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ORIGINAL PAPER

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Using a genetic algorithm for 3-D inversion of gravity data in Fuerteventura (Canary Islands)

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Abstract The use of genetic algorithms in geophysical inverse problems is a relatively recent development and offers many advantages in dealing with the non-linearity inherent in such applications. We have implemented a genetic algorithm to efficiently invert a set of gravity data. Employing several fixed density contrasts, this algorithm determines the geometry of the sources of the anomaly gravity field in a 3-D context. The genetic algorithms, based on Darwin's theory of evolution, seek the optimum solution from an initial population of models, working with a set of parameters by means of modifications in successive iterations or generations. This searching method traditionally consists of three operators (selection, crossover and mutation) acting on each generation, but we have added a further one, which smoothes the obtained models. In this way, we have designed an efficient inversion gravity method, confirmed by both a synthetic example and a real data set from the island of Fuerteventura. In the latter case, we identify crustal structures related to the origin and evolution of the island. The results show a clear correlation between the sources of gravity field in the model and the three volcanic complexes recognized in Fuerteventura by other geological studies.

Keywords Canary Islands · Gravity inversion · Genetic algorithm · Volcanism · Optimisation method

Introduction

Solving the inverse gravity problem entails determining the subsurface mass density distribution that accounts for the observed gravity anomaly field. The solution to this problem is non-unique (e.g. Al-Chalabi 1971) and is, moreover, limited because the data are restricted to a discrete set of inaccurate values. To deal with this issue, additional information about the model parameters (subsurface structure) and the data parameters (statistical properties of inexact data, e.g. Gaussian distribution) is taken into account in the inversion process.

Gravity inversion methods vary depending on the kind of model parameters selected, which may be the density (contrast) or geometrical parameters of the sources of the gravity field (anomalous bodies). On one hand, methods that consider the densities of the elements of a regular subsurface partition as unknowns (with non-discrete values) can use a linear approach (e.g. Camacho et al. 1997). In this case, the solution has a good fit to the observed data, but its geometrical properties are somewhat diffuse due to the smooth variation of the resulting distribution of density contrasts. On the other hand, methods that ascertain the geometrical properties of anomalous bodies with a fixed density contrast (e.g. René 1986; Barbosa et al. 1997; Camacho et al. 2000) correspond to a non-linear context and offer interesting results, limited only by the validity of the hypothesis made.

Generally, inversion methods look for analytical solutions by means of optimization techniques with linear approaches or iterative methods for linearizable problems. Unfortunately, linearized techniques greatly depend on the accuracy of the initial estimation of the model parameters (Rothman 1985). In fully non-linear treatments, local optimization techniques (steepest descendent, conjugate gradients, etc.) have traditionally proven inadequate due to their highly non-linear mathematical formulation, meaning local searches can, in some cases, be prone to being trapped in local minima. Although this is not very important for seismic velocity inversion and ray theory, it can be a significant issue in gravity inversion problem (e.g. Tarantola 1987). In these cases, the appropriate choice of a starting model is necessary in order to obtain satisfactory results. Also, these algorithms need information about the curvature in the solution space in order to establish the solution domain. Moreover, taking into account the inherent

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