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The Permo–Triassic Sequence of the Arabian Plate Abstracts of the EAGE's Third Arabian Plate Geology Workshop, Part I

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11892 Heterogeneous gravity data combination for geophysical exploration research: Applications for basin and petroleum system analysis in the Arabian Peninsula

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Introduction

The GOCE satellite gravity mission was launched in 2009 to measure the gravity gradient with high accuracy and spatial resolution. GOCE gravity data may improve the understanding and modeling of the Earth's interior and its dynamic processes, contributing to new insights into the geodynamics associated with the lithosphere, mantle composition and rheology, uplift and subduction processes. However, to achieve this challenging target, GOCE should be used in combination with additional data sources, such as *in-situ* gravimetric, magnetic, and seismic data sets.

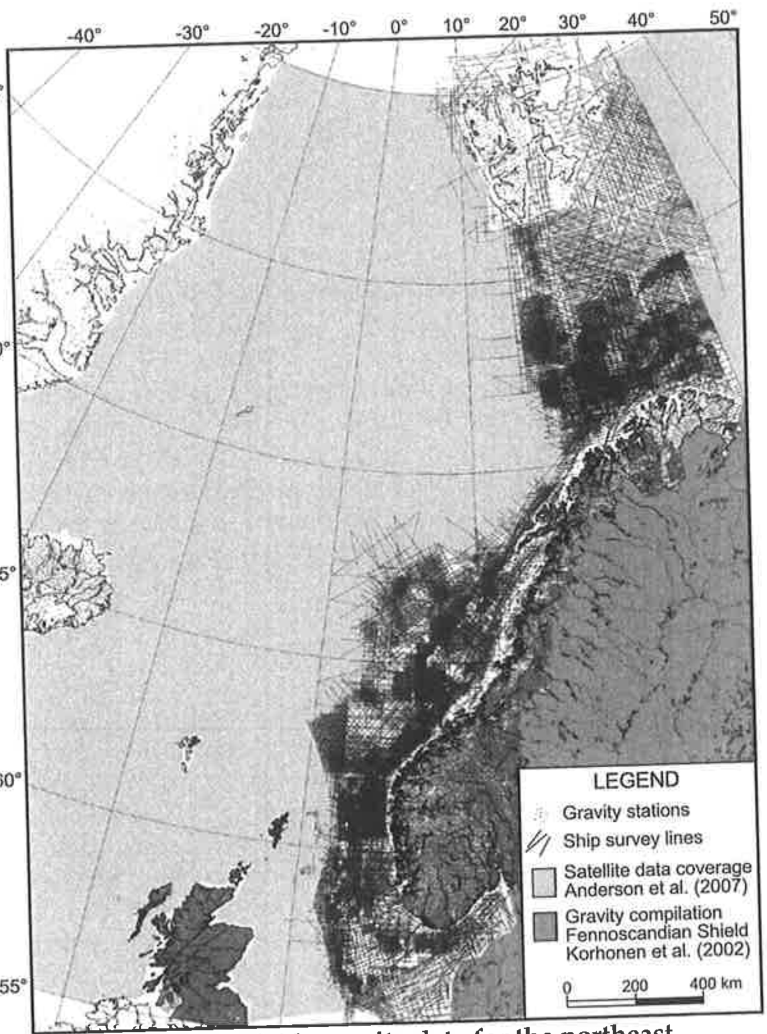

Figure 1: Available gravity data for the northeast Atlantic Margin (Olesen et al., 2010).

We present a study in which it is proposed to invert satellite gravity and gravity gradients, and terrestrial gravity in the well explored and understood Northeast Atlantic Margin. The inversion outcome will be compared with results obtained by means of models based upon other sources like seismic data, magnetic field information or other *in-situ* data. This will provide improved information about the lithosphere and upper mantle.

The GOCE gravity gradients in the gradiometer reference frame will be used in forward and/or inverse modeling in the Northeast Atlantic Margin and the Arabian Peninsula. Not only will the original gravity gradients be used, but they will also be combined with other gravity data, e.g. from GRACE or terrestrial gravimetry (Figures 1 and 2). On the one hand, grids of gravity gradients will be computed, for example at mean GOCE altitude, on the other hand regional, high-resolution gravity fields will be computed using a multi-scale representation.

