Magnetic Source Inversion for a Triaxial Ellipsoid with the Aid of the Genetic Algorithm

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A triaxial ellipsoid is an effective and versatile model as a source for the volcanomagnetic effect caused by the thermal magnetic effect (Sasai, 2006). The genetic algorithm (GA) was initially introduced for the magnetic source inversion in the tectonomagnetic studies by Currenti *et al.* (2005). A mathematical formula to give the magnetic field produced by a uniformly magnetized triaxial ellipsoid was originally presented by Clark *et al.* (1986), which was applied to find volcanomagnetic sources in Taal volcano, the Philippines (Sasai, 2006; Zlotnicki *et al.*, 2008). Model parameters to be determined are the magnetization of the elliptic body (moment, declination, inclination), the coordinates of the center of the ellipsoid (x_e, y_e, z_e), lengths of three axes (a, b, c; $a > b > c$), attitude angles of the ellipsoid (α, δ, γ), which are twelve in total. In the case of thermal demagnetization, first three are known. We conducted the sensitivity tests for the remaining 9 parameters. The attitude parameters (α, δ, γ) behave non-linearly, while the other parameters change linearly, when only each one of them varies for a certain parameter space while the remainders are fixed. We adopted the grid search method, in which the ellipsoid center is fixed and the shape parameters (axis length and attitude) are subject to GA inversion process. Simple but effective FORTRAN subroutines are published by Ishida *et al.* (1997), which are utilized in the present study.

A case study was made for the large geomagnetic dip changes observed during the 1950 eruption of Izu-Oshima volcano by Rikitake (1951). Each parameter space for 6 unknown variables is subdivided into 256 pieces, which is regarded as a gene. A combination of arbitrary choice of 6 genes makes a chromosome and a certain number of chromosomes are generated for each generation. Genetic algorithm is applied to a set of chromosomes for each generation to search for the best-fit model which gives the minimum squared sum of the differences between observed and computed values. The genetic algorithm consists of the processes called as selection, crossover and mutation, respectively. The number of populations or chromosomes NP for each generation, which is specified in advance, is crucial to attain the final goal effectively. We examined the cases for NP = 100, 500, 1000 and 3000. For larger NP, the GA process sometimes breaks. It turned out that the roulette rule, i.e. the standard technique for the selection process, does not work well for larger NP. We specified NP = 100 for the roulette selection, which enabled us to attain rapid convergence to find the minimum squared sum of (O - C)'s.

Rikitake (1951) obtained a source for the large geomagnetic dip changes as a demagnetized sphere of radius 1.7 km (average magnetization was obtained as 30 A/m) at a depth of 5.5 km beneath the Izu-Oshima caldera. However, according to the recent results of aeromagnetic surveys, the average magnetization of the volcano is estimated as 10 A/m (Ueda *et al.*, 1983; Nakatsuka *et al.* 1990), and the Curie depth is estimated as 5 km (Okubo, 1984). We imposed a constraint that the demagnetized ellipsoid is included within the magnetized layer between the sea level and 5 km depth. The best-fit model we obtained is such that $a = 2.99$ km, $b = 2.68$ km, $c = 0.558$ km, $\alpha = 350°$, $\delta = 6.4°$ and $\gamma = 82.9°$, of which center is located at a depth of 3 km beneath around the center of the caldera. It is a N-S oriented, slightly inclined to the north, flat ellipsoid of nearly oblate shape, of which volume is a quarter of Rikitake's (1951) spherical source. Although the source we obtained is reasonable as compared with Rikitake's (1951), it still has a huge volume and a special structure beneath the caldera must be considered in the case of Izu-Oshima volcano.

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