Geomagnetic Dip Changes in the 1950 Eruption of Izu-Oshima Volcano, Central Japan: Magnetic Source Inversion Using Genetic Algorithm (GA)

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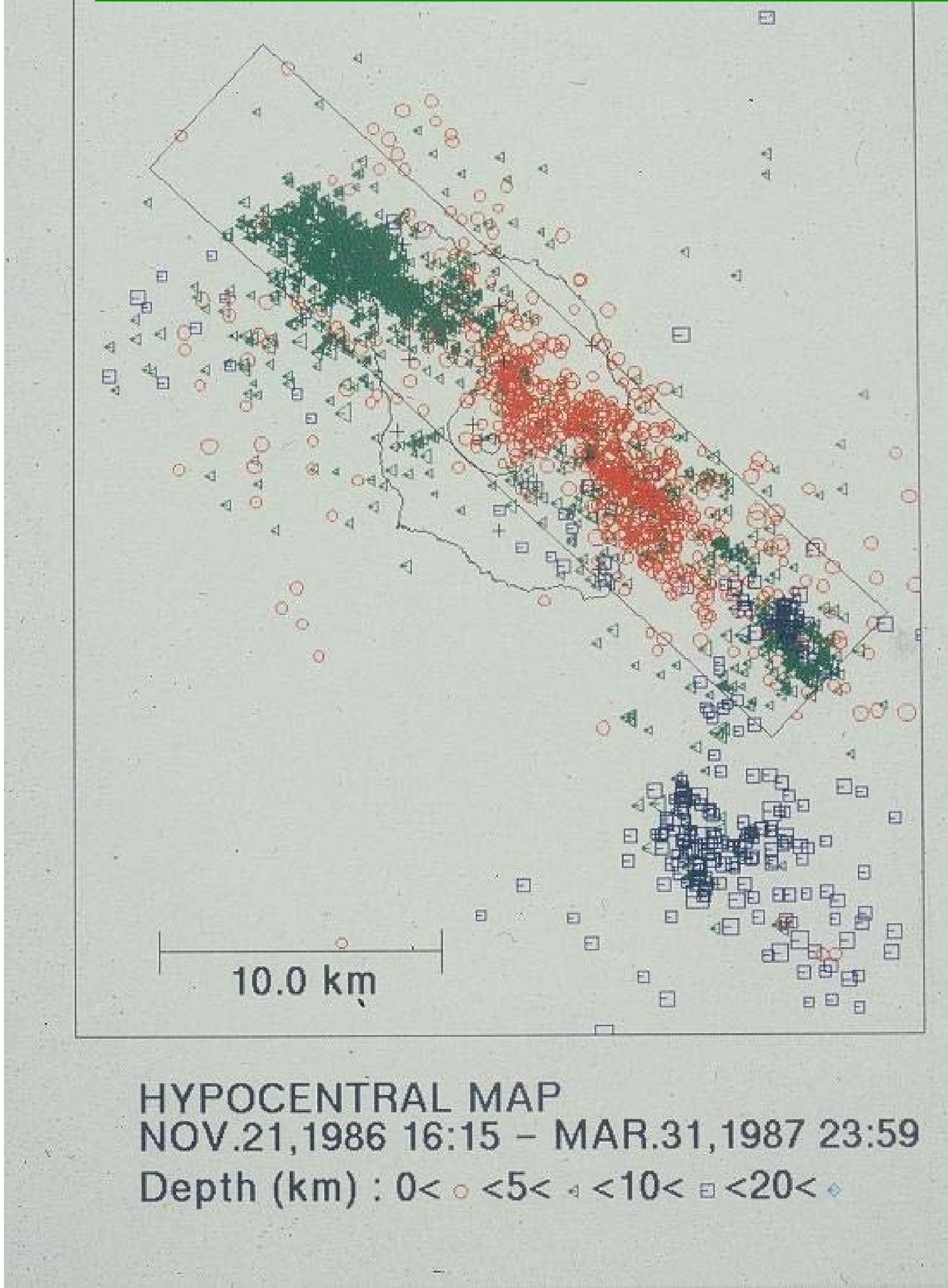
Tokyo Metropolitan City has 21 active volcanoes.

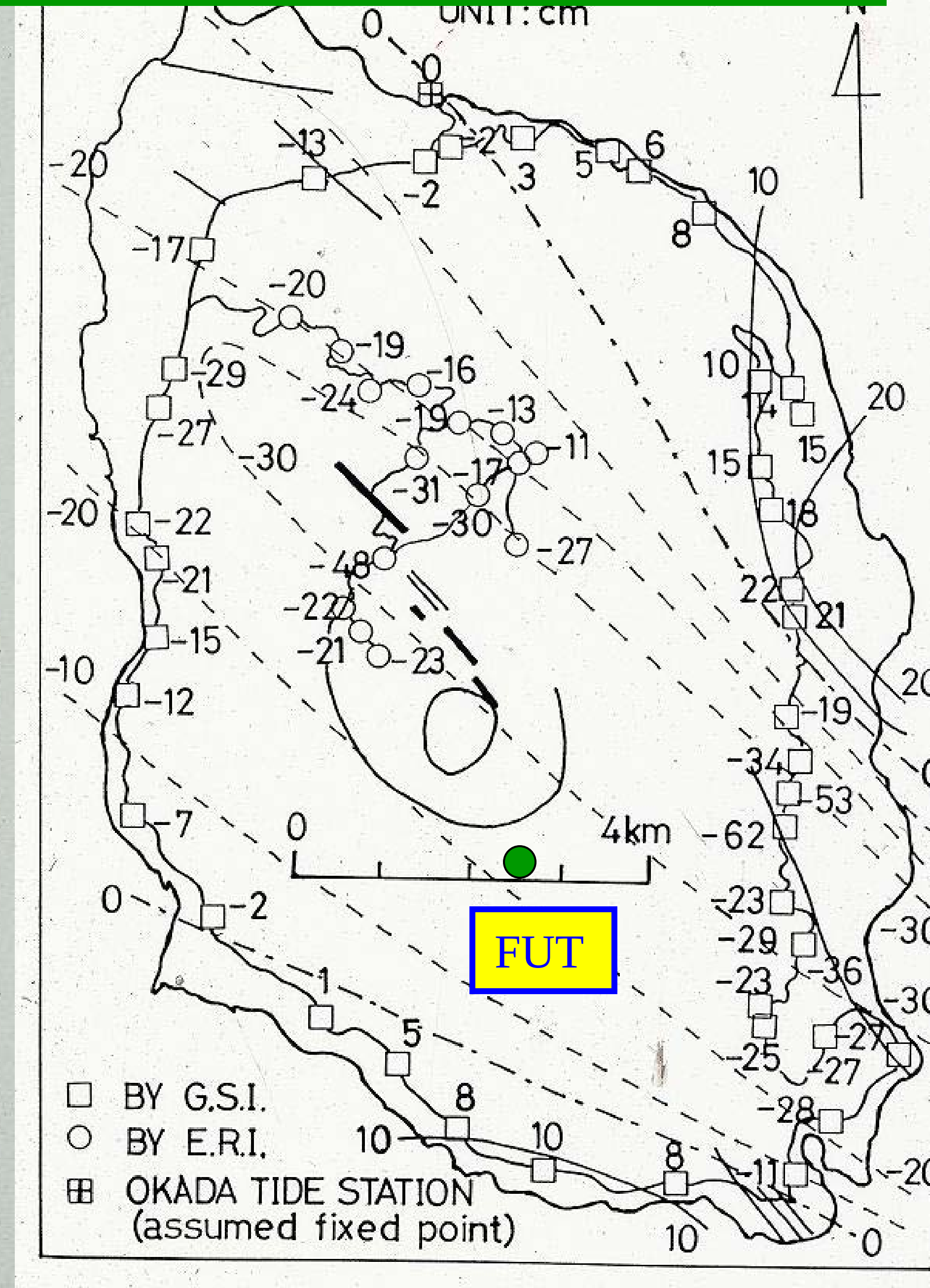
The northern part of the volcanic chain islands is called the Seven Izu Island, where 30,000 people live and many tourists visit throughout the year.

