

GeoPower – border crossing mapping of the underground structure in southern Jutland and northern Schleswig-Holstein for deep geothermal energy use

Niels Balling³, Lars Ole Boldreel¹, Sven Fuchs⁵, Fabian Hese², Morten Hjuler¹, Reinhard Kirsch⁴, L. Kristensen¹, Anders Mathiesen¹, C.M. Nielsen¹, Lars Henrik Nielsen¹, Petra Offermann, N.E. Poulsen¹, Wolfgang Rabbel⁴, Claudia Thomsen²

¹ **GEUS** De Nationale Geologiske Undersøgelser for Danmark og Grønland

² **LLUR** Geologischer Dienst Schleswig-Holstein

³ **Aarhus Universitet** Institut for Geoscience - Geologi

⁴ **Christian Albrechts Universität Kiel** Institut für Geowissenschaften – Geophysik

⁵ **Aarhus Universitet**, now at GeoForschungsZentrum Potsdam



Geologischer Dienst S-H

Landesamt für Landwirtschaft, Umwelt
und ländliche Räume Schleswig-Holstein



Christian-Albrechts-Universität zu Kiel

Institut für Geowissenschaften
Abteilung Geophysik

GEUS
De Nationale Geologiske Undersøgelser
for Danmark og Grønland



GEUS

Aarhus Universitet
Institut for Geoscience
Geologi



A larger version of the GEOPOWER logo, with the stylized arc on the left and the text "GEOPOWER" to its right.

- Aim of the project/project area
- Organisation of the border crossing cooperation
- Geological conditions, data base
- Interpretation of existing seismic data
- Acquisition of new seismic data
- Geological model, thematic maps
- Log interpretation: probability of sandstone in the geothermal formations
- Dissemination of results

Aim of the project:

To provide information on geothermal reservoir horizons in an early planning stage of geothermal installations

Project area:

southern Jutland
- northern Schleswig-Holstein



The project was part financed by the **INTERREG 4A** programme
Region Syddanmark – Schleswig, 2011-2015

INTERREG funding :	576.083 EUR	65%
cofinancing by the project partners:	311.275 EUR	35%



Workflow of the project:

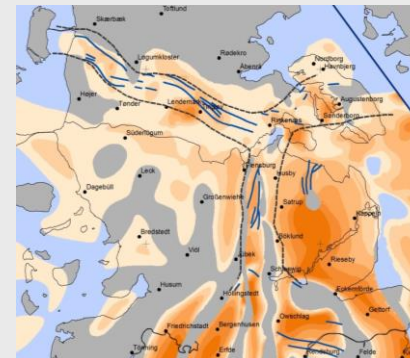
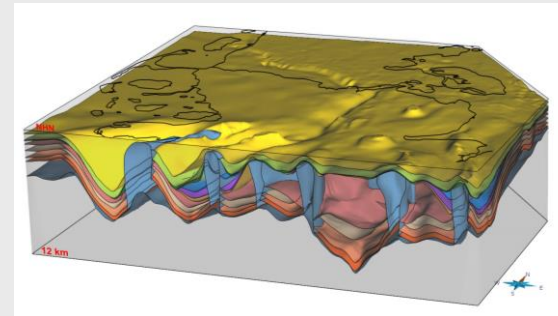
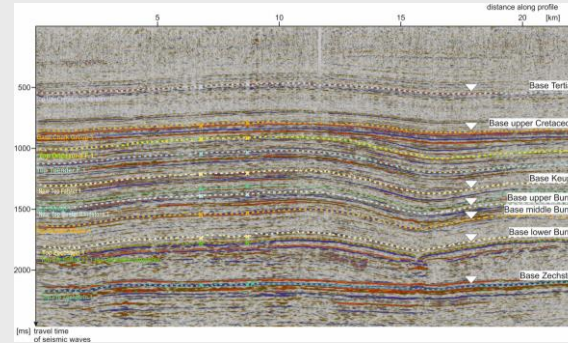
underground information



digital geological model



direct use of the model
or thematic maps



Distribution of tasks:**Geologischer Dienst S-H**

Landesamt für Landwirtschaft, Umwelt
und ländliche Räume Schleswig-Holstein

Coordination**Interpretation of seismic profiles SH****Petrophysical characteristic of reservoir rocks****Geological 3D modelling****Christian-Albrechts-Universität zu Kiel**

Institut für Geowissenschaften
Abteilung Geophysik

Geophysical measurements and interpretation**GEUS**

De Nationale Geologiske Undersøgelser
for Danmark og Grønland

**Interpretation of seismic profiles DK****Petrophysical characteristic of reservoir rocks****Aarhus Universitet**

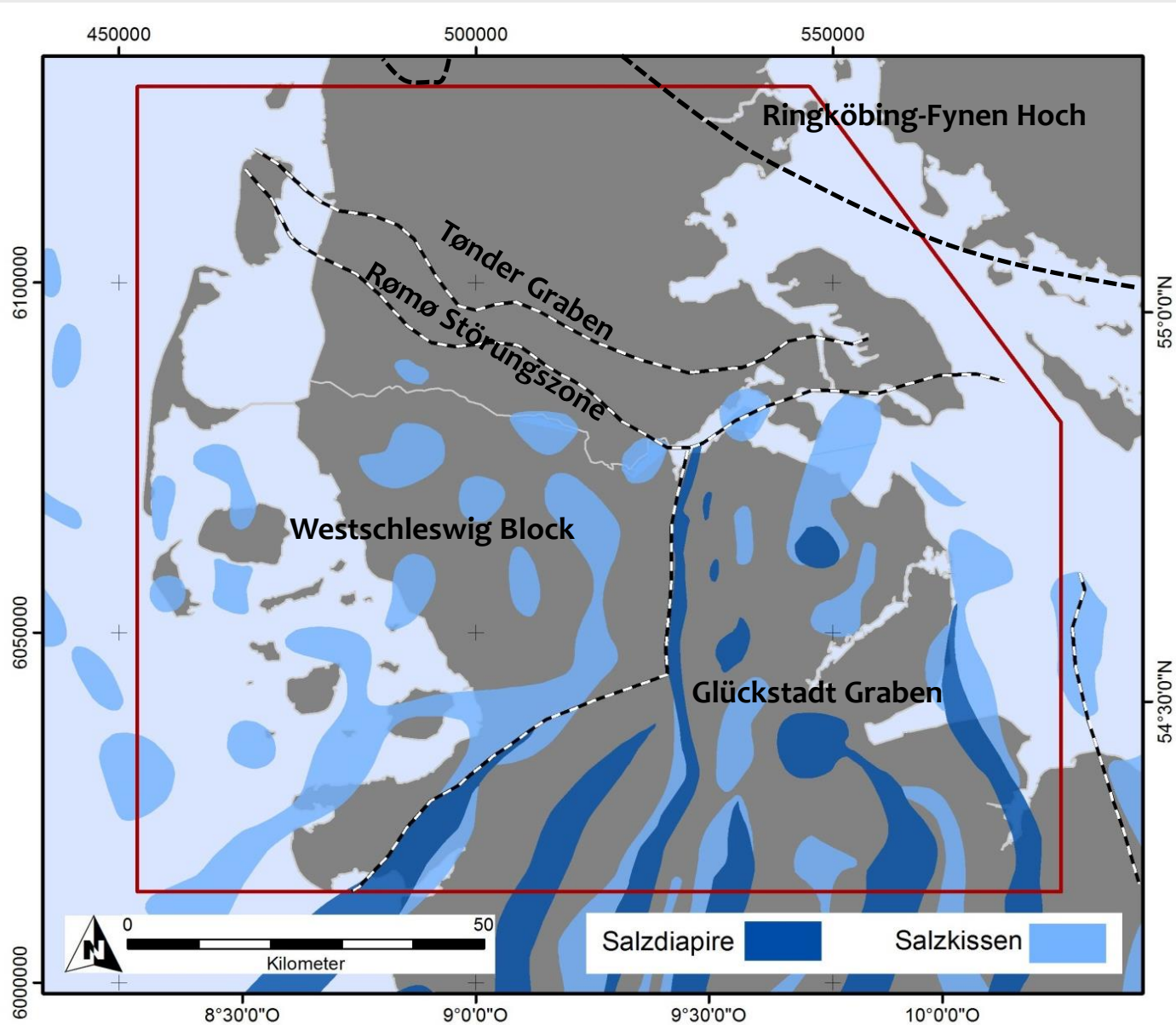
Institut for Geoscience
Geologi

**Modelling of the temperature field**

crossing the border: same sky, same landscape



but different underground conditions



S-Jutland
underground
dominated by
fault systems

**N-Schleswig-
Holstein**
underground
dominated by salt
structures

GEUS/LLUR 2016



geothermal reservoir rocks – lateral variations of depth and thickness

Period/Era	Age/Formation	SH	
		Reservoir	Seal
Tertiary	ca. 1.8		
	Pliozän		
	Miozän		
	Oligozän	Chatt	
	Eozän	Rupel	
Cretaceous	ca. 65		
	Maastricht		
	Campan		
	Santon		
	Coniac		
	Turon		
	Cenoman		
	Alb		
	Apt		
	Barrême		
Jurassic	ca. 145		
	Berrias / Wealden		
	Tithon		
	Kimmeridge		
	Oxford		
	Callov		
	Bathon		
	Bajoc		
	Aalen		
	Toarc		
Triassic	ca. 250		
	Pliensbach		
	Sinemur		
	Helwig		
	Rhätkeuper		
	Steinmergelkeuper		
	Oberer Gipskeuper		
	Schilfsandstein		
	Unterer Gipskeuper		
	Lettenkeuper		
Permian	ca. 250		
	Ob. Muschelkalk		
	Mittl. Muschelkalk		
	Unt. Muschelkalk		
	Rot		
	Solling-Folge		
	Hardegsen-Folge		
	Detfurth-Folge		
	Volpriehausen-Folge		
	Quickborn-Folge		
Carbon.	ca. 250		
	Bernburg-Folge		
	Calvörde-Folge		
	Fulda-Folge		
	Friesland-Folge		
	Ohre-Folge		
	Aller-Folge		
	Leine-Folge		
	Stäufurt-Folge		
	Werra-Folge		
Zechstein			
Rotliegend			
Oberrotliegend			
Unterrrotliegend			
Oberkarbon			



