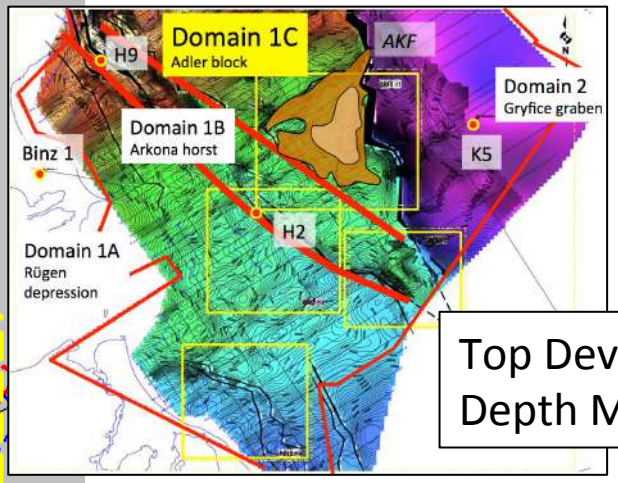
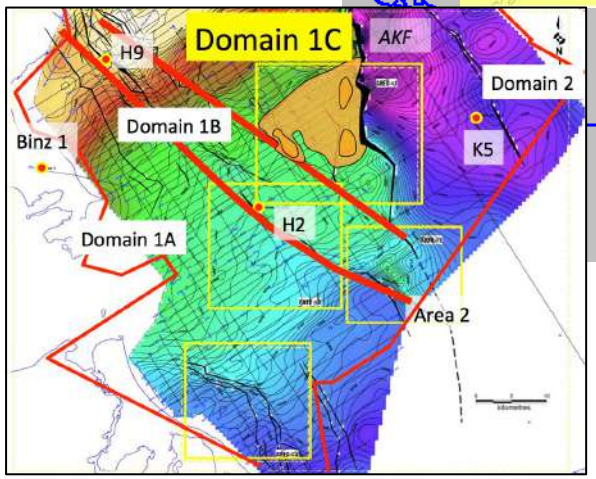
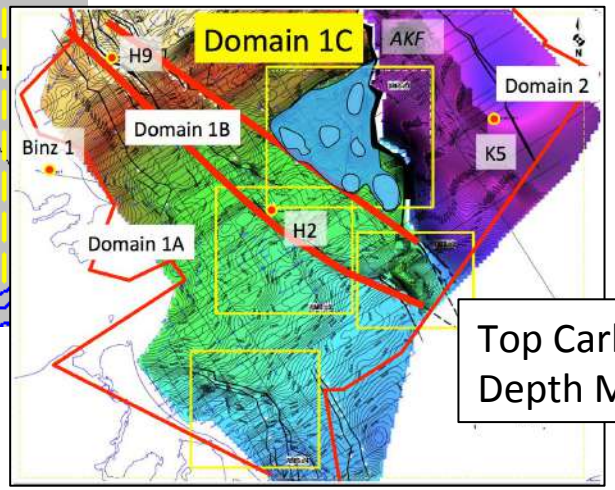




Top Devonian Depth Map

Top Permian Depth Map





Top Carbonif. Depth Map

SEISMIC BASEMAP W/ BOUNDARY OF ZOOM-IN

Concluding Remarks

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Devonian and Carboniferous areal extent is much larger than previously mapped → the newly mapped stack contains prospects and leads that need to be tested.

Upper Carboniferous and Zechstein have been identified as the main reservoirs

- Upper Carboniferous has a top seal issue that needs to be resolved
- Zechstein is best developed in the Gryfice graben and has unpredictable reservoir qualities.

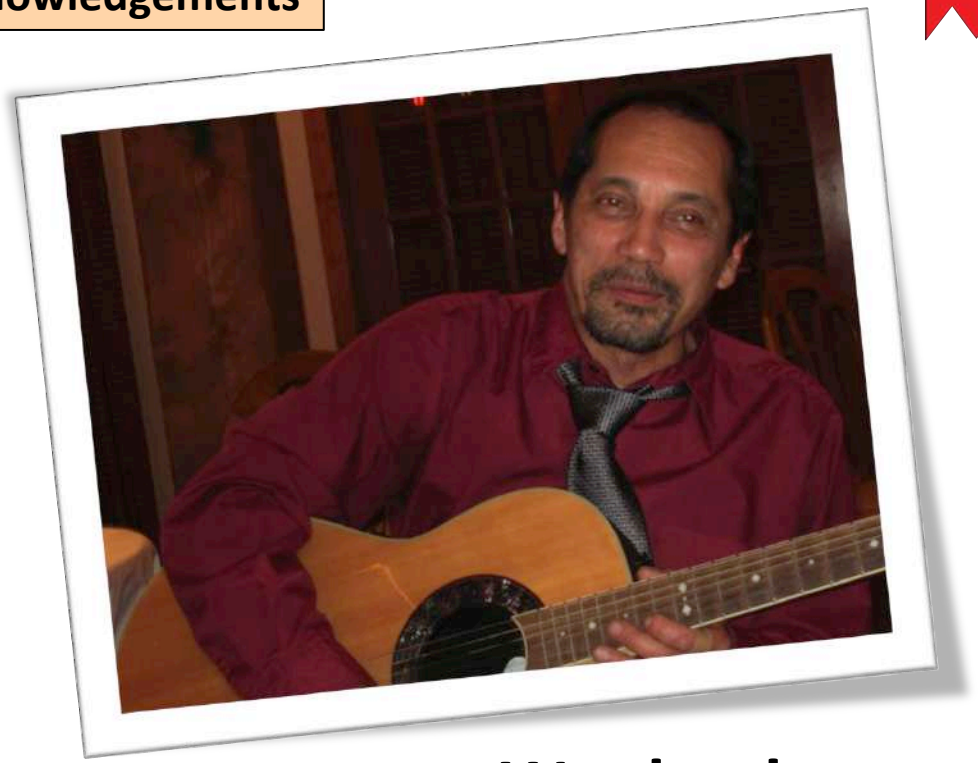
Alpine inversion anticlines associated with NNW-trending TTZ-related faults are the main traps – they postdate early migration phases from Lower Paleozoic sources but pre-date late migration as well as Zechstein oil migration.

Prospects may be stacked: several targets can be tested with a single vertical well.

Additional seismic is required for key areas.

Acknowledgements

Caspar David Friedrich
Chalk Cliffs on Rügen (1818)



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