Central Arabia Salt Basin inferred by Gravity Modeling

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Summary

Riyadh Salt Basin (RSB) in central part of the Arabian Platform (AP) contains thick salt deposits at depth. The salt layers are overlain by younger sediments which are, in turn, covered by Phanerozoic marine limestone. Most of the oil-gas fields in the Arabian Platform are known for deep-seated salt diapirism as well as for their characteristic gravity anomaly signatures. Here we report the results of gravity forward and inverse modeling for the southern part of RSB covering an area of approximately 40,000 sq. km, on the basis of terrain-corrected Bouguer Anomaly (BA) and Decompensative Isostatic Residual Anomalies (DA). The combined use of BA and DA is found to be a potentially powerful geophysical tool for investigating shallow-depth geologic bodies, below cover rocks in a rather large terrain like the Arabian Platform where, no other geophysical control exists. 3D gravity models interpreting the basement relief under this part of RSB are partly constrained by eight drill holes penetrating to depths of approximately 3 km in the sediments overlying the salt column, as well as the relevant density information. The present approach in gravity modeling better delineates the RSB configuration below the cover rocks and also determines the thickness of the salt layer that directly overlies the basement. On a plan view, RSB has a complex architecture; the fault systems bounding it orient in different directions transgressing deeper into the basement, suggesting tectonic deformation of the salt layer in deep basin areas. Such basement faults demarcate the Ar Rayn terrane boundary beneath cover rocks in the Arabian Platform, while other faults belong to the Najd fault system.

Introduction

The RSB is concealed below the Phanerozoic marine limestone, with shale, as cover rocks in central part of Arabian Platform; three major grabens mapped in its central part are: Nisah, Awsat, and Durma, all of which are structurally controlled by normal faults. The RSB is surrounded by the Ghawar and its satellite oilfields (Figure 1) numbering about 60; 56 oilfields and 4 gasfields, on all three sides (Abu-Ali et al., 1990); the fourth side forms its western boundary against the Arabian Shield where the Platform is downfaulted (Mooney et al., 1985). Continental shelf deposits of Jurassic through Meso-Cenozoic age constitute the major sediment succession for the Arabian Platform, thickness of the sedimentary sequence varies extensively across Arabian Platform reaching up to 13,700 m towards the northeast. Sediment thickness in the present study area near Riyadh is nearly 3 km (Le Nindre et al., 2003). Earlier geophysical surveys brought out general disposition of the basins in this part of Arabian Platform, suggesting a large variation in sediment thickness and the effects of basement tectonics in shaping the basinal geometry (Ibrahim et al., 1993). RSB is of much exploration interest due to its geographical proximity to the Ghawar and its satellite oilfields; the Ghawar being the largest oil-gas field in the world. Most of these oil-gas fields in Arabian Platform are known for deep-seated salt diapirism and their distinctive gravity signatures (Edgell, 1992).

The main goal of the present study is to demonstrate the feasibility approach of utilizing the B.A. and DA for geological interpretation of deep basin geometry of the study area, that forms part of

RSB where the surface geology is obscured by cover rocks, and to argue how the gravity forward and inversion modeling can be better constrained with rather limited control by exploratory drilling data.