The 1986 eruption of Izu-Oshima volcano. Phase I: The summit eruption from the central cone Mihara-yama.

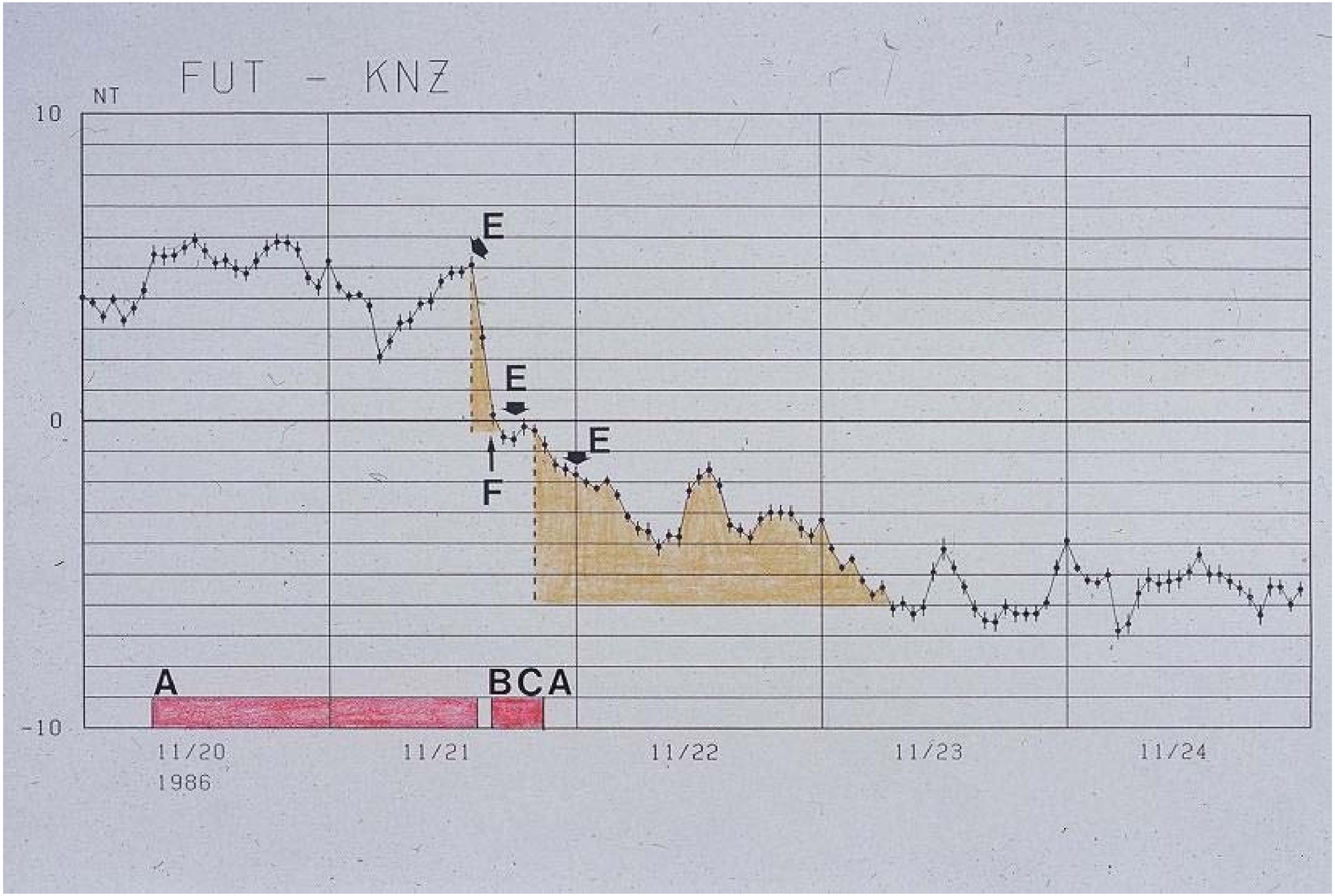
The 1986 eruption of Izu-Oshima volcano. Phase II: Fissure eruption on November 21, 1986. Sub-Plinean to fire-fountain eruptions.

Evidences for dyke intrusion (Left: Epicenters, Right: Leveling)