Dogger (Mittlerer Jura)

Rhät (Oberer Keuper)

Gassum Fm.

Mittlerer Buntsandstein

Bunter Sandstone Fm.

GEUS/LLUR 2016

GEUS, LLUR (2016):
GeoPower - Varme fra
 undergrunden til Sønderjylland –
 Schleswig/Erdwärme für die
 Region Südjütland - Schleswig
 public report of the
 GeoPower project

data base: drillings

Jutland: 18

Basis M. Bunter: 14

Basis U. Bunter: 13

Basis Zechstein: 11

Schleswig-Holstein: 210

Basis Tertiär: 156

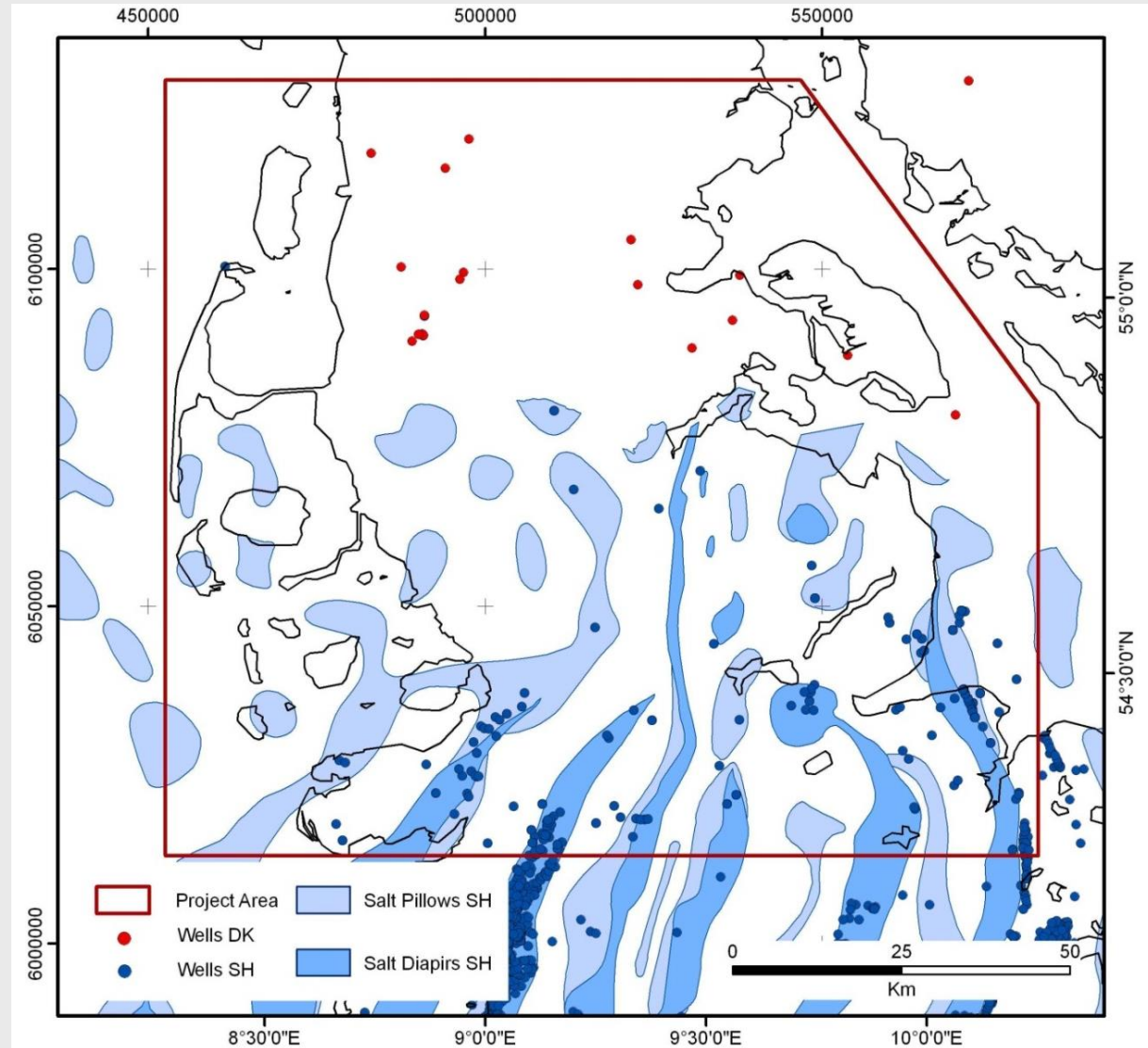
Basis Kreide: 130

Basis Keuper: 13

Basis Röt: 9

Basis Bunter: 5

Basis Zechstein: 5



(GEUS DK, Kohlenwasserstoff-Datenbank der Länder – Landesamt für Bergbau, Energie und Geologie Niedersachsen)