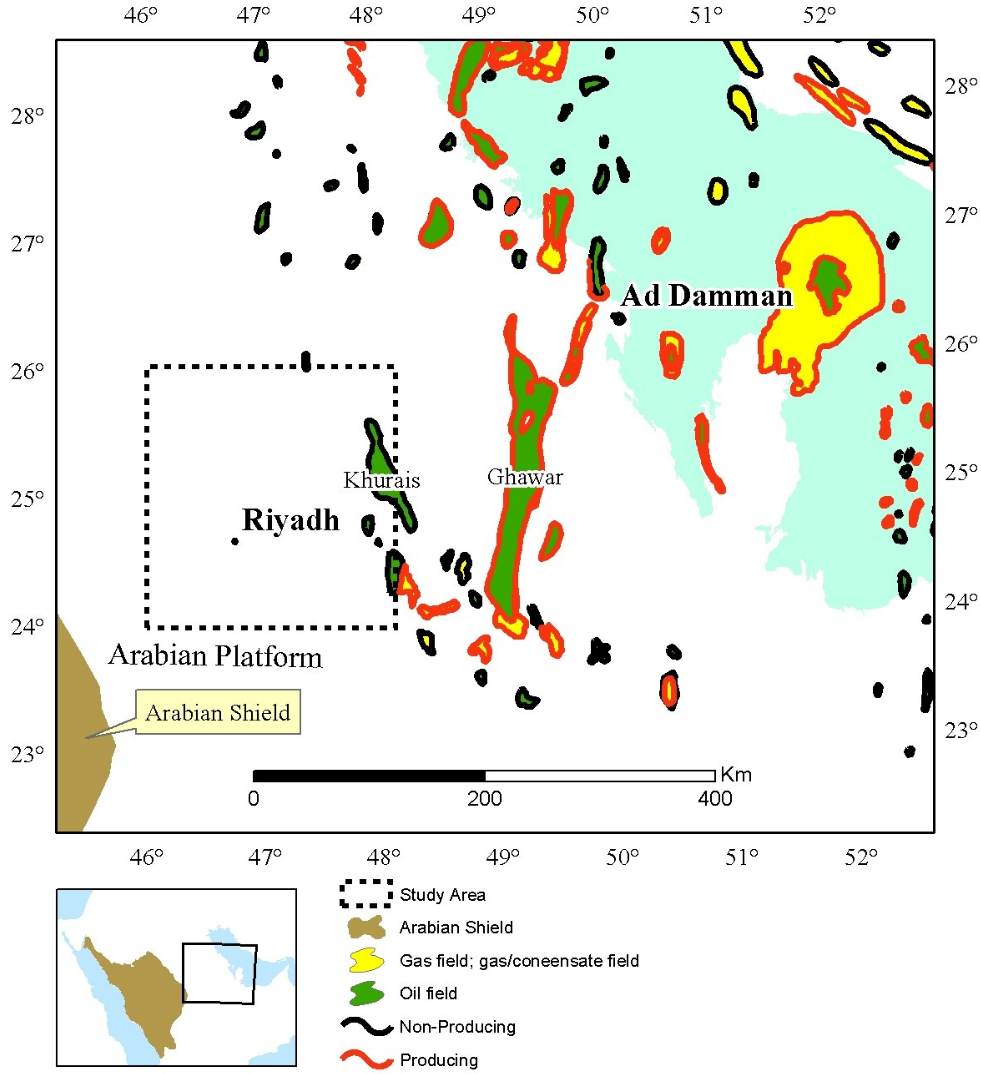

Figure 1 Location map of the study area shown oil and gas fields.

Decompensative Gravity Anomaly

Decompensative anomaly (DA) is mostly due to the difference in density in the upper 15-20 km of crust (Cordell et al., 1991). Decompensative correction will remove the associated anomalies from the deeper sources of the crust by isolating their effects at depth of 40 km. therefore upward continuation has been applied to the isostatic residual anomaly and the resultant field is subtracted from the isostatic anomaly to get the decompensative anomaly Figure 2. That ranges from -25 to 30 mGal with noticeable increase at the borders but decreasing abruptly towards the center and southern parts of the map area. Four gravity profiles in east-west direction are selected for subsurface interpretation of gravity anomalies across the major anomaly zones appearing on the DA map (Figure 2). Each profile is of 152 km length, with profile separation of 25 km, and 500 meters data sampling interval. Density and some geological constrains were gained from published geological maps and few wells (Figure 2) drilled in the study area of RSB. The average density for each sedimentary rock unit is determined using the drilled cores from the available wells.

