[PS]Insights into Basin Formation and Lithospheric Structure of the Barents Sea*

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Search and Discovery Article #30093 (2009)
Posted May 17, 2009

*Adapted from poster presentation at AAPG International Conference and Exhibition, Cape Town, South Africa, October 26-29, 2008. Companion presentations are "The Use of Multi-Level Potential Field Data in Regional, Geophysical Modeling" (Search and Discovery Article #40426 (2009)) and "Satellite Gravity and Geoid Studies Reveal the Formations Underlying Large-Scale Basin Structures" (Search and Discovery Article #40427 (2009)).

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Abstract

We present a 3D density model of the Barents Sea Region, which provides new insights into the regional lithospheric setting and evolution of the regional sedimentary basins. The tectonic setting and lithospheric structure of the Barents Sea area is still not completely understood due to the lack of integrated geophysical studies. Seismic information is available from the seismic velocity models BARENTS50. In a first step, we analyse the relation of the wavelength content in the potential fields and possible source location or density contrast. We focus on the upper mantle density variation using geoid undulations and on the basement geometry by the gravity field anomaly. Analysis of magnetic data additionally helps to study the upper basement structure. We present a forward model that allows us to adjust the model parameters in order to get the best fit between the modeled and observed anomalies simultaneously for the gravity field, geoid and magnetic anomalies. We also discuss the accuracy, uncertainties and limitations of our model in respect to the available database. The 3D model defines the basin geometry and the crustal structure of the Barents Sea Region on a regional scale. The density distribution gives new insights into the link between lithosphere structure, basement properties and basin architecture. The different basin geometries between the Eastern and Western Barents Sea are clearly expressed by different lithospheric structures, and especially the mega-scale basins in the Eastern Barents Sea are an outstanding feature, as they correlate with a high-density/velocity structure in the upper mantle and visible in filtered geoid undulations. The link between the upper mantle structures and the Eastern Barents Sea Basin is certainly a key to unveil the formation of the mega-basins with up to 20 km of sedimentary succession.

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1- INTRODUCTION

We present a new regional study of the Barents Sea.
Combining different databasis, we developed a new 3D density model of the Barents Sea, which combines the velocity model Barents50 with detailed modeling of potential field data.
The model is a base to increase our understanding the basin and lithospheric structure of the entire Barents Sea region and constrain its different structural styles.
The new model will not only apply to studying the the lithospheric geometry and its density distribution, but also to link shallow and deep parts of the lithosphere.
Considering seismic data, three possible geological scenarios have been tested on the Eastern Barents Sea basin. The loading effect and the loading balance have been calculated for all three cases and the results are discussed with respect to the basin formation in the Eastern Barents Sea.

2- THE DATABASE

- Seismic data
- Structural maps
- Petrophysical data
- Velocity-density relation

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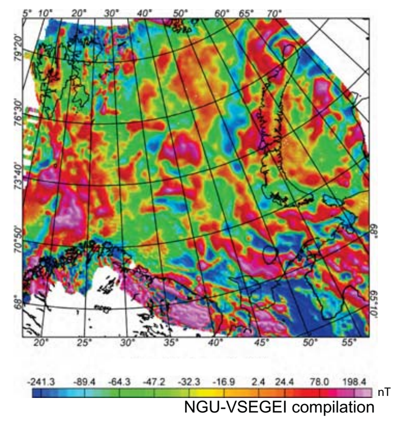
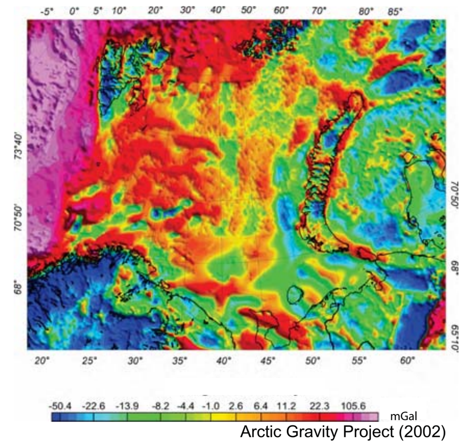
- Crustal geometry
- Velocity distribution
- Density estimations