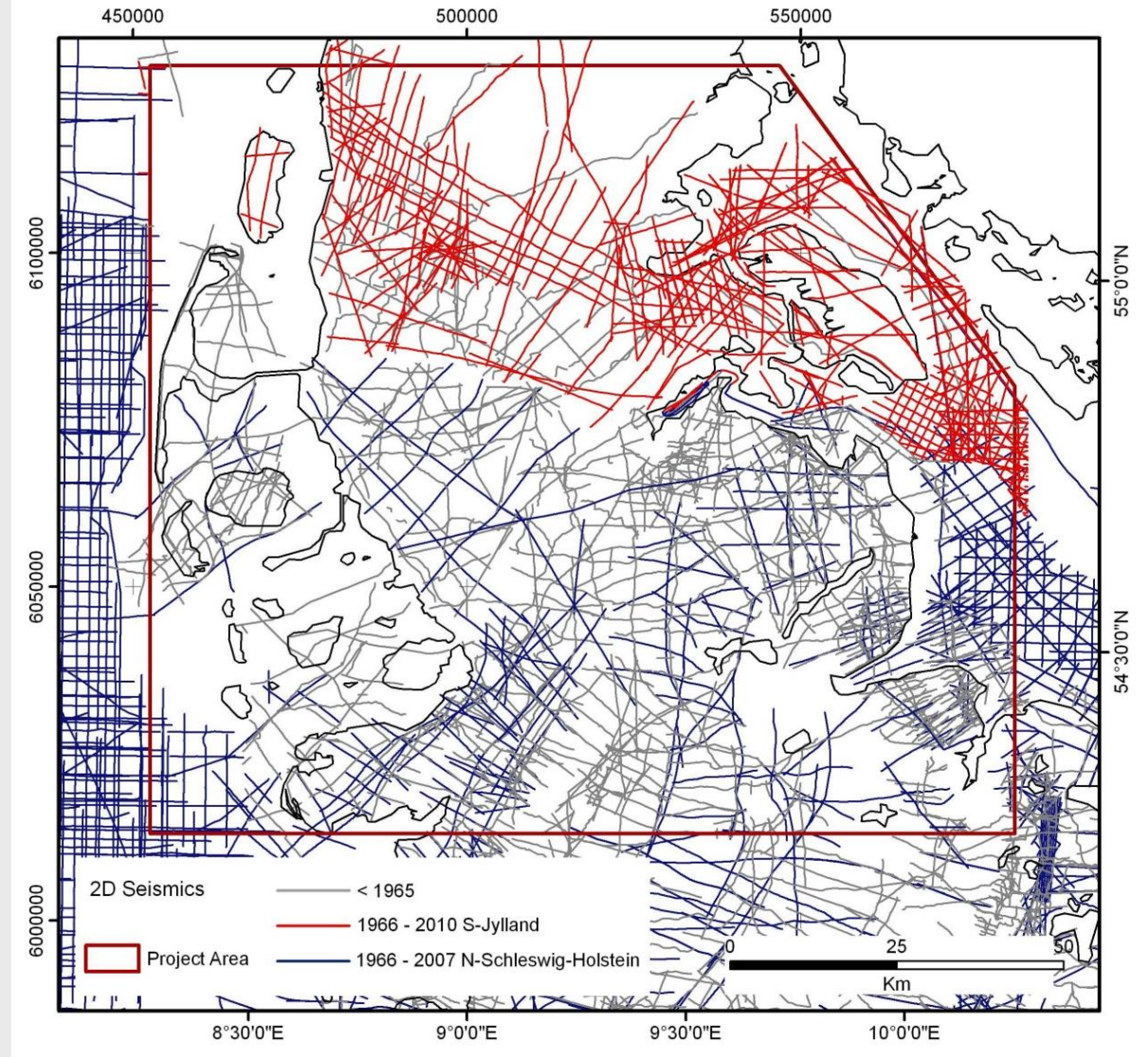
GEUS/LLUR 2016

data base: geophysics

reflection seismic profiles

Jutland: 360
 1942 – 1965: 36
 1966 – 2006: 324

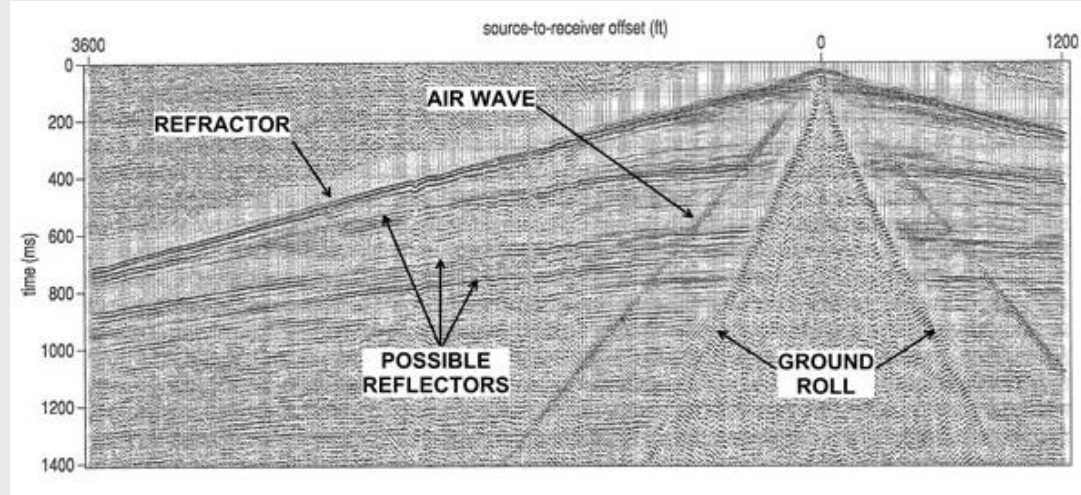
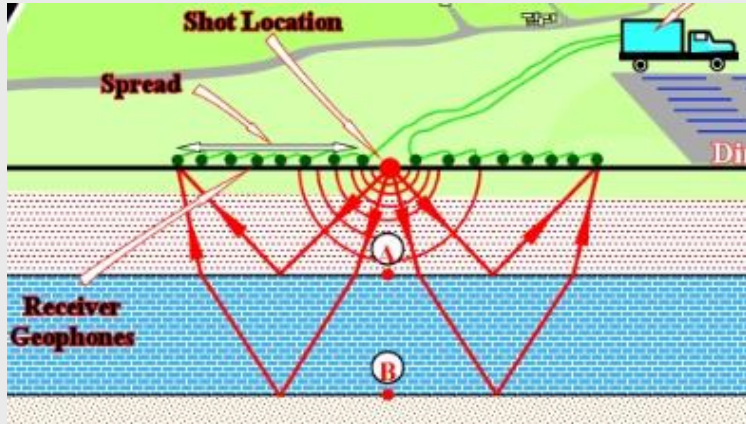
Schleswig-Holstein: 955
 1942 – 1965: 716
 1966 – 2006: 239



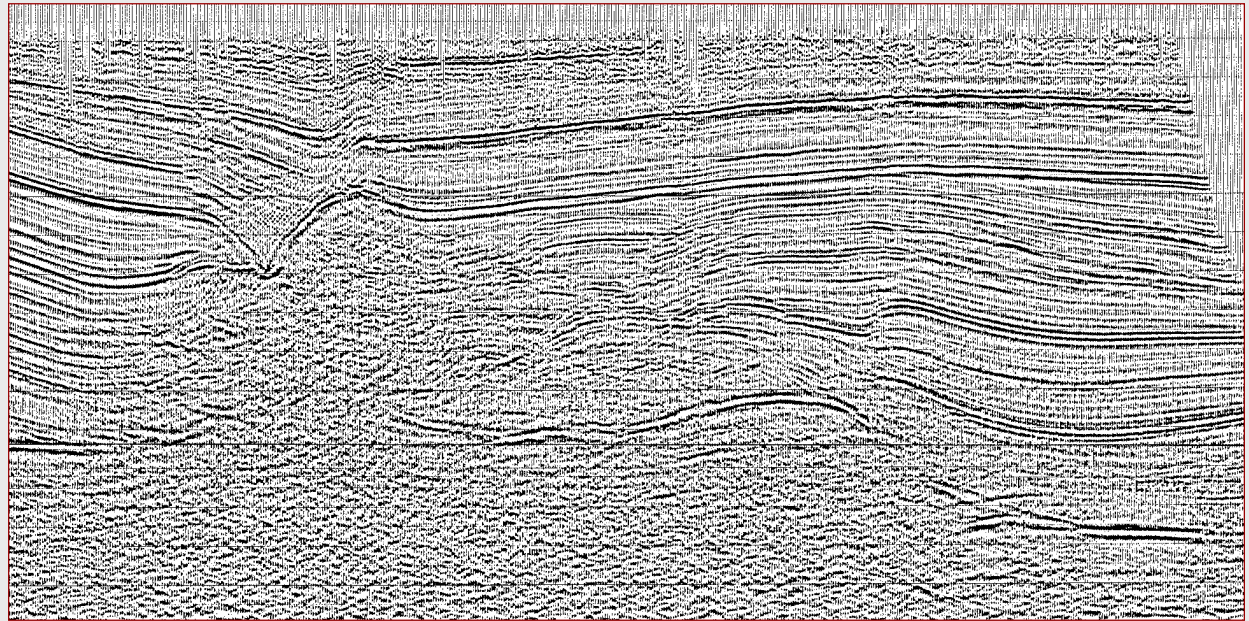
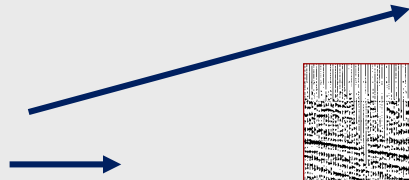
(GEUS DK, Kohlenwasserstoff-Datenbank der Länder – Landesamt für Bergbau, Energie und Geologie Niedersachsen)