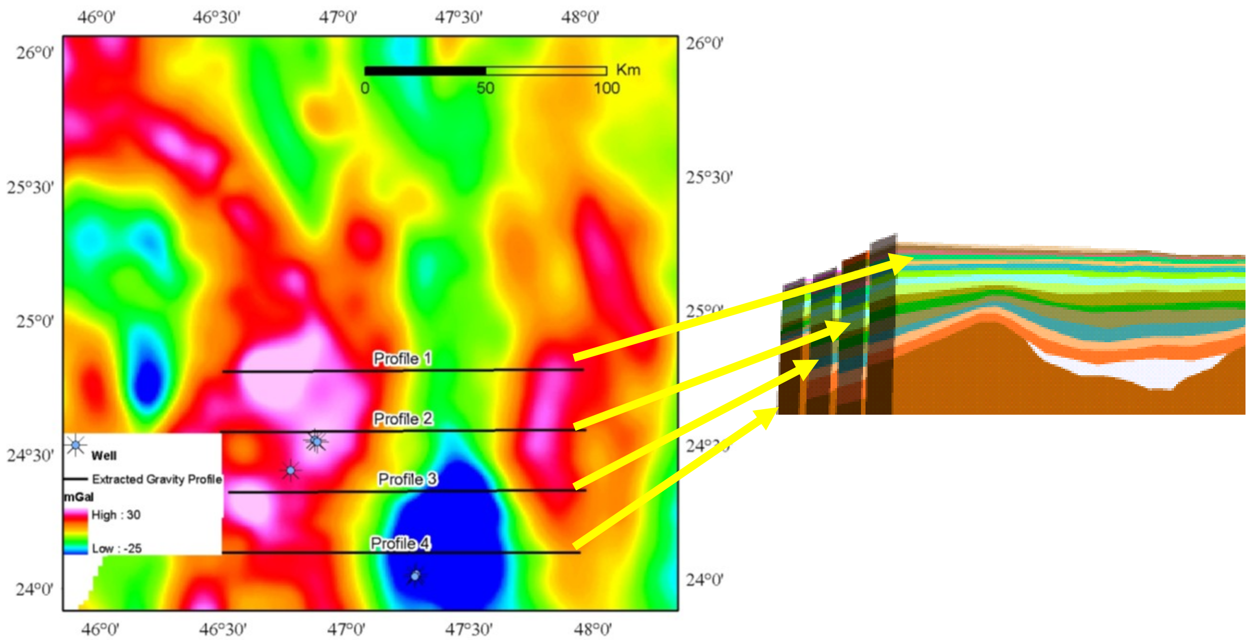

Figure 2 Decompensative gravity anomaly map shown location of wells and the extracted gravity profiles used for 3D Modelling.

Gravity forward modeling

Only profile no 2 is illustrated (Figure 3) in this extended abstract due to limited page numbers. This model includes the sedimentary sequence and the basement complex taking into account the thickness for each formation and density data. Interpretation for Profile 2 shows that there is a small slope to the east, with minor change in sediment thickness, while the salt layer thickens in central part as demanded by gravity anomalies. It is presumed that the salt column is rather homogeneous and is of uniform density with depth – a situation usually encountered with deeper salt columns. Furthermore, the sedimentary sequence and its underlying basement locate at shallower depths along the eastern and western fringes of the profile. This can be explained by the presence of deep-seated major faults cutting the basement complex and sedimentary section.

The main results emanating from model study commonly suggest that: (i) the greatest thickness of the salt layer can be expected below the profile no 3, (ii) the basement rocks and the overlying sedimentary section have been uplifted from the eastern and western borders of the map area while the intensity of uplifting clearly diminishes towards the central part, thus forming the deepest part of the basin, (iii) general dip of the basinal sediment strata is towards south (where the Minjur Formation is encountered at 1600 m depth below profile no 3 or it reaches 1650 m depth below profile no 4), and (iv) the overall geological setting is largely controlled by subsurface fault system and tectonic movements affecting the whole area throughout its geological history.