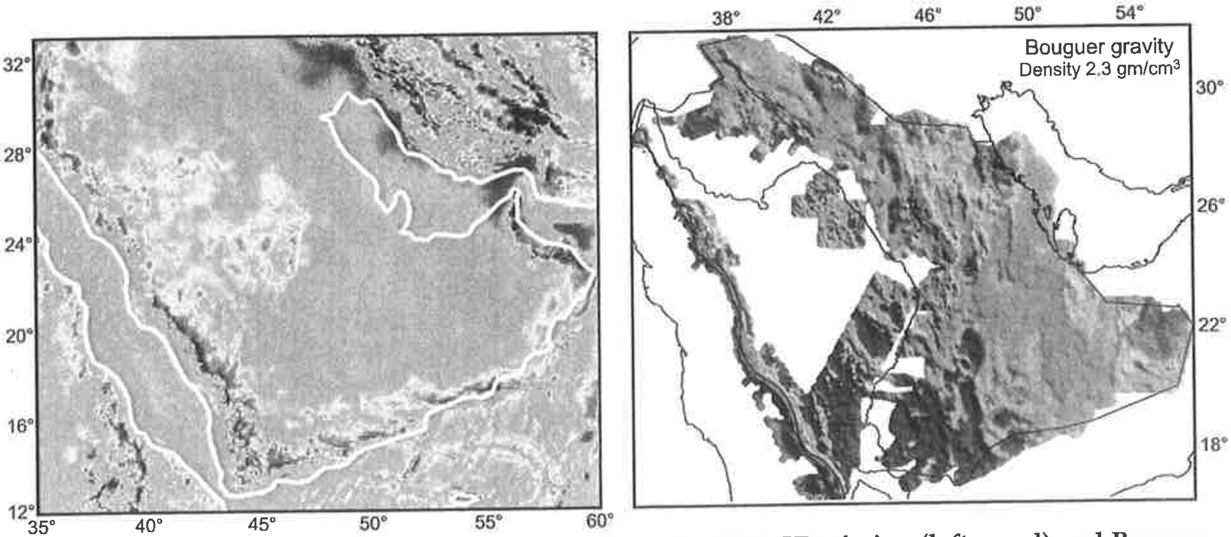

Figure 2: Gravity data from the region obtained from the GRACE mission (left panel) and Bouger gravity anomaly map based on compilation of land and airborne surveys (right panel) (Oncel, 2010).

One of the outcomes of the Atlantic Margin study will be a sensitivity matrix that will be used as input to study the Arabian Peninsula, in general, and the Rub' al-Khali Desert in Saudi Arabia, in particular. In terms of modeling and data availability this is a frontier area. Here GOCE gravity gradient data, in combination with other data, will be used to better identify the structure and composition of the crust and the lithospheres in the region. The improved model of the crust and the lithosphere will allow us to calculate the evolution of the basal heat flow in the region. Based on the improved heat flow model, the maturity of the main source rocks in the study area will be estimated which will improve our understanding of the petroleum systems in the region.

Application for the Arabian Peninsula

Gravity gradient data are generally sensitive to the density structure of the upper crust. It provides a better resolution of the edges of geological features (such as faults, lineaments and large intrusions). Gradient data from GOCE have the potential to identify the extent of different structures with varying densities in the lower crust in the Arabian Plate. Thus, it can help to identify density zonation in the basement and enhance structural boundaries within the crust on a regional (Terranes) scale (Figure 3). Using the gravity anomaly maps obtained from GOCE data, in combination with land-measured gravity data, gravimetrical backstripping of the basin will be performed in order to identify basement inhomogeneity and Moho topography. The outcome of this phase is a model of the crust and the lithosphere of the study area. This includes the thickness and composition of the crust and the lithosphere.

Heat Flow Modeling and Source Rock Maturity

The structural model of the crust and the lithosphere, obtained from the gravity data, is then used for modeling the basal heat flow within the basin. We use a grid-based stochastic tool (PetroProb) developed by TNO to model basal heat flow. It is based on the inversion of basin subsidence data to calculate the tectonic subsidence in the area and the tectonic heat flow (Figure 4). It takes into account the sedimentation, erosion and paleo-water depth history in the basin. It also incorporates the effect of sedimentation infill and heat production in the crust. The uncertainties in the crustal and lithospheric structures are included in the heat flow modeling tool. The tool allows the calibration of the model to measured temperatures and maturity in order to reduce the uncertainties in the input parameters.