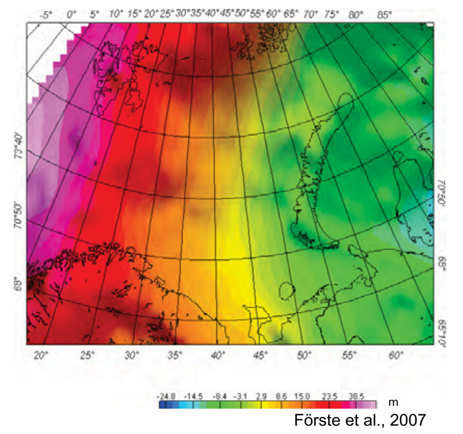
3- POTENTIAL FIELD DATA



Magnetic anomaly map reflects mainly the magnetic properties of the crust



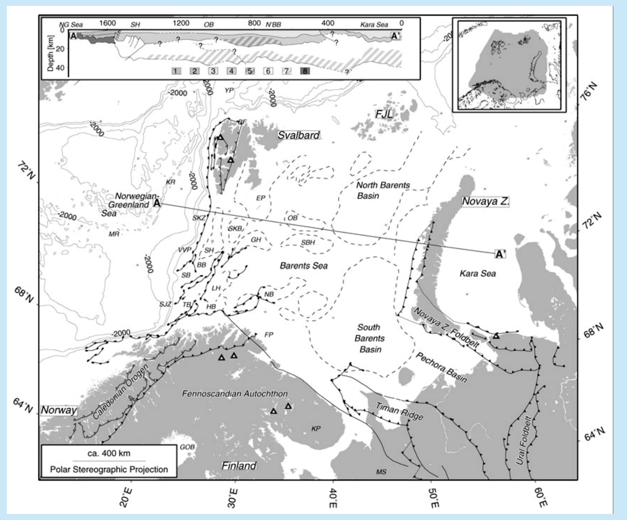
Bouguer anomaly map shows density distribution in the lithosphere



Geoid undulations reflect large-scale density anomalies in the lithosphere and below

4- THE NEW DENSITY MODEL

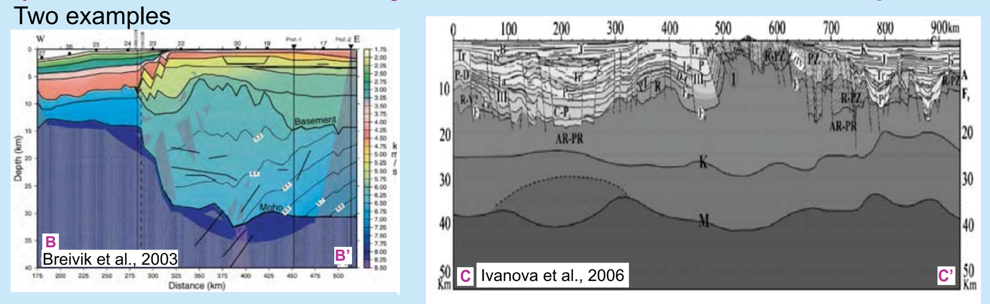
An initial model was set up by combining all the pre-existing information.
Information from the Barents50 model was integrated with 2D seismic profiles to constrain the geometry of the model. Densities were calculated from seismic velocities.
The complex geometry of the basins, basement and crust in the Barents Sea was addressed by dividing the study area in different geological areas. The simplified 3D structure reflects the changing petrophysical properties (density, velocity).
A comparison between the modeled and observed potential fields allowed us to interactively converge towards a better and reliable solution.