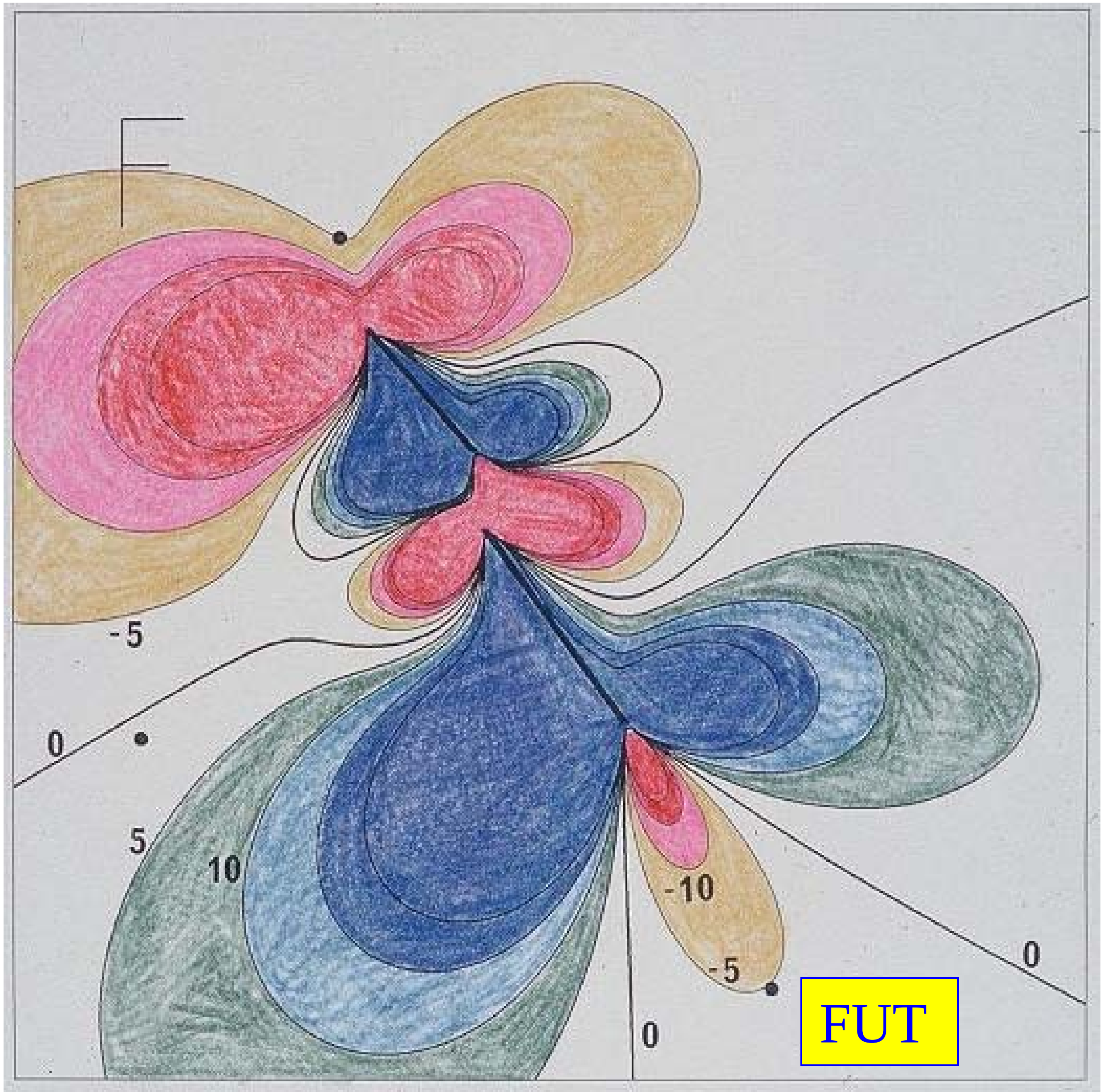




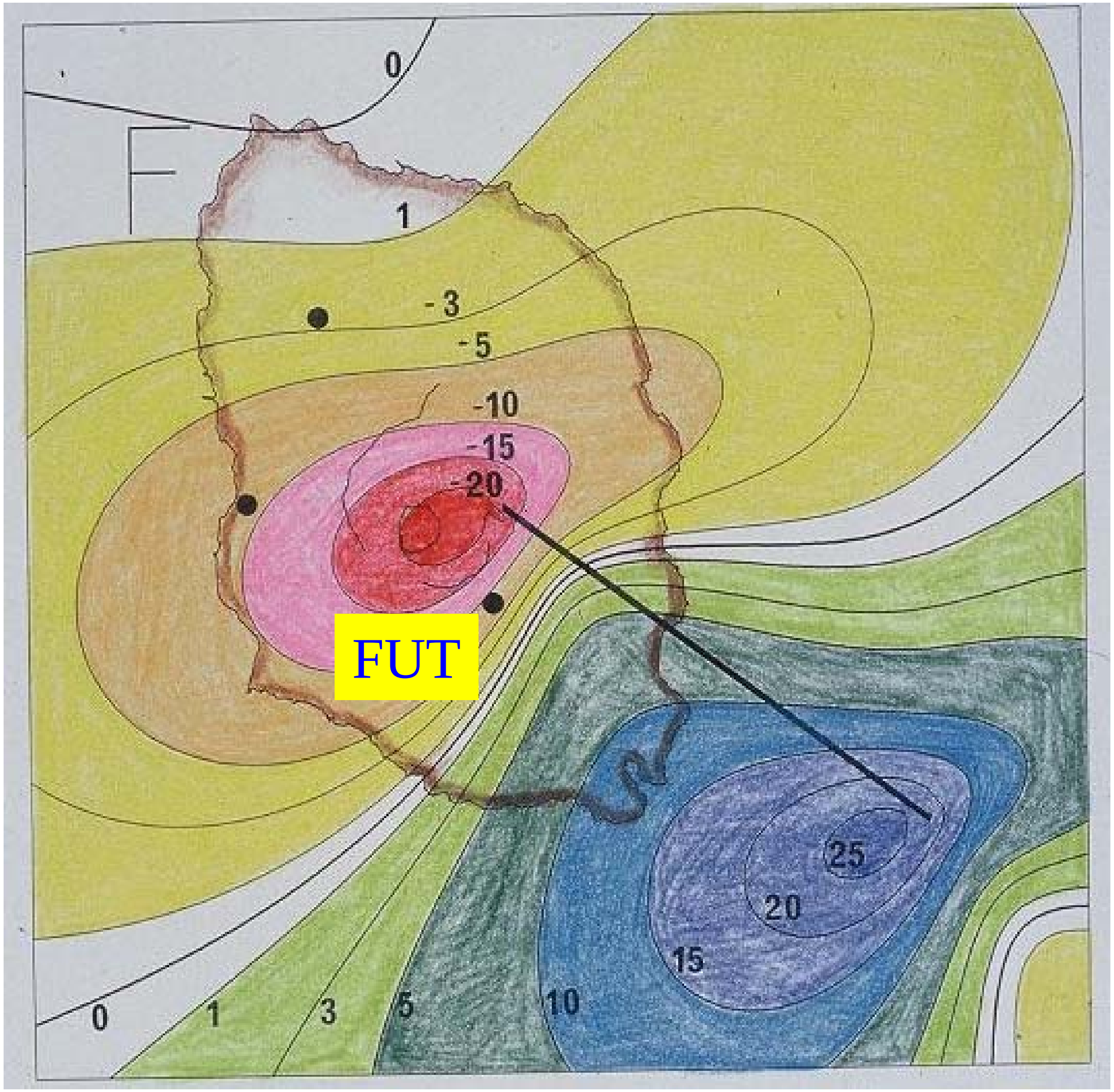
Total Intensity Changes at FUT (nT): Two Step Changes



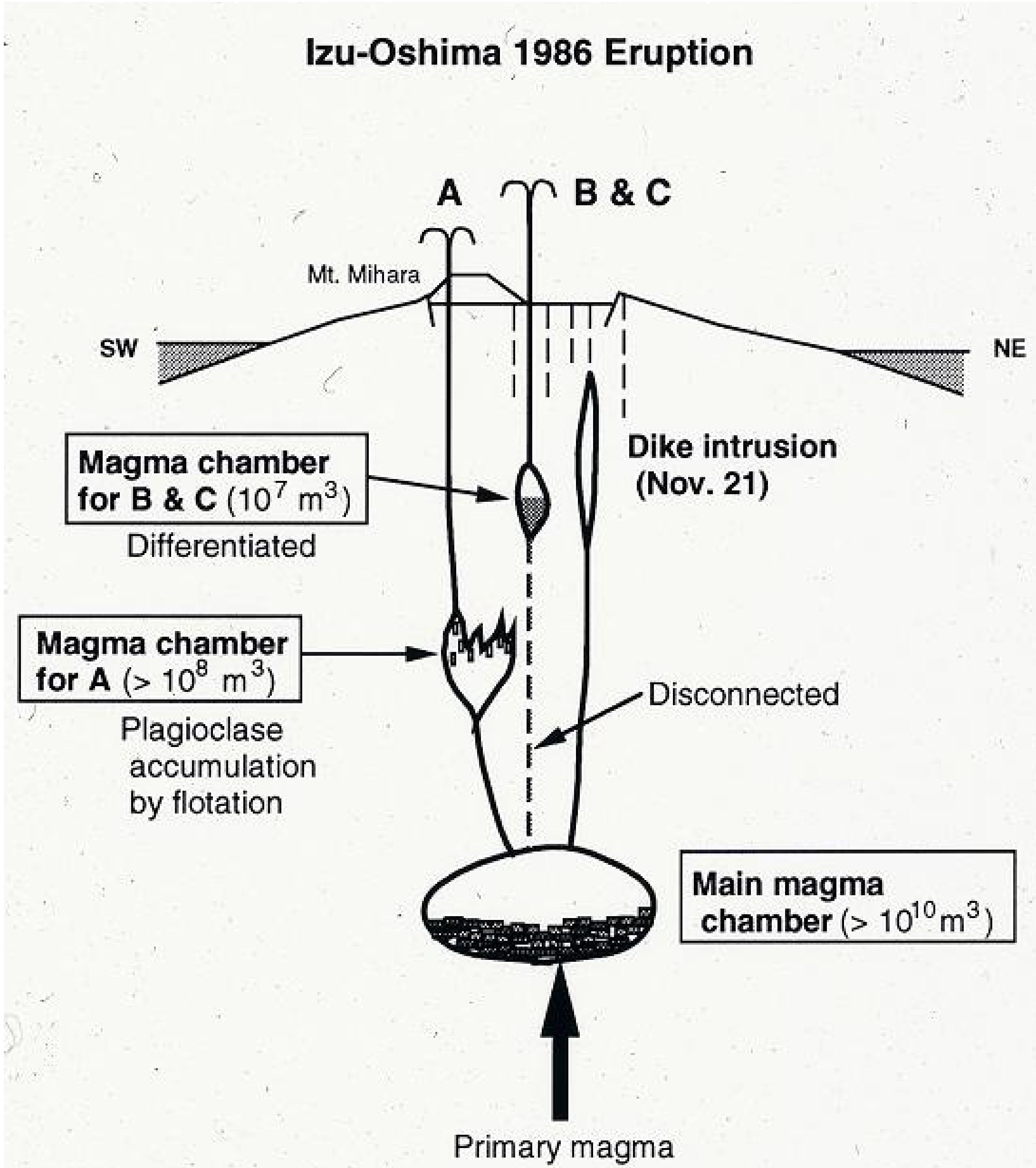
Piezomagnetic Total Intensity Changes due to B and C Dykes