The thickness, structure and properties of the crust and the lithosphere are essential inputs to PetroProb to model the tectonic heat flow (Figure 5). The model includes the radiogenic heat of the

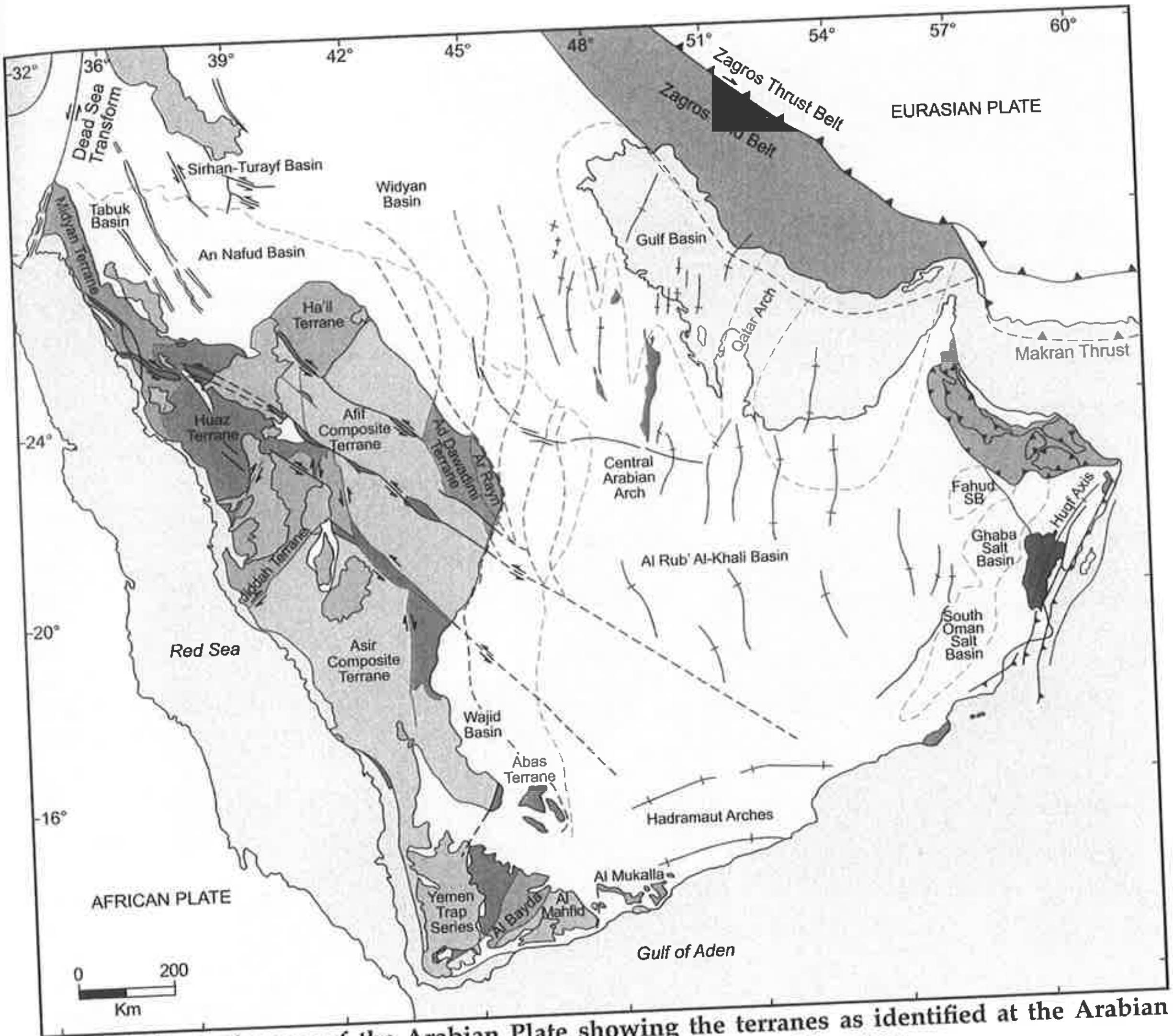

Figure 3: Tectonic map of the Arabian Plate showing the terranes as identified at the Arabian Shield (Ministry of Petroleum and Mineral Resources, Saudi Arabia, 1998).