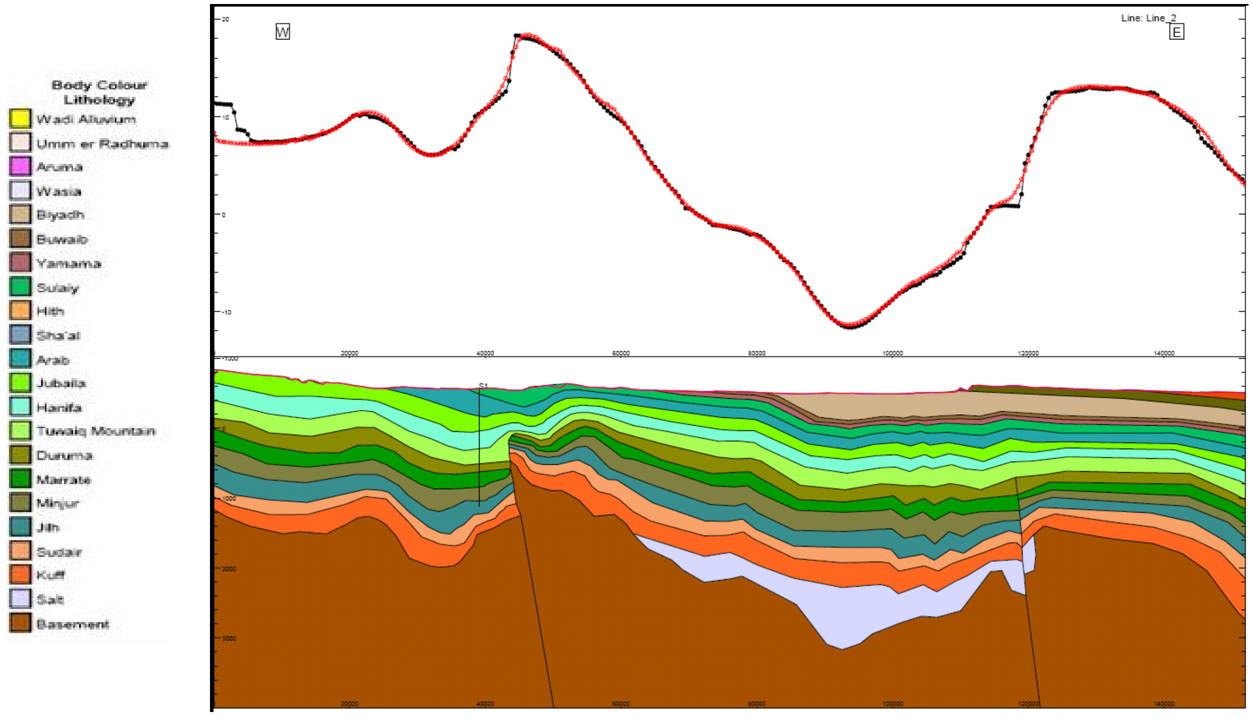

Figure 3 Gravity model for profile no. 3 shown the salt layer.

Conclusions

Decompensative Isostatic Residual Anomaly (DA) map identifies most of the geological structures better than BA. map. It becomes possible to model the salt layers using the forward modeling of DA, with rather limited well control. It the first attempt to model the subsurface geometry of the Jurassic salt layer and to provide geologic interpretation for deeper part of the Riyadh Salt Basin. Also the Najd fault system—the most conspicuous fault in this region, is clearly mapped. A detailed basement relief map for part of the central Arabian Platform, including the Riyadh Salt Basin, is prepared for the first time using the new approach discussed in the present study. This approach also made it possible to infer the structural boundary for the Ar-Rayn terrain of the Arabian Shield beneath the Phanerozoic cover rocks in the Arabian Platform.

Acknowledgements

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