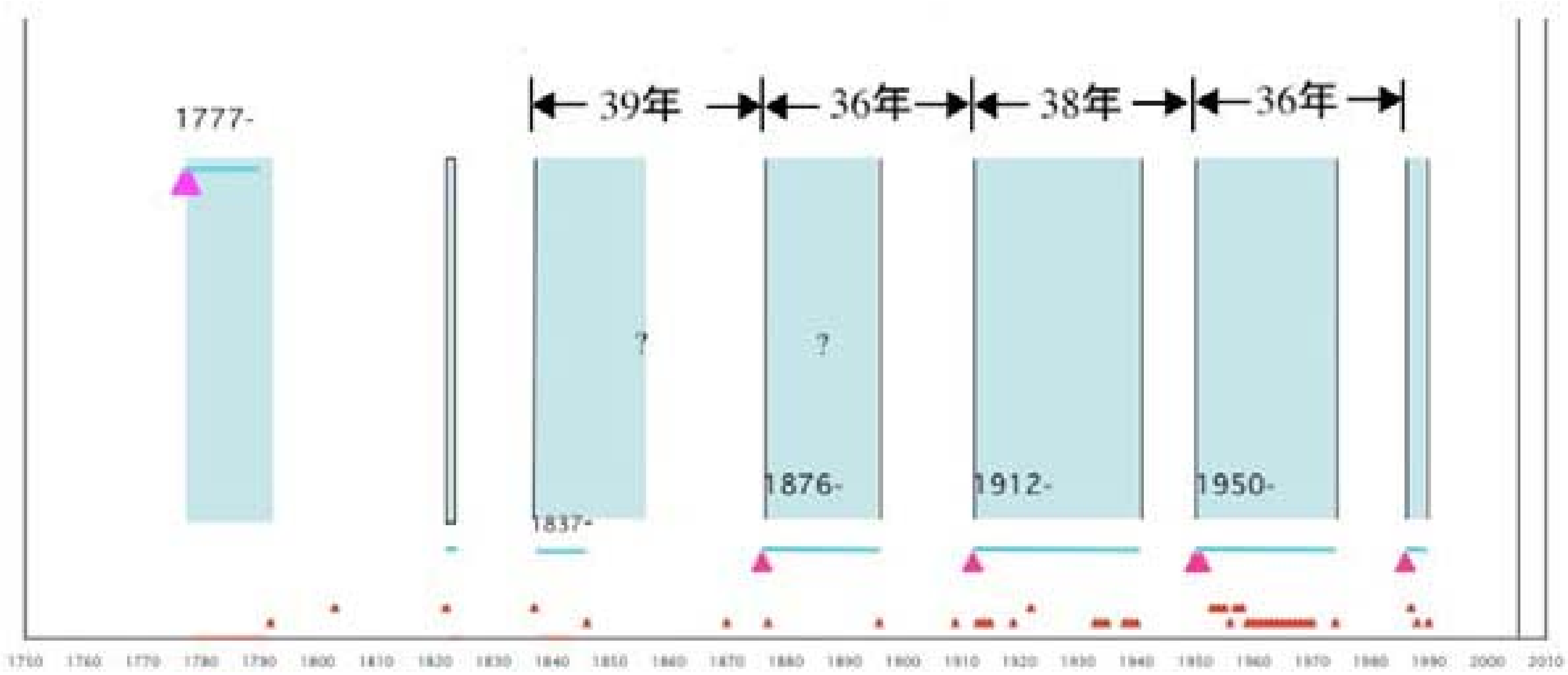
Piezomagnetic Total Intensity Changes due to an Intrusive Dyke



A Model from Petrology : When such an intrusive event happened?



Izu-Oshima volcano has erupted at every 36 to 39 years' interval since 19th century. The last eruption before 1986 took place in 1950.

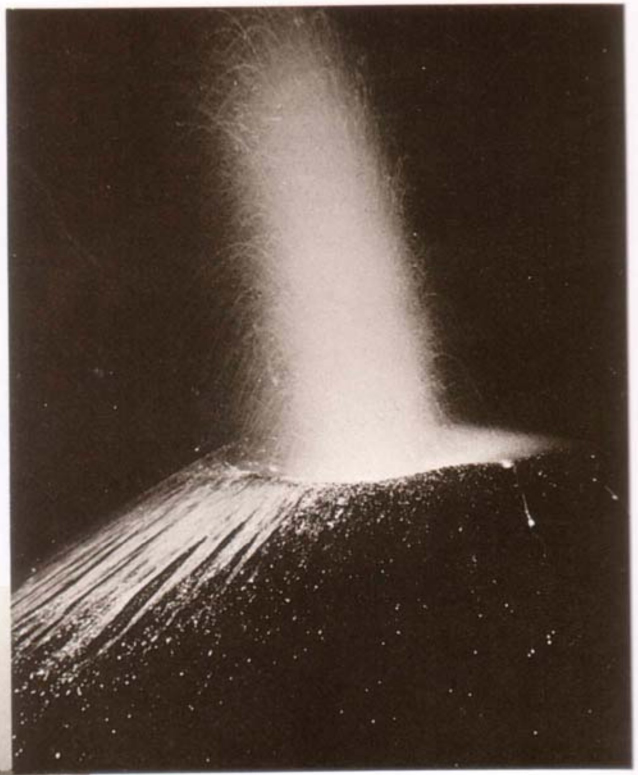


The 1950-51 eruption was the summit eruption from the central cone Mihara-yama. It was only 5 years after the world war II.