GEUS/LLUR 2016



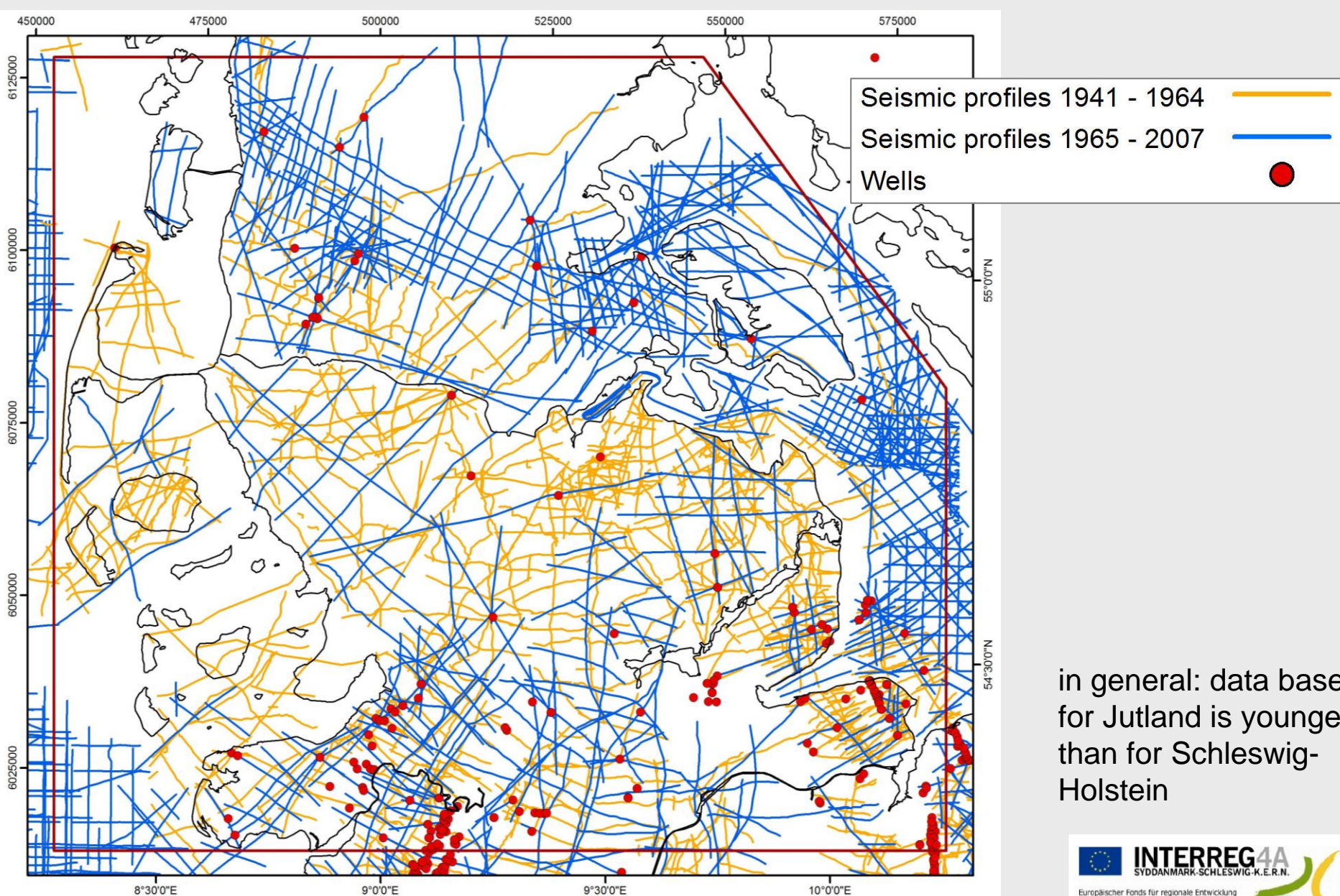


1942 – 1965:
after 1966:



(GEUS DK, Kohlenwasserstoff-Datenbank der Länder – Landesamt für Bergbau, Energie und Geologie Niedersachsen)

GEUS/LLUR 2016



in general: data base for Jutland is younger than for Schleswig-Holstein

additional data base

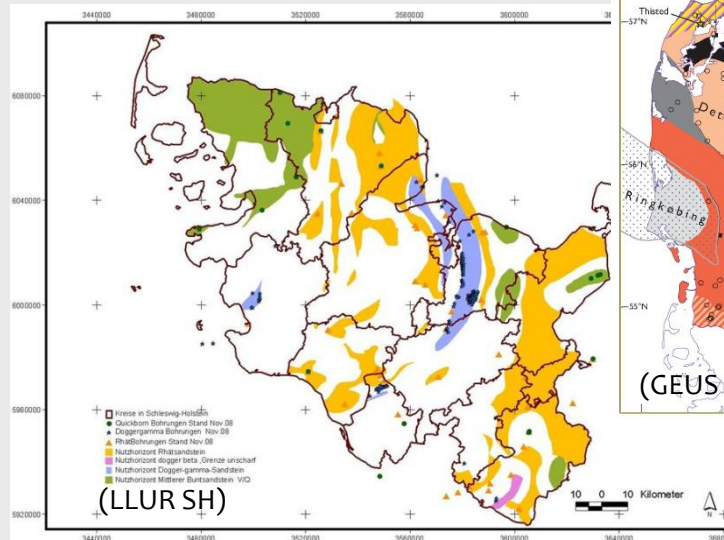
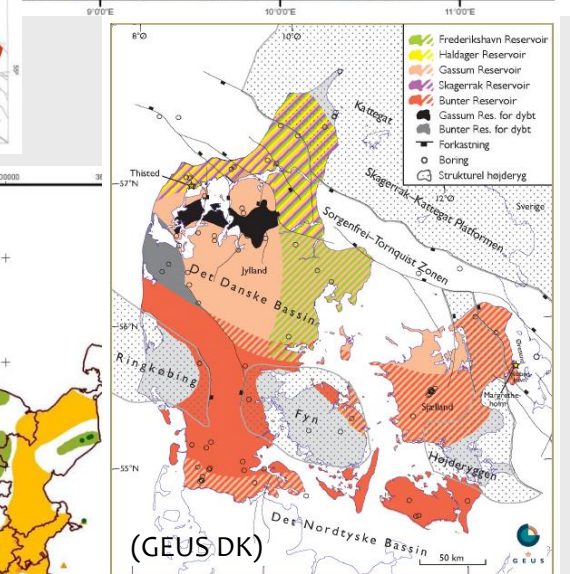
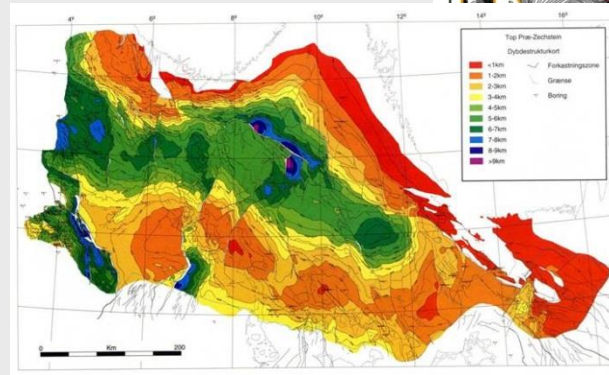
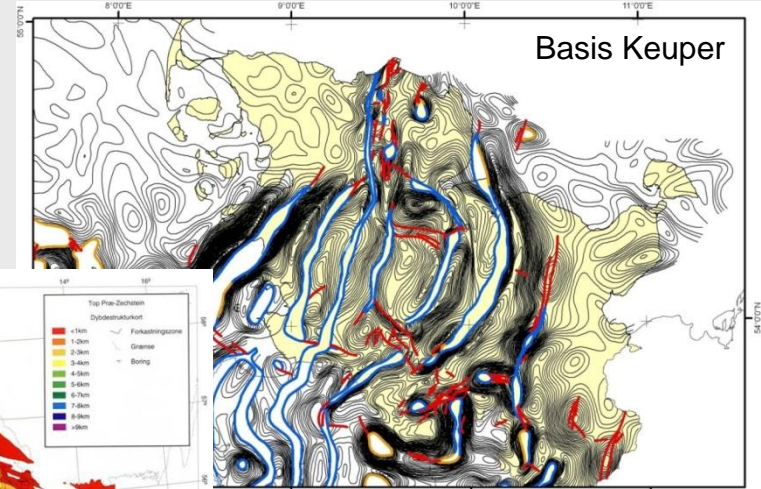
Geotektonischer Atlas von NW-Deutschland

(Baldschuhn et al. 2001, BGR)