Basin outline in the Barents Sea (Ritzmann et al., 2007)

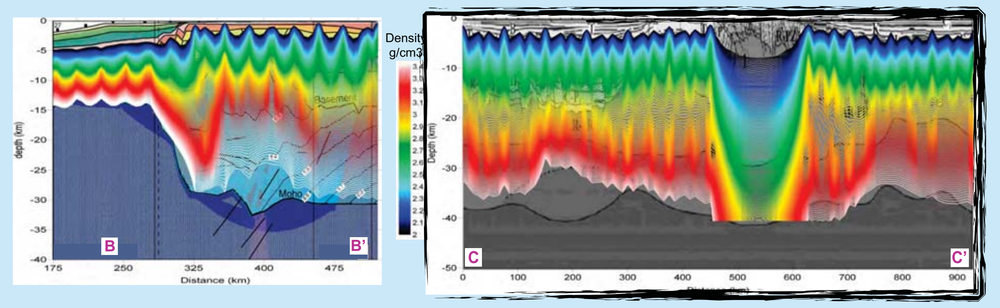
I) Seismic data -> velocity distribution and structural interpretation

Two examples



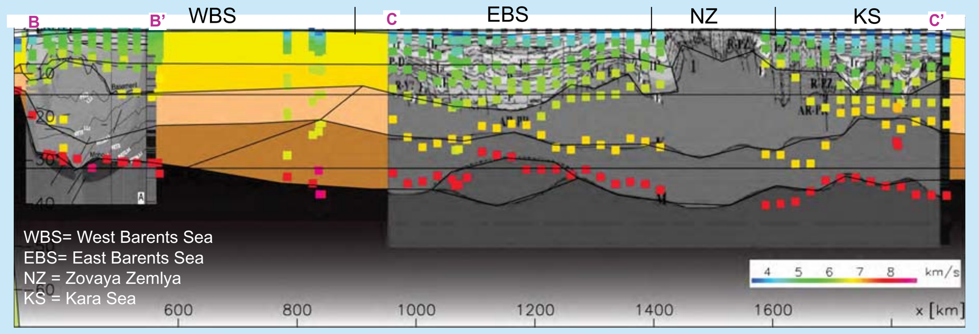
II) Velocity/density relations -> densities distribution estimation

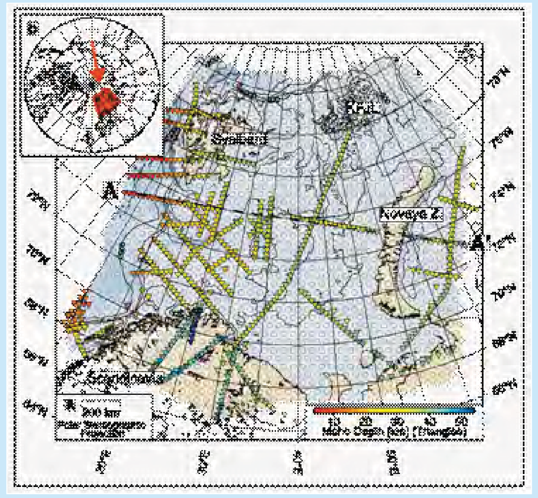
The crustal seismic model BARENTS50 (Ritzmann et al., 2007) was converted in densities using velocity/density relations for crystalline rocks (Christensen and Mooney 1995).



III) The density 3D model set up: view along a transect

The collected information has been integrated in the definition of the density model





IV) The velocity model Barents 50

The figure to the left shows the diistribution of seismic lines used to define the velocity model with 50 km x 50 km resolution (Ritzmann et al., 2007).

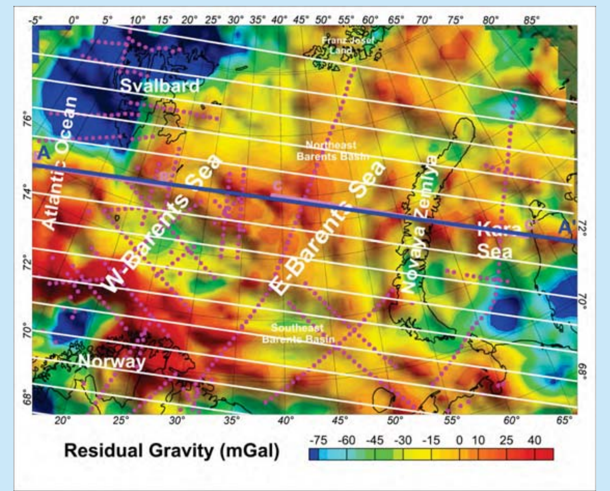
This low-resolution model, built for earthquake tomography, is the basis for the set-up of the new 3D model.