三原山噴火

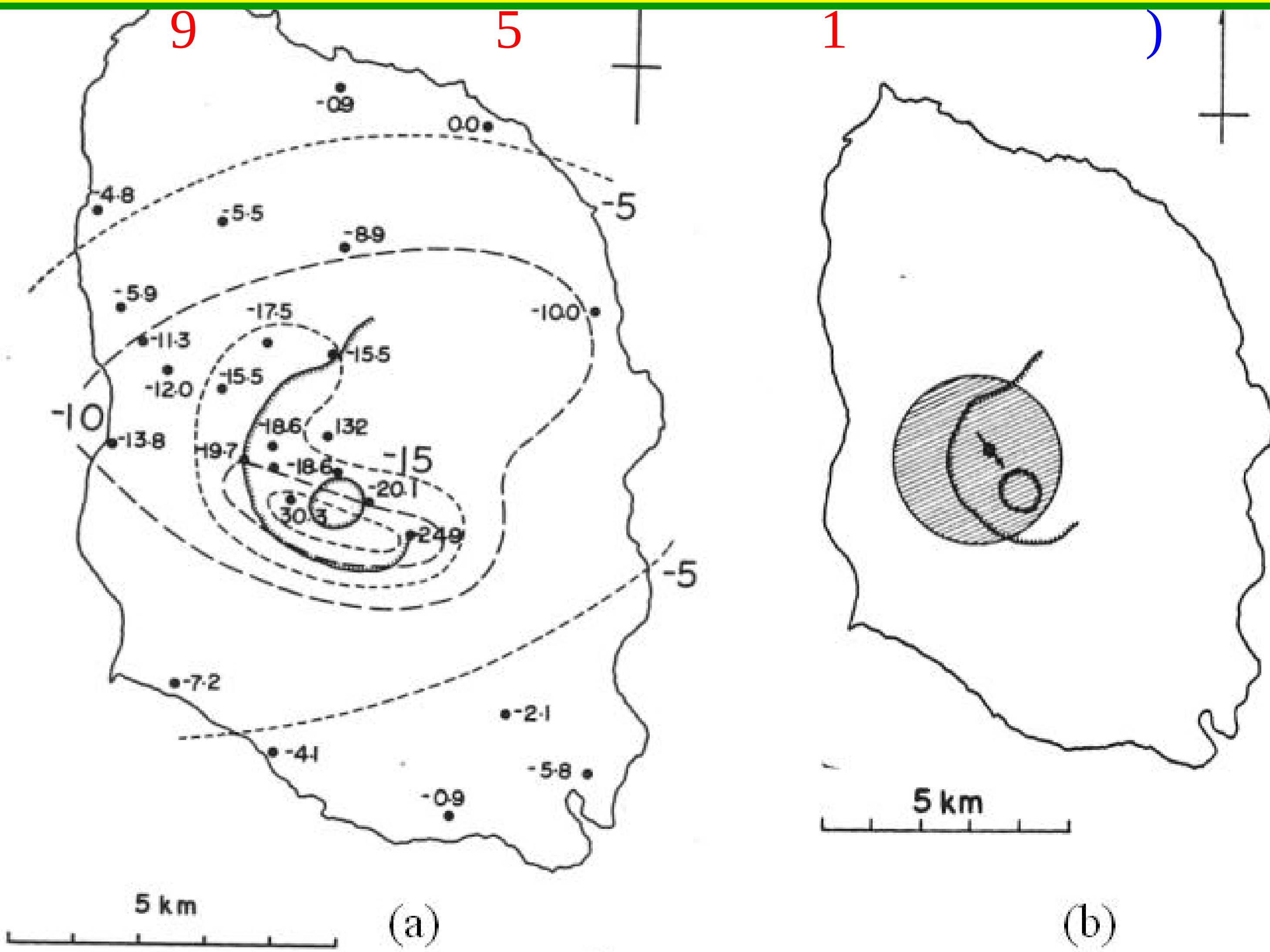
昭和２５～２６年にかけて噴火し、流れだされた溶岩は表砂漠を埋めつくした。

生木を持って溶岩の側まで行き、クルルっと溶岩をまるめて灰皿を造ったりもした。



溶岩の海

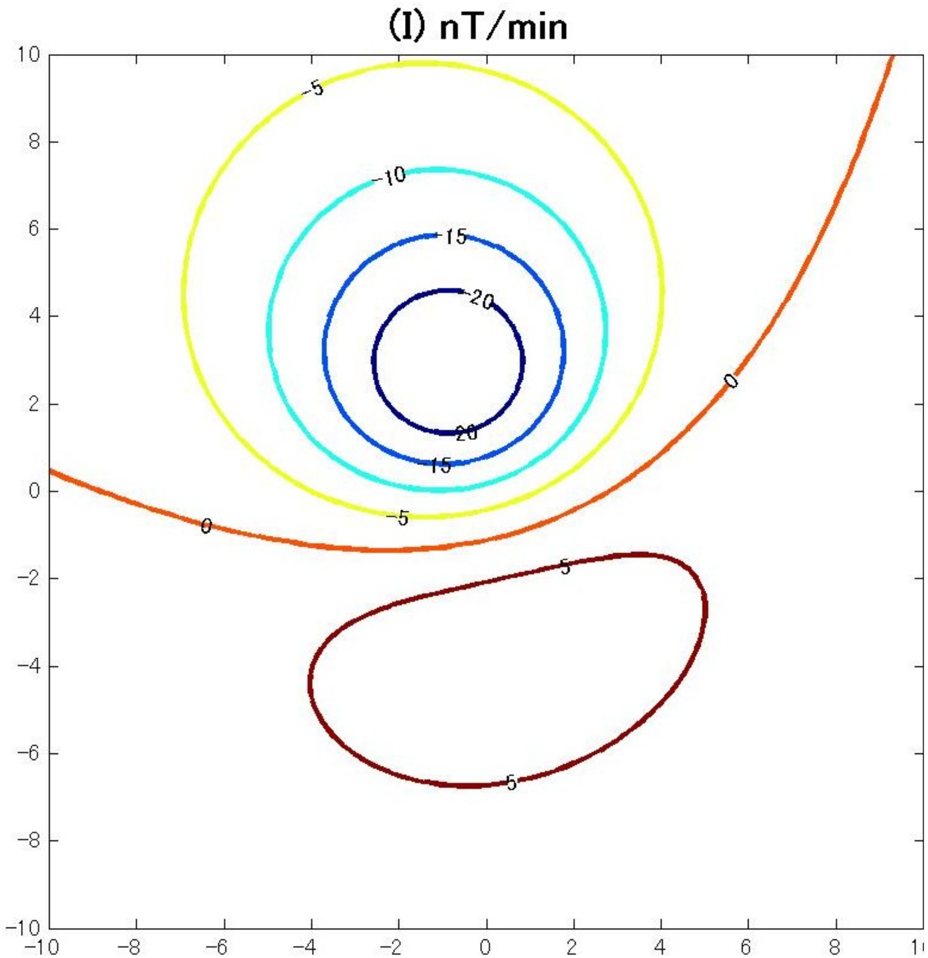
Geomagnetic Dip Changes between July and September 1950 (Left). Magnetic Dipole and Equivalent Demagnetized Sphere (Right): Inclination −63° Declination S42° W, Radius 1.7km (Assumed 30A/m, If magnetization = 10A/m ―> Radius 2.5km) (Rikitake, 1951).