Studies on geopotential by GEUS DK and LLUR SH

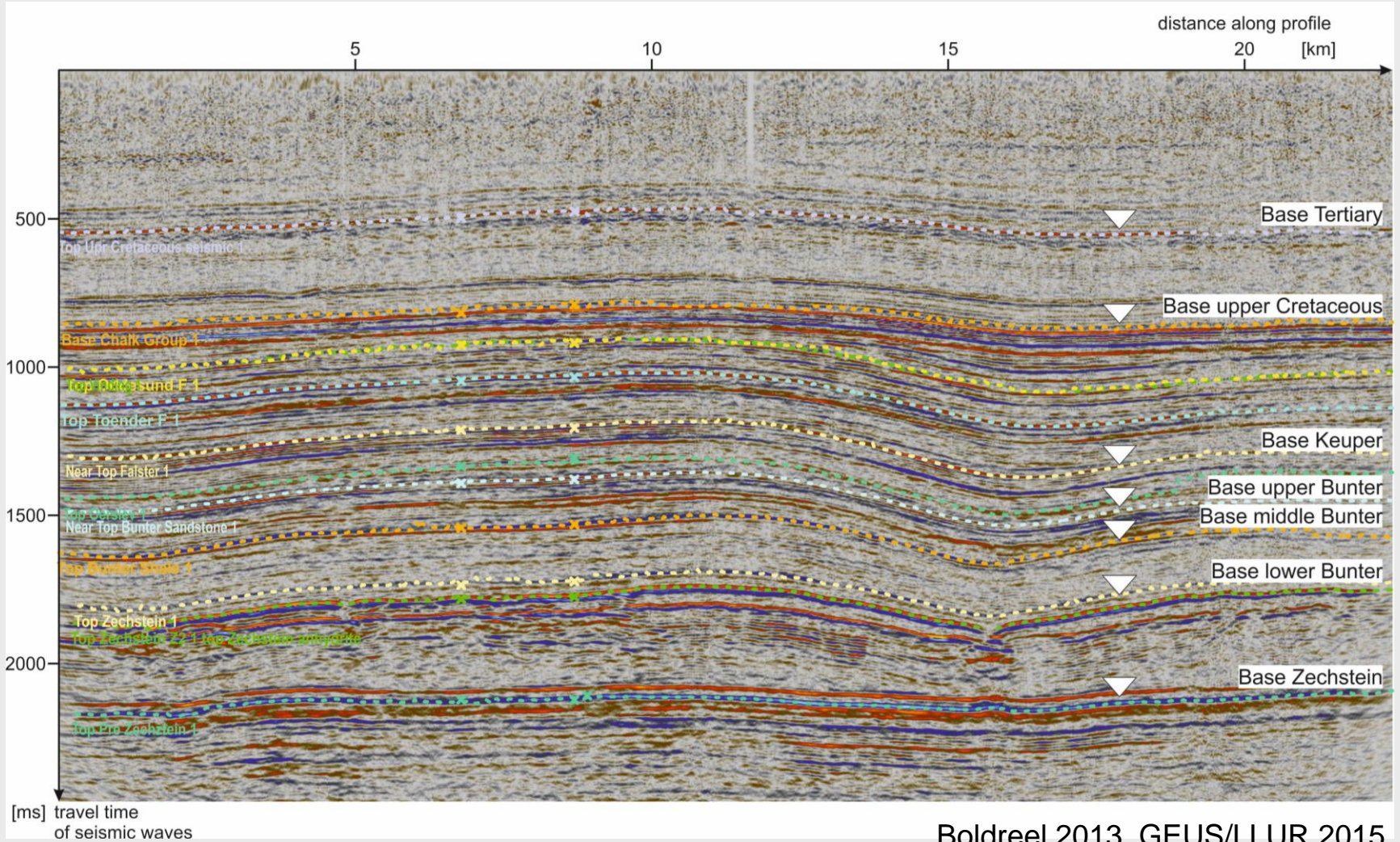
published maps

(z.B. GEUS DK, Vejbaek et al. 1997, 2007)



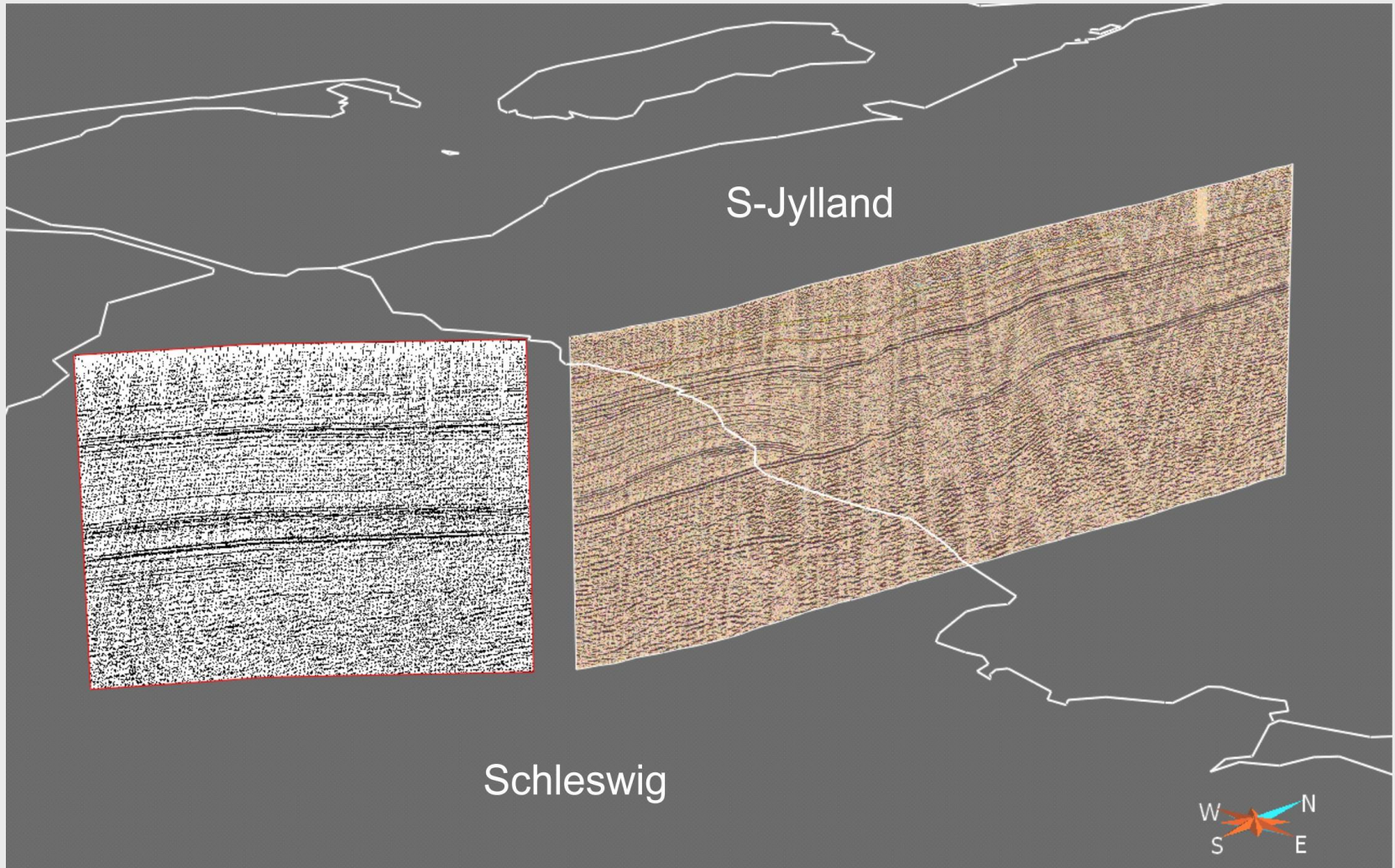
GEUS/LLUR 2016

reflection seismic data interpretation (example from Jutland)