V) A discussion of alternative density models for the Barents Sea

Along the transect (AA') through the 3D Barents Sea density model, we discuss three alternative structures for the crust and upper mantle in terms of their response in the gravity field and isostatic balance of the crust. The models address the uncertainties in the determination of the crust-mantle boundary between the Eastern Barents Sea megabasins and models proposing a mixture of mantle and crustal material.
Careful analysis of these models is importnat to understand subsequently the isostatic response of the lithosphere to the large sediment loading (up to 20 km sediment thickness) and to evaluate the evolution of the Eastern Barents Sea basins.
The table to the right shows the parameters used in the model, and below three alternative models are discussed.

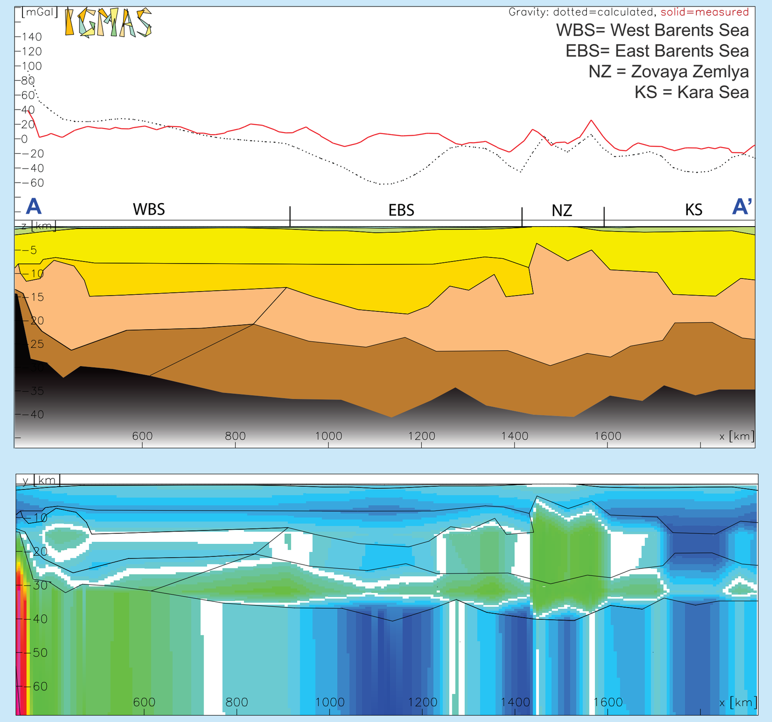
3D bodies:	Model definition	density (g/cm³)
water	water	2,200
upper sediments	upp-sed	2,300
middle sediments	mid-sed	2,550
lower sediments (below 7,5 Km no effect of compaction)	low sed	2,780
upper crust in the West Barents Sea	upp-crustW	2,810
upper crust in the East Barents Sea	lw-crustE	2,870
lower crust in the West Barents Sea	upp-crustW	2,980
lower crust in the East Barents Sea	lw-crustE	3,000
“mantle mixture” high density body	mantle mixture	3,250
upper mantle	upp-mantle	3,321
lower mantle	lw-mantle	3,321
low density mantle due to the Atlantic rifting	rif-anom-mantle	3,170

The Barents Sea is divided in 12 3D-bodies characterized by constant density.