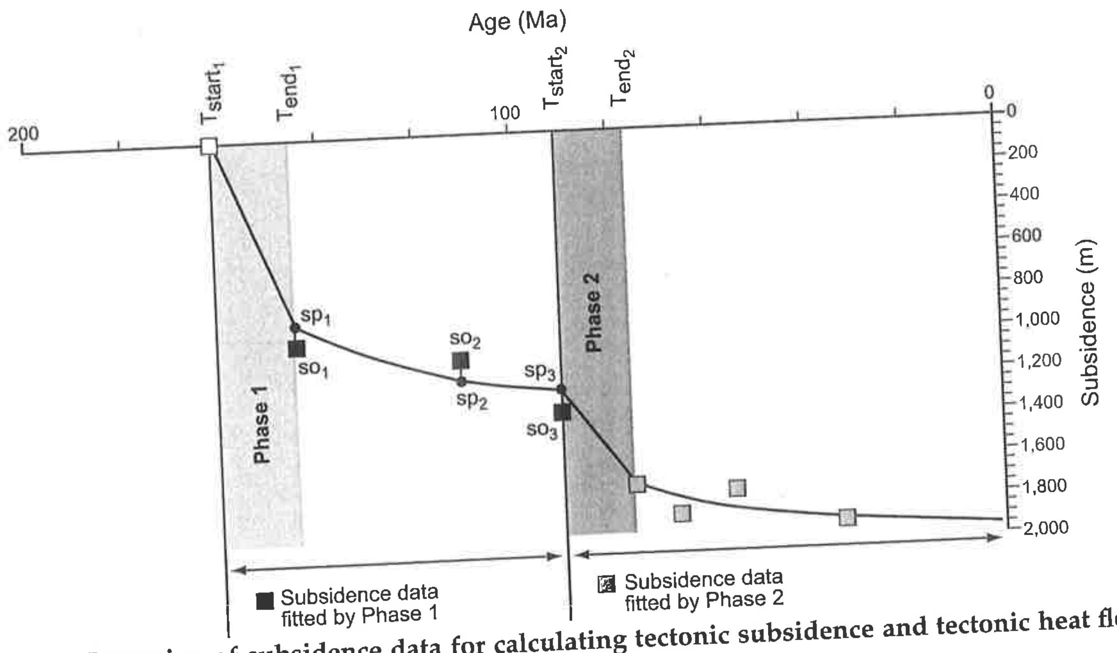

Figure 4: Inversion of subsidence data for calculating tectonic subsidence and tectonic heat flow (Van Wees et al., 2009).

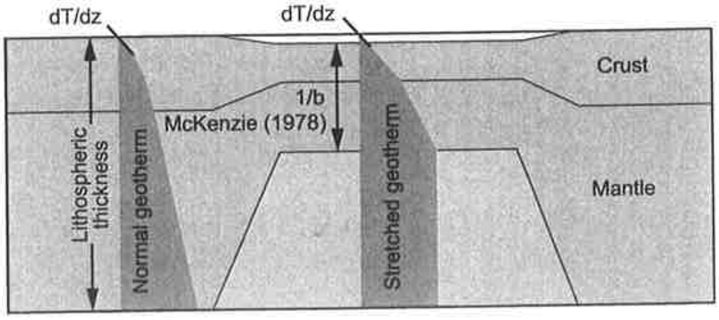

Figure 5: Schematic of the tectonic model of the lithosphere behind the basal heat flow modeling tool (PetroProb) (modified after Van Wees et al., 2009).