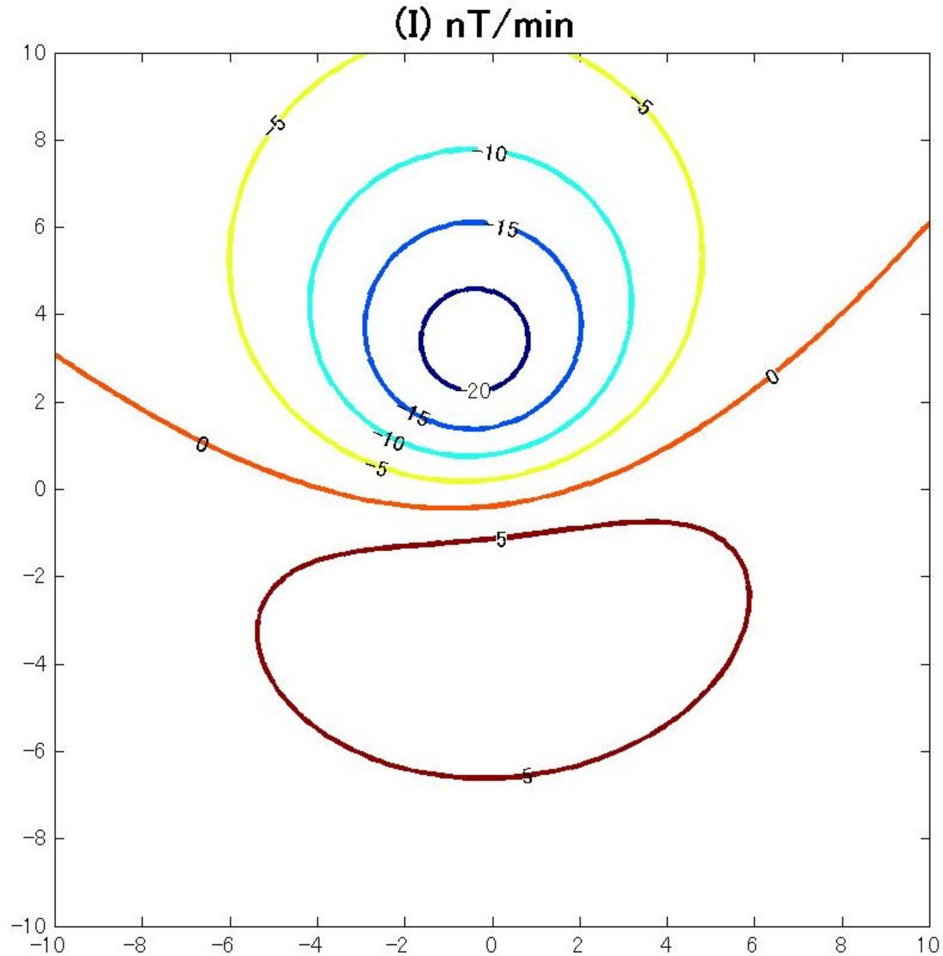
Magnetic Source due to Thermal Demagnetization (Dipole)

- Direction of magnetization is known (Anti-parallel to the Main Field).
- Linear inversion to minimize squared (O-C) with only one unknown parameter Mo (magnetic moment).
- Search for the best-fit dipole at a densely enough grid interval.

Rikitake’s (1951) solution (Left) and the best-fit thermally-demagnetized sphere (Right). The distribution of geomagnetic dip (in minutes of arc) at a plane surface of 700 m above sea level.   .

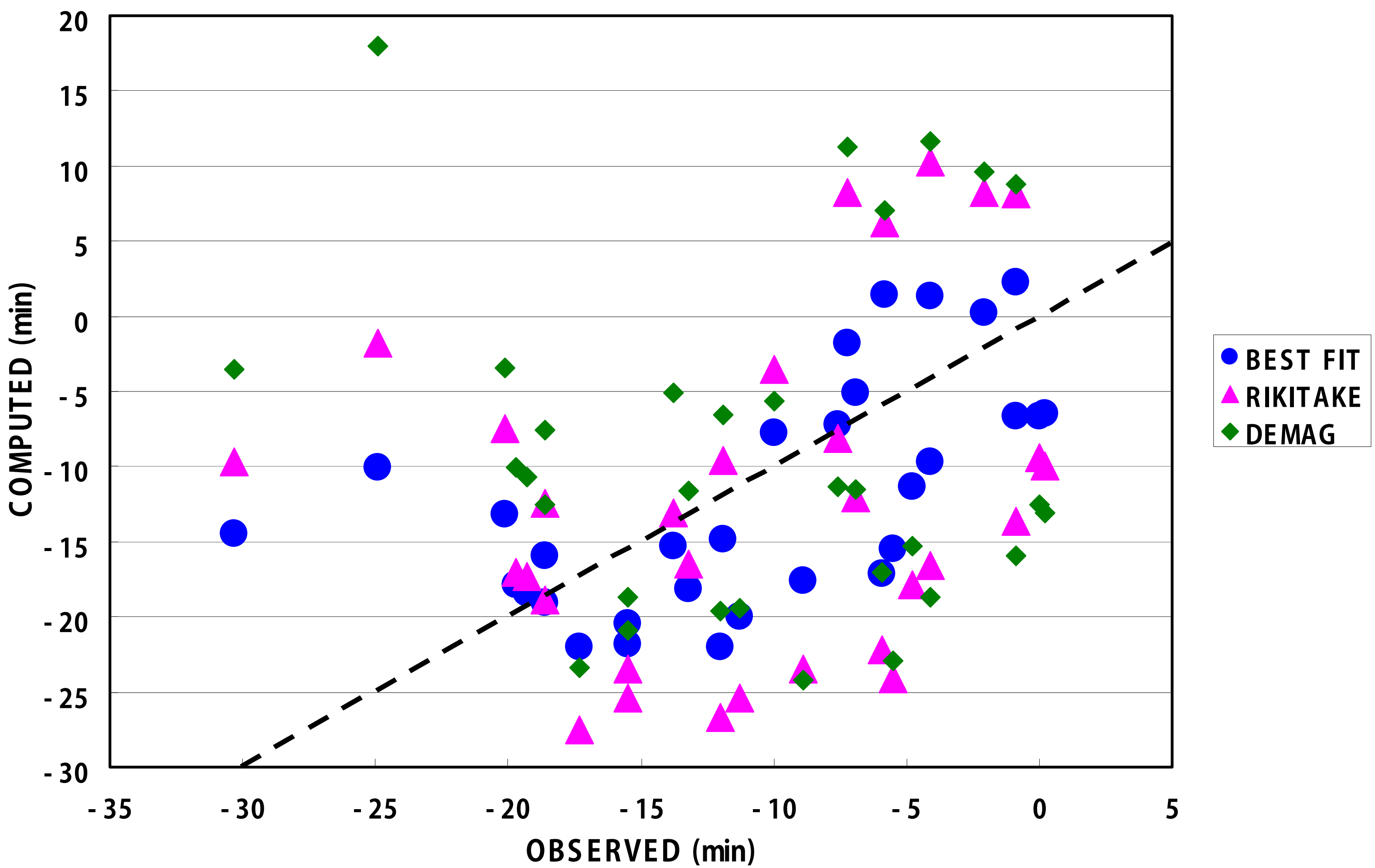


(Depth 5.5km,   Radius 2.5km)



(Depth 6.3km,   Radius

Comparizon of the fitness of Observed vs. Computed among three dipole models. The dotted indicates the fitting line. Circle : Best Fit. Triangle: Rikitake model (demagnetization vector is deflected to the east). Demagnetized Rikitake model (Demag).



Fatal Defects in the Dipole Models: The source bulges out!

- The basement rocks of Izu-Oshima volcano are weakly magnetized. (Ueda, 1988)
- The Curie depth is estimated as 5 km around this volcano. (Okubo, 1984)
- The source must lie between 0 to 5 km depth.
- We search for a triaxial ellipsoid model.