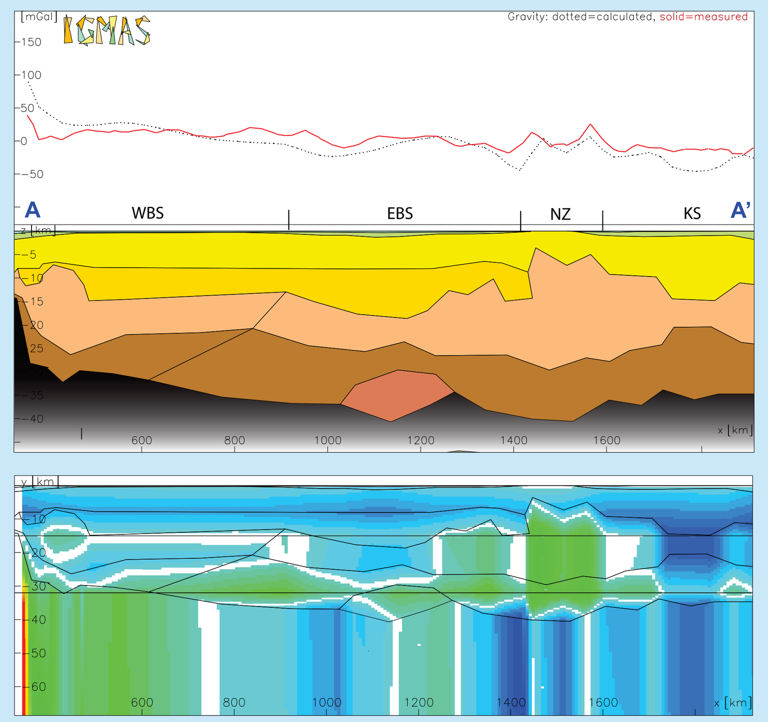
Residual gravity as calculated as the difference between the modeled and observed gravity field for model 2: Mantle mixture - high-density body The 3D model is built along profiles, indicated by the white lines, with the software package IGMAS, developed by the University of Kiel, Germany. The transect AA'is used to present the model(s) in more detail to the left.

Deep Moho (thickening of the crust)



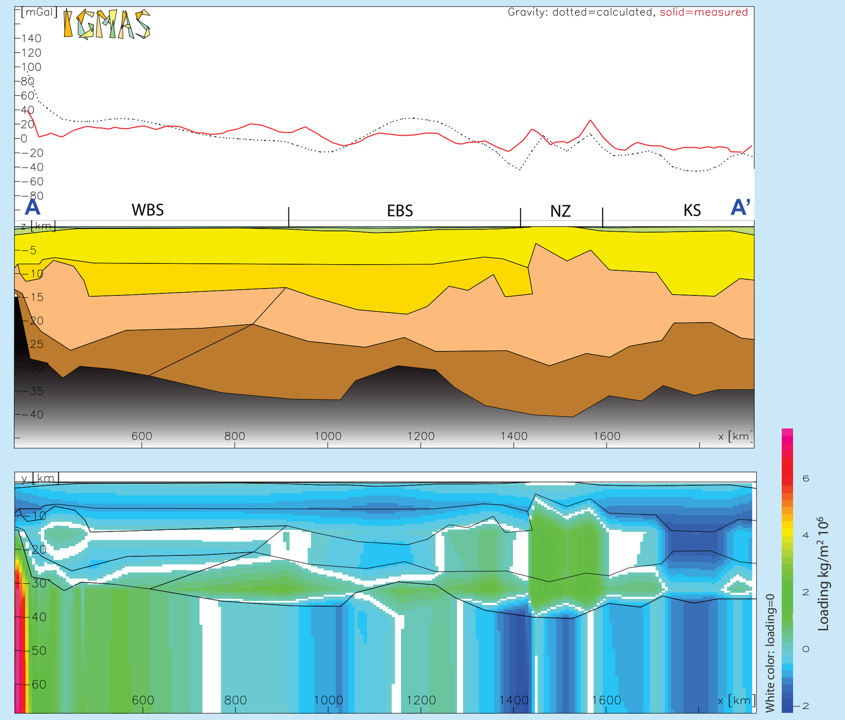
- This model shows a deep Moho (~38km) below the ESB.
The gravity response of the model gives a reseanable fit to the observed gravity field except the area over the EBS.
- Loading, which represents local isostatic compensation, shows a balance (white color) at about the Moho level.
- Below the EBS mass deficiency is indicated both in the lower crust and upper mantle: additional masses are required.