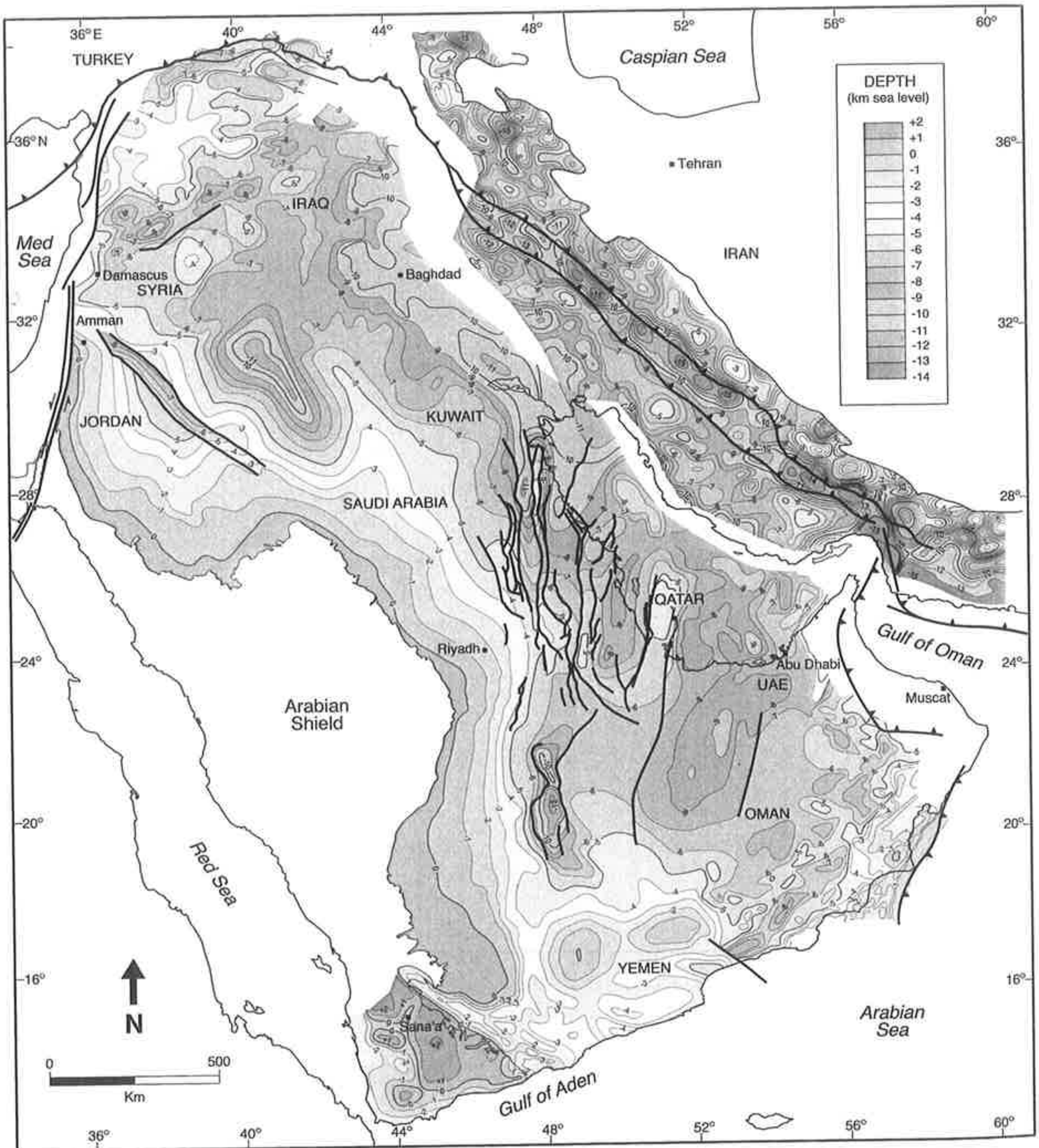

Figure 6: Basement depth map of the Arabian Plate (Konert et al., 2001).

basement due to the effect of radiogenic elements in the crystalline basement. Different zonations in the basement can be assigned varying radiogenic element concentrations and thus varying heat flow contributions. The maturity of the source rocks in the basin are estimated based on the modeled heat flow and regional maturity maps are produced of the Paleozoic and Mesozoic plays in the Arabian Peninsula.

Data and Input Model

In addition to Bouguer anomaly grids and GOCE gravity gradient data, information on the litho-stratigraphy of the study area is needed to build an initial geological model. Using the basement depth map, well information and regional cross-sections, a geological model can be constructed (Figure 6). The resolution of the input model will be adjusted to the resolution of the GOCE gravity data. Information on the evolution of the basin is required in order to construct our tectonic model which will make use of the gravity anomaly maps. Boundary conditions necessary for our models (such as paleo-water depth and surface water interface temperatures) are available from published literature. Validation of the models is done using temperature and maturity measurements in the region.

Outcome of the Study

The gravity gradient data will be used to build a new model of the crust and the lithosphere in the Arabian Peninsula (and the Rub' al-Khali Desert). Based on that, a regional tectonic heat flow model will be calculated for various geological ages. Using the heat flow maps and the geological model of the area, new maturity maps will be generated for the main Paleozoic and Mesozoic source rock units in the region.

User Group

We intend to establish a User Group to ensure involvement of the user community in the study. On the one hand, the User Group could contribute to the definition of the required products and the outcome. For example, where do we want to focus the study, what interval and petroleum system to be looked into, etc. On the other hand, the User Group could be involved in the evaluation of the products that will be generated to assess their use for hydrocarbon exploration as well as Earth interior modeling. The User Group can involve, in addition to TNO and its partner in this project, universities, research organizations as well as oil companies in the region who are the potential users of the publically available data.

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