Formula for the magnetic field due to a triaxial ellipsoid (Clark, et al., 1986; Sasai, 2006)

$$\frac{X_x}{2\pi abcJ_x} = -A(\lambda) + \frac{2x^2}{g}\frac{1}{(a^2+\lambda)^2}\frac{1}{\sqrt{\varphi(\lambda)}}, \quad \frac{X_y}{2\pi abcJ_y} = \frac{Y_x}{2\pi abcJ_x},$$

$$\frac{Y_x}{2\pi abcJ_x} = \frac{2xy}{g}\frac{1}{(a^2+\lambda)(b^2+\lambda)}\frac{1}{\sqrt{\varphi(\lambda)}}, \quad \frac{Y_y}{2\pi abcJ_y} = -B(\lambda) + \frac{2y^2}{g}\frac{1}{(b^2+\lambda)^2}\frac{1}{\sqrt{\varphi(\lambda)}},$$

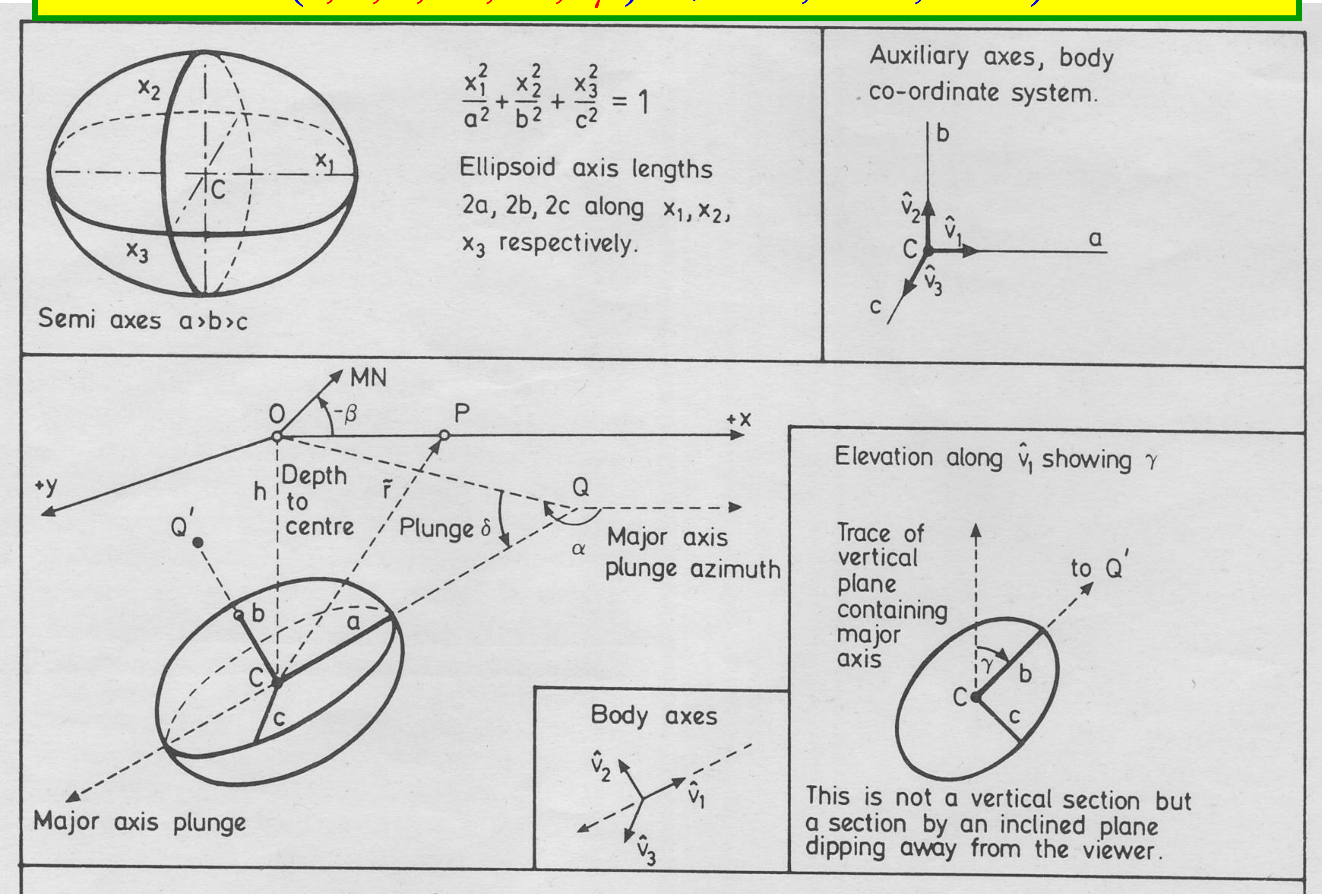
$$\frac{Z_x}{2\pi abcJ_x} = \frac{2xz}{g}\frac{1}{(a^2+\lambda)(c^2+\lambda)}\frac{1}{\sqrt{\varphi(\lambda)}}, \quad \frac{Z_y}{2\pi abcJ_y} = \frac{2yz}{g}\frac{1}{(b^2+\lambda)(c^2+\lambda)}\frac{1}{\sqrt{\varphi(\lambda)}}, \tag{17}$$

$$\begin{aligned} \frac{X_z}{2\pi abcJ_z} &= \frac{Z_x}{2\pi abcJ_x}, \\ \frac{Y_z}{2\pi abcJ_z} &= \frac{Z_y}{2\pi abcJ_y}, \\ \frac{Z_z}{2\pi abcJ_z} &= -C(\lambda) + \frac{2z^2}{g}\frac{1}{(c^2+\lambda)^2}\frac{1}{\sqrt{\varphi(\lambda)}} \end{aligned} \tag{18}$$

ここで

$$g = \frac{x^2}{a^2+\lambda} + \frac{y^2}{b^2+\lambda} + \frac{z^2}{c^2+\lambda} \tag{19}$$

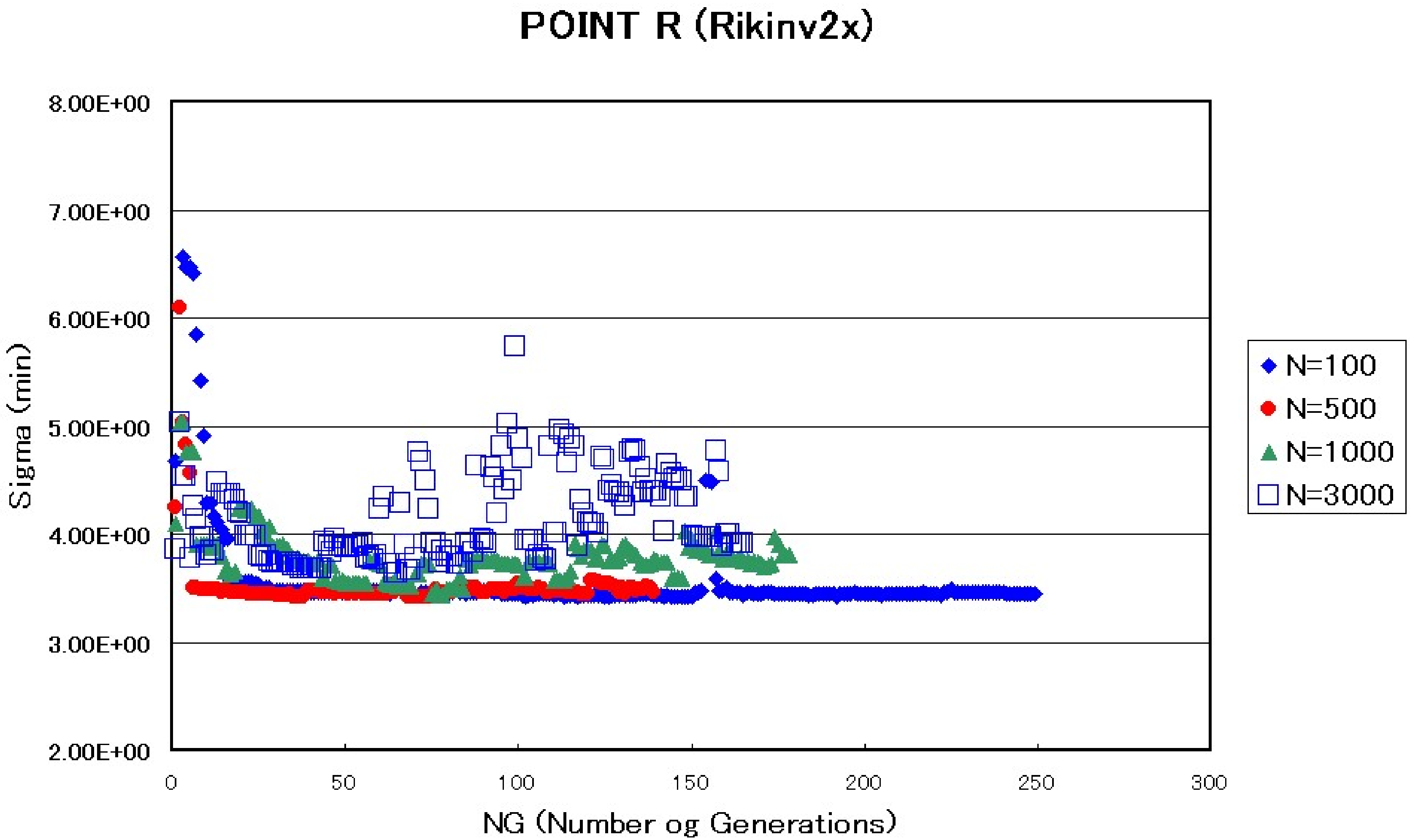
Parameters for the shape and attitude of a triaxial ellipsoid : (a, b, c, α, δ, γ) （Clark, et al., 1986)