Boldreel 2013, GEUS/LLUR 2015

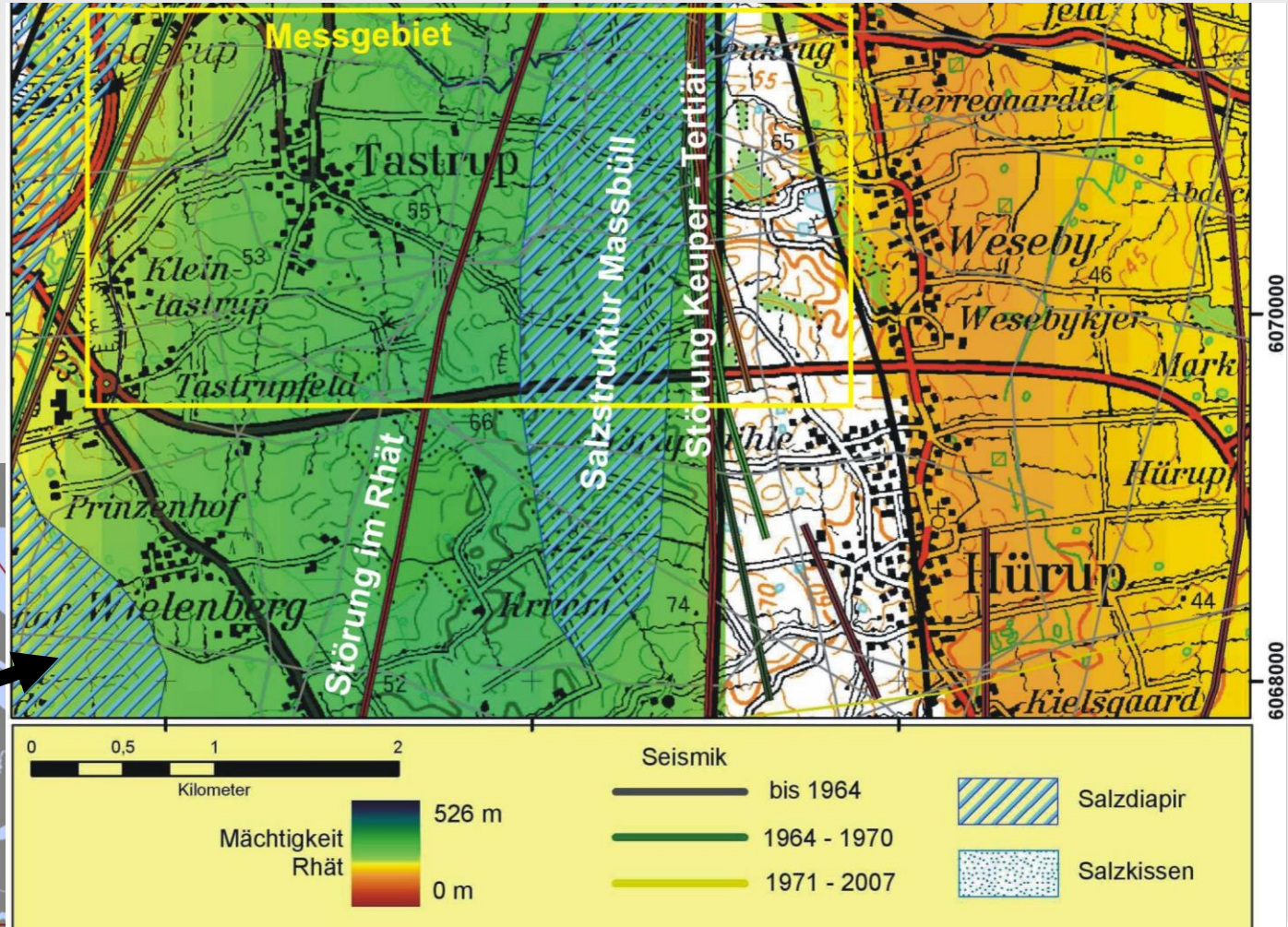
good match of seismic data



GEUS/LLUR 2016

closing of a data gap near Flensburg

uncertain
location of a
saltstructure



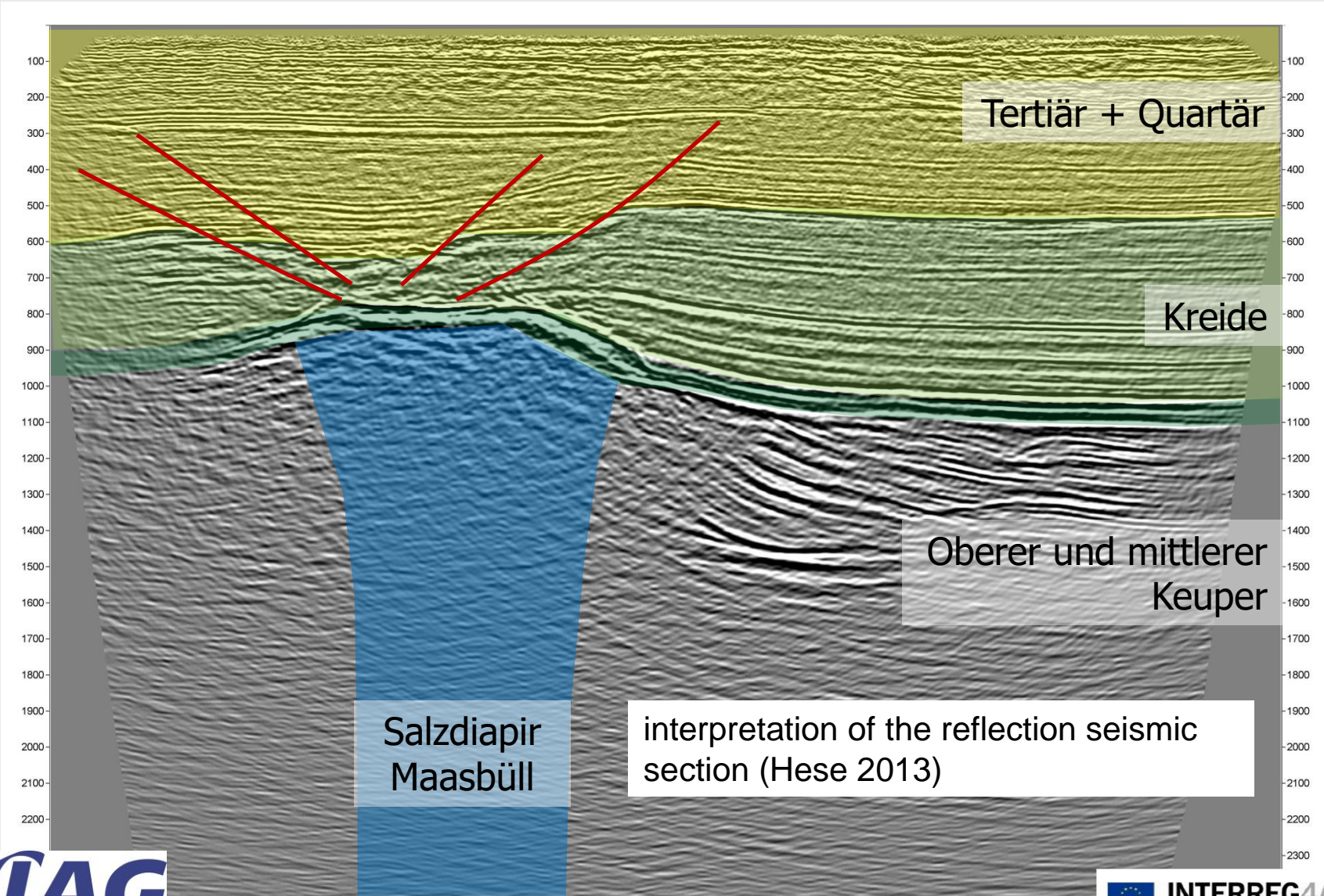
Mecking 2013

handmade reflection seismic profile

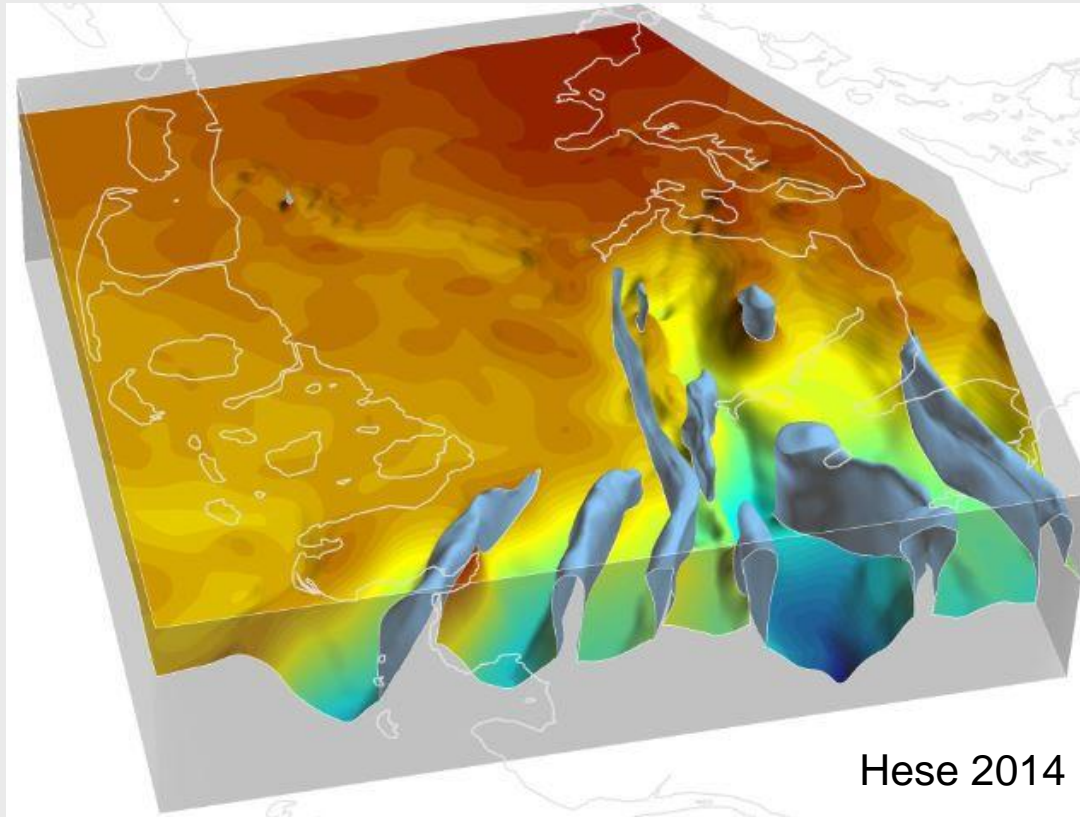


Kiel University in
cooperation with
Leibniz-Institut
für Angewandte
Geophysik
Hannover (LIAG)
and LLUR-SH