“Mantle mixture”- high density body



- This model features a high-density body in the lower crust, representing a mixture of crust and mantle material, or possible eclogitization, on top of the deep Moho.
The gravity response of this model shows the best fit with the observed gravity field.
- The loading of the crust is balanced (white color) near the Moho level.
- The model indicates isostatic compensation and does not require additional masses in the upper mantle below the ESB.

Shallower Moho (thinning of the crust)

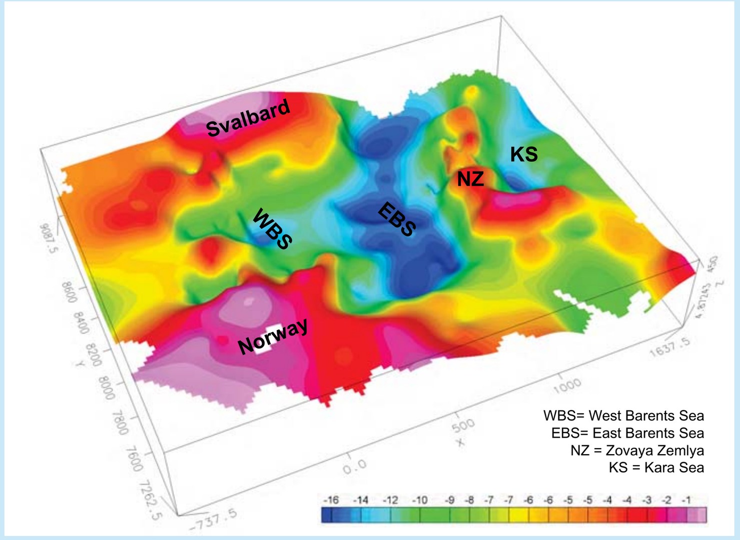


- The model features a shallow Moho (crustal thinning) below the ESB.
- The shallow Moho gives a gravity effect, which is too high compared to the measured gravity anomaly.
- The loading of the crust is balanced at about the Moho level, but below the ESB the loading is not compensated as well as in model 2.

VI) Geological Implications

Hot melted upper mantle material leads to destruction of the continental lower crust → **“Oceanisation” and “basification” (possible eclogitization) of the crust** → rapid **increase of velocity/density** in the crystalline crust below the basins → as a result of density increase the **crustal block sinks** into the upper mantle → **Moho uplift**

“oceanisation” or “basification” of the crust ↔ Moho uplift



3D TOP BASEMENT as extracted from Model 2 with the high-density body showing clearly the differences between the Eastern and Western Barents Sea

5- CONCLUSION

- The available databases were compiled and integrated with potential field data.
- A new 3D density model for the entire Barents Sea is presented.
- We tested three different scenarios for the crustal and upper mantle structure below the Eastern Barents Sea basin.
- The best agreement with the observed gravity field was obtained from the model including a high-density body in the lower crust (a standard deviation of 38 mGal).
-Uncertainties are connected to the interpretation of the seismic data in terms of crustal base.
- The crustal loading illustrates the differences between the WBS and the EBS and the consequences of the different lithospheric structures for the isostatic state of the Barents Sea Region.
- Dynamic modeling has to be performed to test the implications of the different crustal configuration for thee volution of the Easteren Barents Sea basins.
- A preliminary basement configuration is presented, but this part of the model needs further refinement (e.g., incldung more seismic profiles, especially in the Eastern Barents Sea.

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Acknowledgements

This study is part of the PETROBAR project, financed by the PETROMAKS programme of the Norwegian Research Council and StatoilHydro.

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