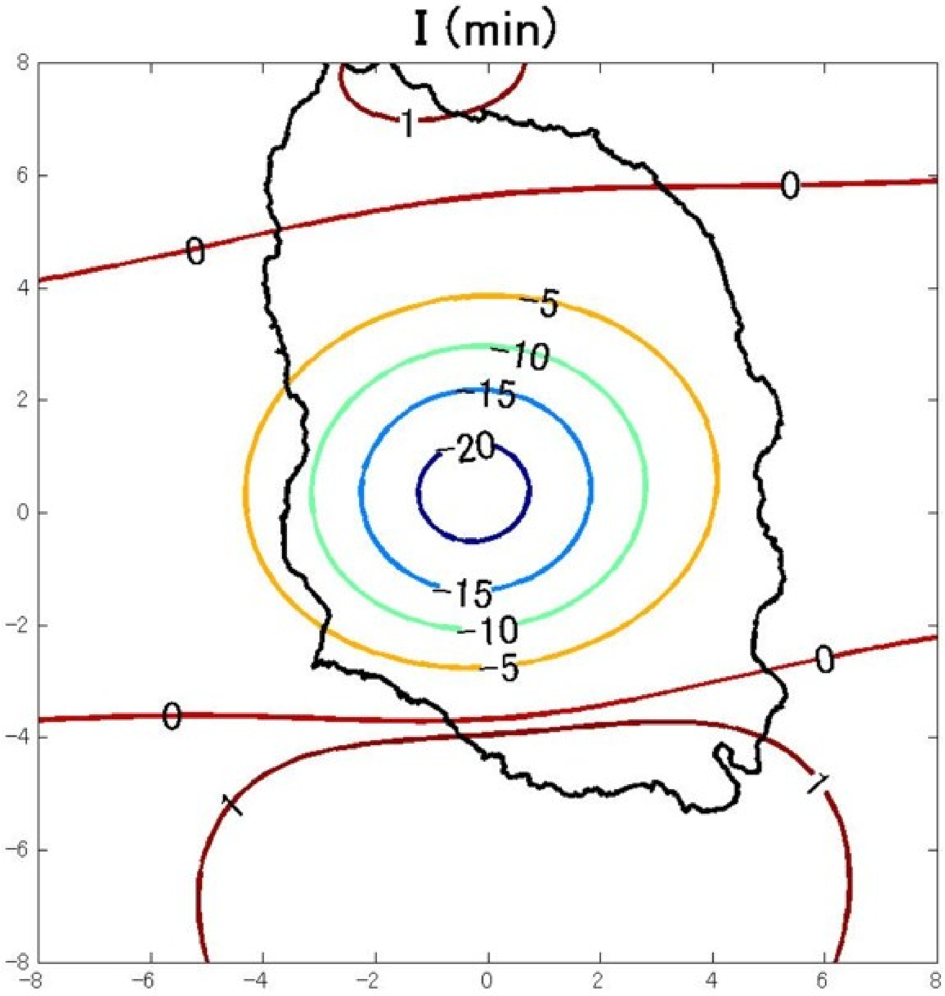
Inversion for a best-fit ellipsoid

- Grid points inside the caldera at every 0.1 km width with 0.1 km spacing in depth between 1 km and 3 km.
- Each grid point is the center of an ellipsoid.
- We search for the best-fit model, which minimizes the squared sum of (O - C), using GA (Genetic Algorithm) at each point.

Convergence of minimum sigma to the best-fit solution. Choice of N (number of populations) is important. We choose N=100.



The best-fit ellipsoid： a = 2.99 km, b = 2.68 km, c = 0.558 km, α = N350° E, δ =6° , γ =83° , (-0.8kmN, +0.2kmE) from R, D=3.0km

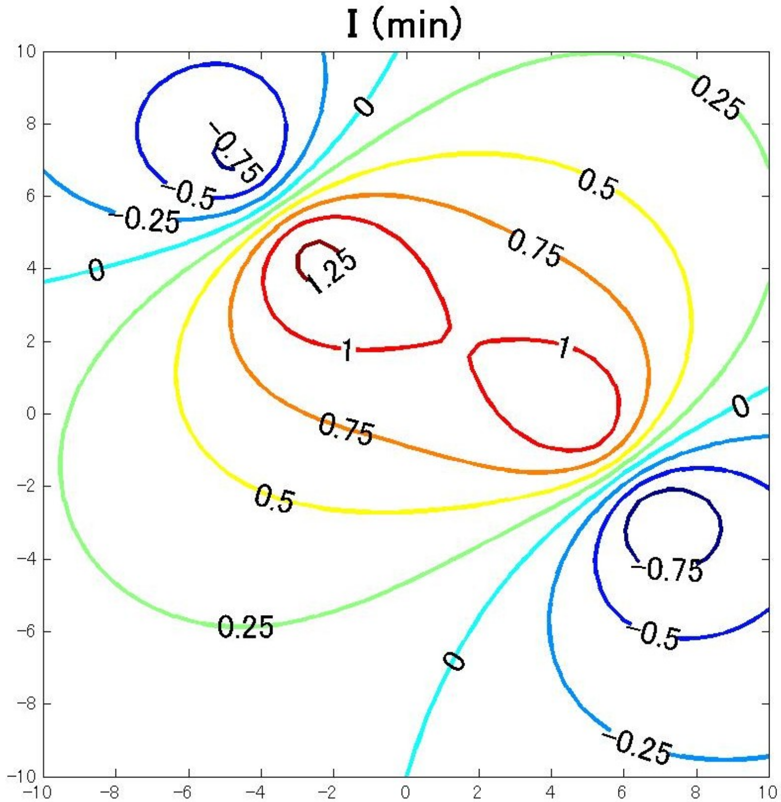


Features of the ellipsoidal source

- An almost N-S oriented, slightly inclined to the north, flat ellipsoid (nearly spheroid).
- The center of ellipsoid is as shallow as 3 km below the sea level.
- The volume is smaller than the dipole source (sphere).
- Thickness of the ellipsoid (~1km) is much larger than the ordinary intrusive dyke (~10m).

What happened during the Phase I eruption in 1950?

- Different from magma "intrusion" as 1986. (See right.)
- Magma stole into a vacant space, which was initially occupied by strongly magnetized volcanic ash.
- GA is a powerful tool for magnetic source inversion.



Dip changes due to the piezomagnetic effect.