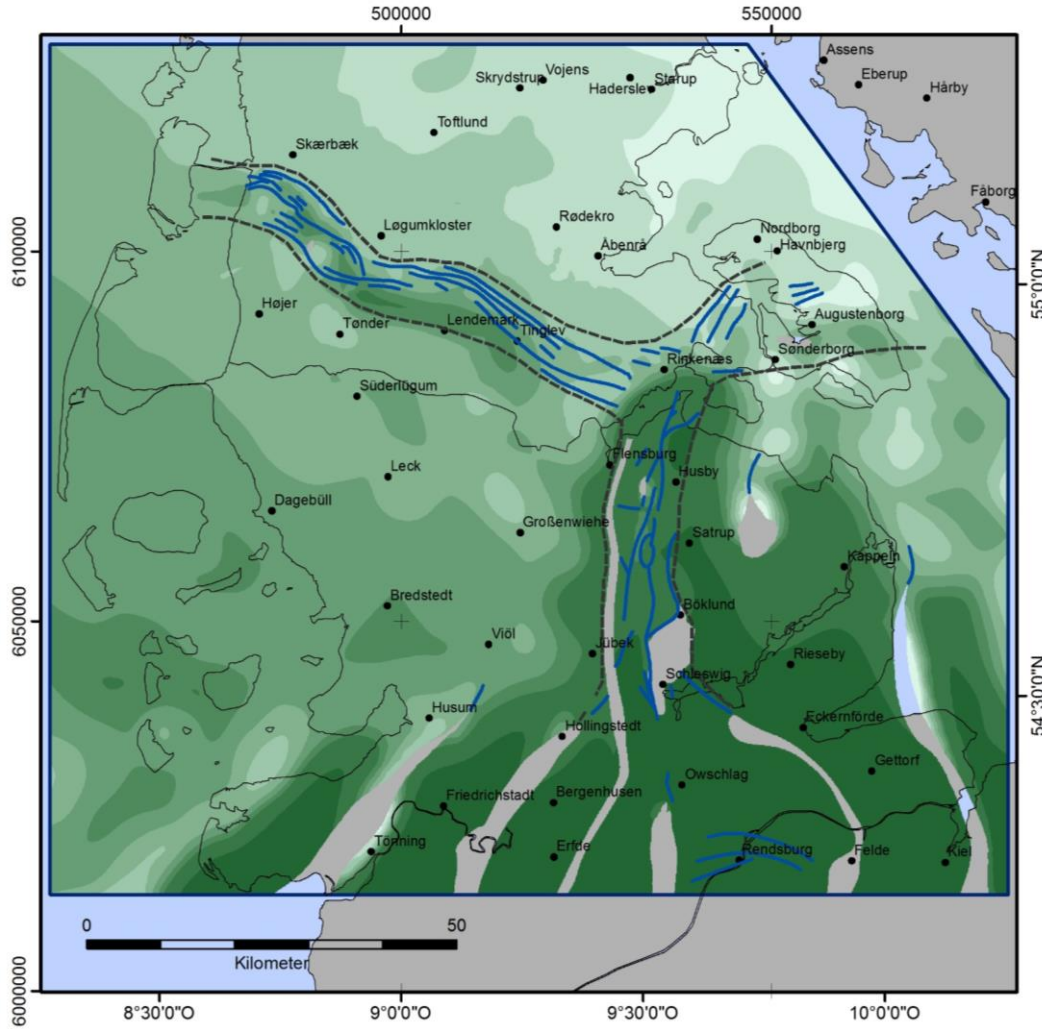


our result: GoCAD model of the project region



deducible from the model

- synthetic drilling for each location
- synthetic cross sections anywhere
- for each layer of the model: maps of depth and thickness



— Top Middle Bunter fault traces
 - - - Trend of the fault system

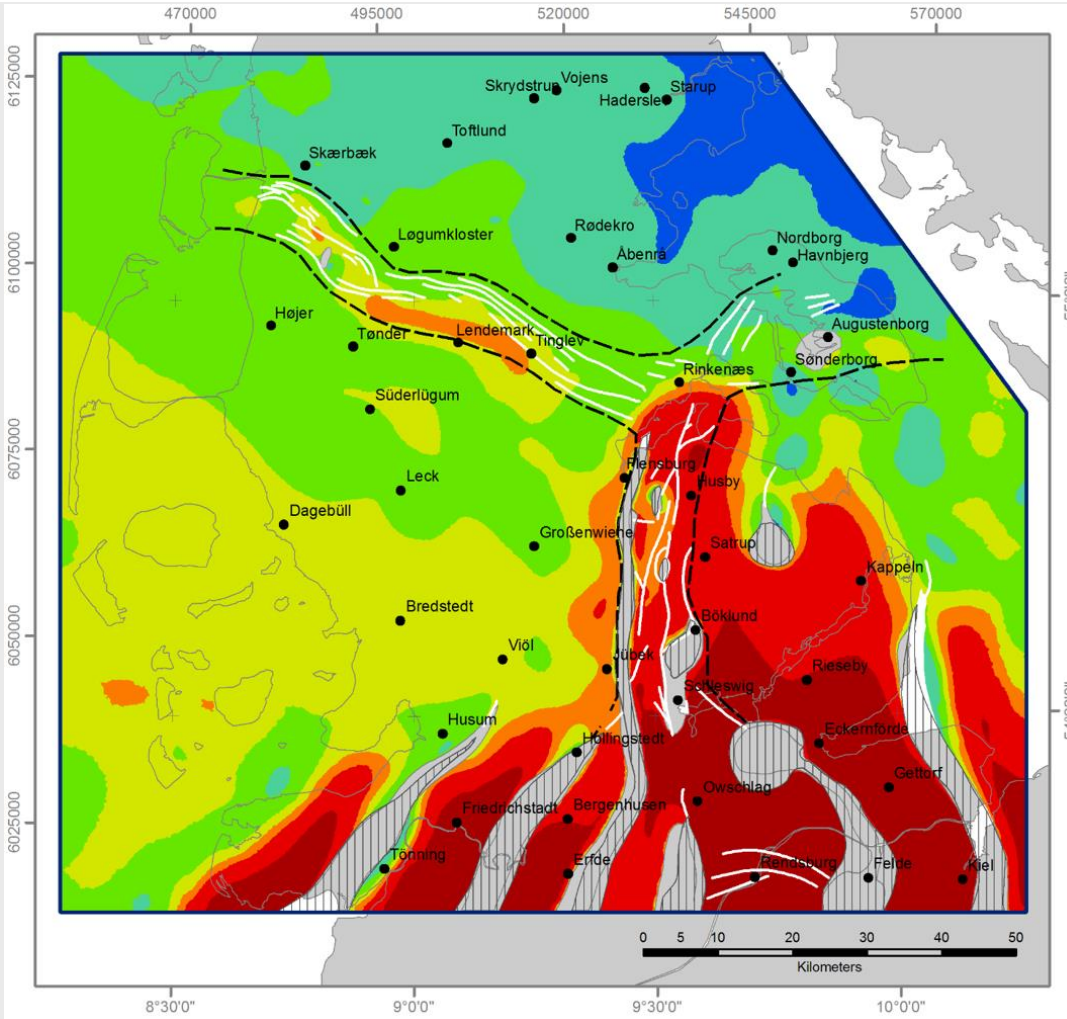
example of thematic maps:
 depth to top of reservoir horizon
 middle bunter

GEUS/LLUR 2016

Middle Bunter

Top (m)	-1.500 - -1.250	-2.000 - -1.750	-2.500 - -2.250
	-1.250 - -1.000	-1.750 - -1.500	-2.250 - -2.000
			-3.500 - -2.500
			>-7.200 - -3.500



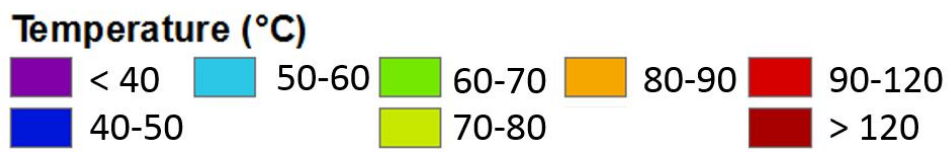


Trend of fault system
 Salt diapir and salt wall

temperatur model - based on
 the geological model,
 temperature logs and thermal
 conductivity of rocks

Fuchs & Balling 2016 a, b

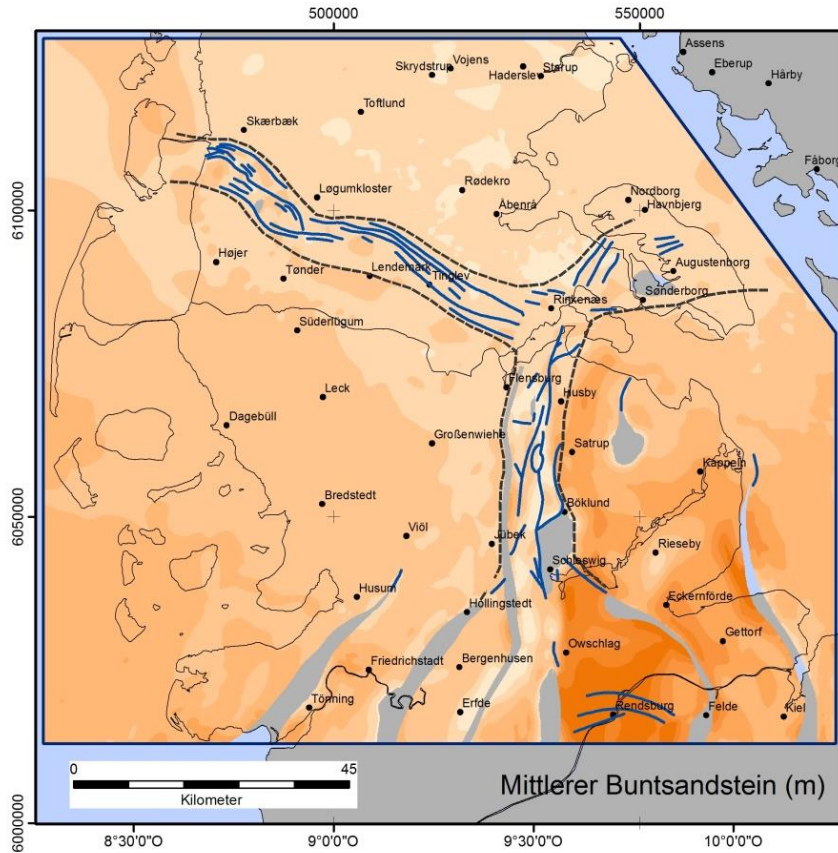
Top Bunter sandstone



Hydrothermal reservoir horizons, requirements for use:

