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2D Nonlinear Basement Modeling for Hydrocarbon Exploration by Gravity Data, Carlisle England Area

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INTRODUCTION

Gravity in geophysics is an efficient approach to analyze the Earth crust structure, in mineral exploration, Hydrocarbon exploration, hydrogeology, glaciology, etc. The inversion of gravity data to achieve the basement relief of a sedimentary basin has been performed as a common task bythe nonlinear techniques [1, 2, 3]. The bottom relief determination of the sedimentary basin is an essential step in Hydrocarbon exploration for prospecting the location of possible stratigraphic traps [4]. It is used in hydrogeology studies to understand the geological structure of aquifers [5, 6], and it is used for reaching the flow rate of discharge in glaciology [7, 8, 9].

METHODOLOGY

In the case of nonlinear inversion data, the following equation (Equation 1) can be written [10]:

$$d=A.m \qquad (1)$$

d is the gravity data vector (mGal), A,m are the kernel matrix and model parameter vector (m) respectively.

A nonlinear inverse problems can be solved by minimizing an objective function which depends on the observed and predicted data and defined as follow [11]:

$$F(m)=\frac{1}{2}F_d(m)+\frac{\beta}{2}F_m(m) \qquad (2)$$

where β is regularization parameter. If the function F(x) is a smooth function for the model parameters, the function can be limited using the Taylor series for the function which can be written in the following equation (Equation 3) [12]:

$$F(m+\delta m)=F(m)+\gamma^T\delta m+1/2\delta m^T H.m \qquad (3)$$

where terms of the gradient vector (γ) and the Hessian matrix (H) can be calculated using the following equations (Equations 4 and 5) [11].

$\gamma=-(GT(d_0-d(m))+\beta I)$ (4)

$H=G^T G+\beta I- m G^T(d_0-d(m))$ (5)

$$G_{ij}=\frac{\partial d_i(m)}{\partial d_j} \quad (6)$$

The derivative G_{ij} can often be found analytically using Equation 6 (8). In equation (5), $\nabla_m G^T$ appears with the data misfit. Moreover, the appearance of $\nabla_m G^T$ with the data describes the nonlinear dependency of the data on the model parameters. Moreover, the nonlinearity is usually weak; therefore, it is neglected in the computation of the Hessian matrix [13].

Finally, the amount of δm can be calculated using subspace method [14]:

$\delta m=-V(V^T H V)^{-1} V^T \gamma$ (7)

The "T" sign is a transpose matrix and where V is the base vector which is calculated using the singular value decomposition method (SVD) of the matrix Hessian.

RESULT AND DISCUSSION

The obtained results from inversion of synthetic model with free noise and 1% and 5% noise show that the algorithm is stable against data contaminated with different level of noises. Also, data misfit from observed gravity data and predicted data shown that proposed algorithm is good estimate from our model by making a compression between obtained results from inversion of real gravity data and geological section at the study area.

CONCLUSION

In this method, a set of data for modeling two layers is used and aiding second data is not needed. Also, in this method, basis vectors are used to increase the speed of modeling. Moreover, in this method, the dimension of inverse matrix is smaller.

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