- Temperature: 60°C (1500 m) without heatpump (Schulz 2008)
- Porosity: 20%
- Permeability 0,25 D
- and: sandstone thickness at least 15 m (Matthiesen et al. 2013)

one Problem left: the reservoir horizons mostly have a considerable thickness, but are formed as a mixed layering of sand- und mudstone

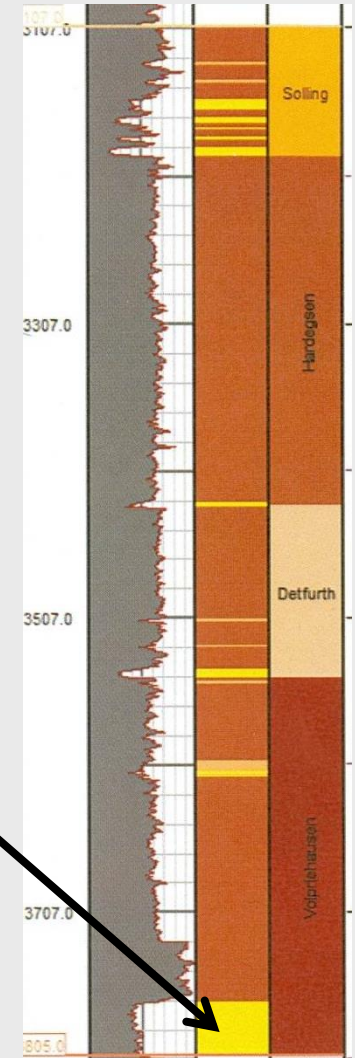


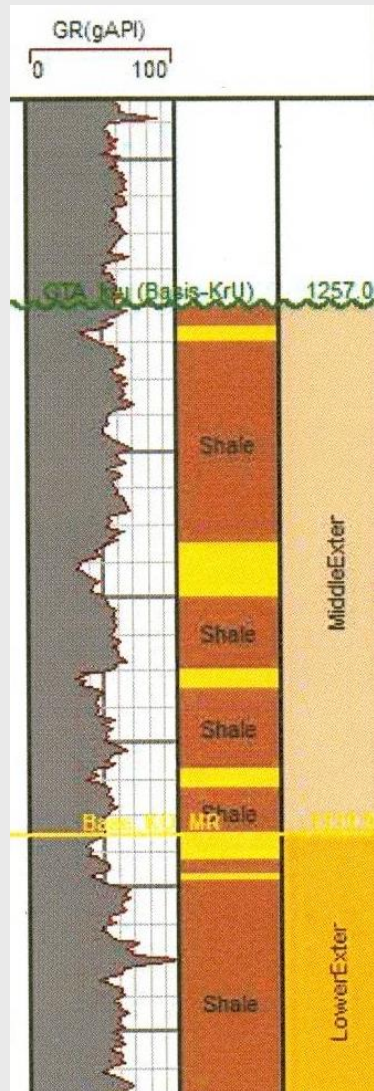
Legende

Mächtigkeit (m)	51 - 250	501 - 750	1001 - 1250
< 50	251 - 500	751 - 1000	1251 - 1500
		1501 - 2130	

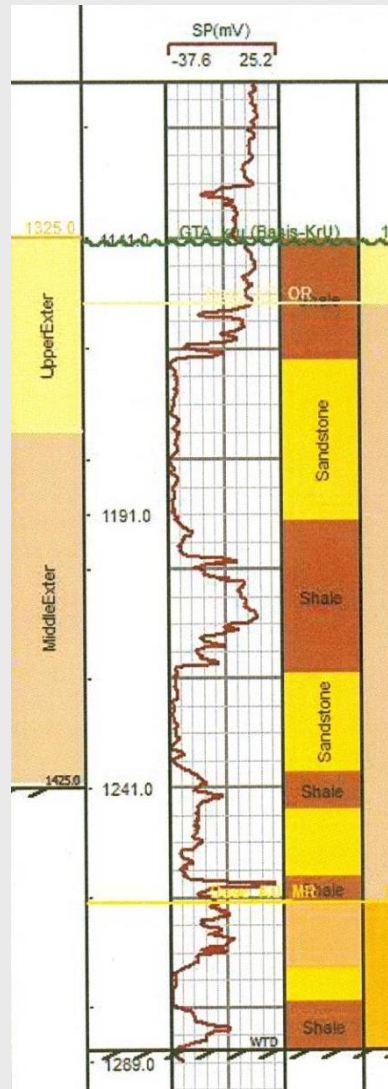
Sandstone

GEUS/LLUR 2016





Gamma Ray (GR)



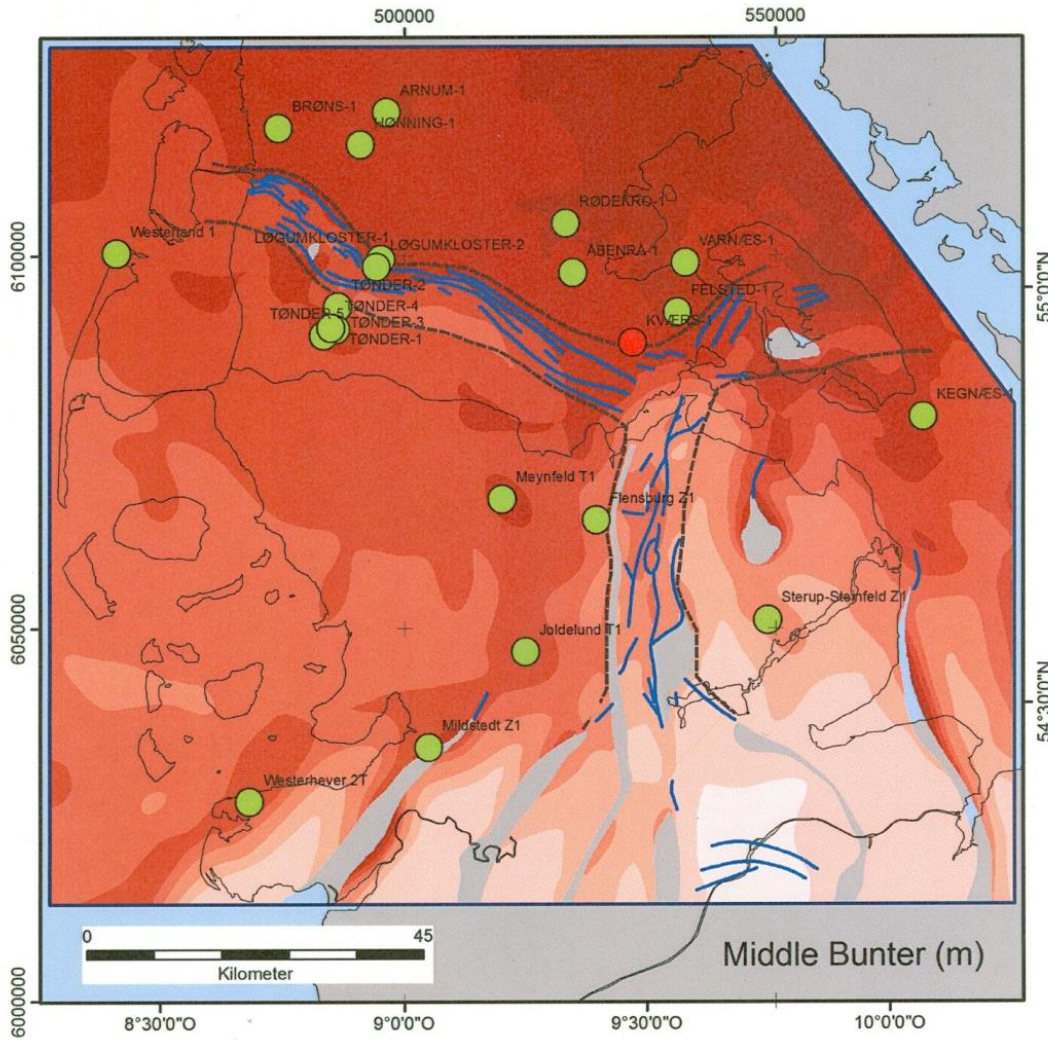
Eigenpotential (SP)

Interpretation of borehole logs (mostly gamma and self potential) in terms of sandstone thickness in the reservoir horizon

- 2038 m Tonstein, dunkelbraun, r grünstichig, z.T. heller gefleckt feinsandig, vereinzelt anhydritis Daneben wenig Anhydrit (zerbohrt)

- 2086 m Sandstein, hellgrau, brä durch grüne, orange und schwarze kelt, glimmerarm. Gestein überwie

GEUS/LLUR 2016




Bunter Sandstone

● at least 15 m of sand detected in the borehole

GEUS/LLUR 2016

Legend

Base (m)	-7499 - -5000	-3999 - -3000	-2499 - -2000
	-9300 - -7500	-4999 - -4000	-2999 - -2500
			-1999 - -1500

- public report including thematic maps
- geological model part of the geothermal information system GeotIS
operated by Leibniz Institute of Applied Geophysics 
- geological model is base for consultancy and further research
at GEUS and LLUR-SH

and now?

open for new cooperation!