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Correction to the Paper "Multiple Tension-Crack Model for Dilatancy: Surface Displacement, Gravity and Magnetic Change"

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An error was found in a formula for the gravity change associated with the multiple T33 crack model presented by SASAI (1986), which will be referred to as paper I. A discrepancy was pointed out by Okubo, who has done theoretical work on gravity changes due to various kinds of dislocation sources (OKUBO private communications). He showed that the gravity change caused by density changes in an elastic half-space arising from the T33 type strain nucleus should be null. Following his suggestion, I reexamined the derivation of eq. (4.19) in paper I.

The source of mistakes is the Fourier transform of div U_{33}, i.e. eq. (A.4) in Appendix A. It should be read as

$$\frac{4\pi}{\Delta U}(\mathrm{div}\,U_{33})^* = 2(\alpha-1)ke^{-k\zeta_1} + 2(1-\alpha)(k+2k^2\xi_3)e^{-k\zeta_2} \qquad (A.4')$$

Substituting (A.4') into eq. (4.15), we obtain

$$\begin{aligned}\delta g_4^* &= \rho G\Delta U(1-\alpha)\int_0^\infty [ke^{-k\zeta_1} - (k+2k^2\xi_3)e^{-k\zeta_2}]e^{-kz'}dz' \\ &= 0 \end{aligned} \qquad (4.15')$$

Inversion of eq. (4.15') gives simply

$$\mathrm{G4}:\ \delta g_4 = 0 \qquad (4.16')$$

The density-related gravity change vanishes in the case of a single T33 crack, which entirely coincides with OKUBO's (in preparation) result.

The total gravity change by a single T33 crack is given by

$$\delta g_{33} = (-\gamma + 2\pi G\rho)\Delta h_p + \Delta U(\rho_0-\rho)G\frac{\xi_3}{R^3} \qquad (4.17')$$

Hence the final result for the gravity change associated with the multiple T33 crack model is reduced to

$$\delta G_{33} = (-\gamma+2\pi G\rho)\Delta H_{33}(x, y) + 2\pi(\rho_0-\rho)G\frac{\Delta h_0}{h_{33}}\int_0^\infty Q_1(k)e^{-kD}J_0(kr)kdk \qquad (4.19')$$

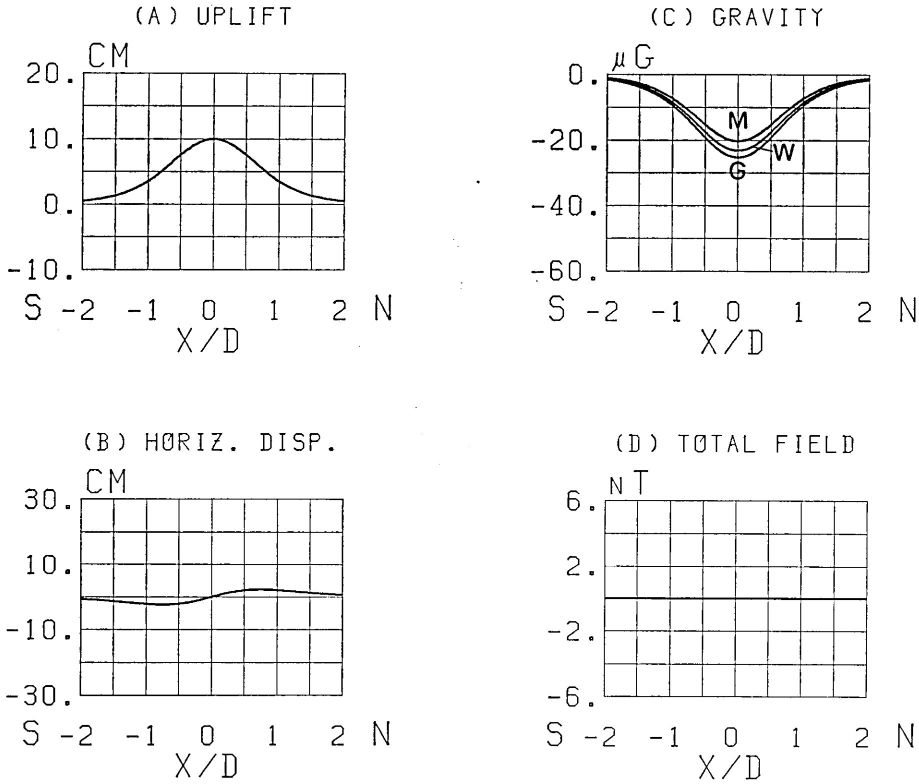

Fig. 8′. The multiple T33 crack model with $D=1.0$ km, $\sigma_r=\sigma_z=0.5$ km.

Fig. 8 in paper I should be replaced with Fig. 8′, according to the revised formula (4.19). Comparing Fig. 8′ with Fig. 4 and 9 in paper I, we may summarize: the gravity change accompanying a given amount of surface uplift is largest in the case of the multiple T11 crack model, least in the T33 model and intermediate in the multiple Mogi model. This implies the gravity data can be used to specify the type of cracks.

The density-related gravity change corresponds to the piezomagnetic field. It is interesting that the piezomagnetic change associated with the T33 type strain nucleus is practically zero (SASAI 1980), except for minor influence from the Curie point isotherm. In the limiting case of the Curie depth approaching infinity, we have no piezomagnetic change with the T33 crack. OKUBO (priv. com.) also found that the density-related gravity change vanishes for the strain nuclei of W_{23} and W_{31}, i.e. the dip-slip type of shear dislocations (MARUYAMA 1964). Again the piezomagnetic changes are negligible for such strain nuclei (SASAI 1980). The stress-induced part of the gravity and magnetic field behaves in quite a similar manner for dislocation sources. No intuitive explanation for such characteristics is available yet.

There are some misprints in paper I. One is the Fourier transform of U_{33}^{z}. Eq. (A.3) should be read as

$$\frac{4\pi}{\Delta U}U_{33}^{z*}=\pm(\alpha k\zeta_1+1)e^{-k\zeta_1}-\{1+(2-\alpha)k\xi_3+\alpha(k+2k^2\xi_3)z\}e^{-k\zeta_2} \qquad (A.3')$$

The results for the uplift, i.e. eq. (4.6), is valid, which can be derived from eq. (A.3′).

The formula for the uplift due to a single T11 crack is errorneous. Eq. (5.7) should be read as

$$\Delta h_p(x, y)=\frac{\Delta U}{2\pi}\left[\left(2-\frac{1}{\alpha}\right)\frac{\xi_3}{R^3}+\left(\frac{1}{\alpha}-1\right)\left\{\frac{1}{R(R+\xi_3)}-\frac{x^2(2R+\xi_3)}{R^3(R+\xi_3)^2}\right\}\right.$$
$$\left.-\xi_3\left(\frac{1}{R^3}-\frac{3x^2}{R^5}\right)\right] \qquad (5.7')$$

The final result for the resultant uplift, eq. (5.1), is correct.

A minor misprint is found in eq. (3.31), which should be rewritten as

$$\frac{\delta G_{00}}{\Delta H_{00}}=-\gamma+\frac{2\pi G\rho_0(\lambda+\mu)}{\lambda+2\mu} \qquad (3.31')$$

Finally I am greatly indebted to Shuhei Okubo for his suggestions. Discussion with him was useful not only for correcting my error, but for better understanding of the roles of gravity and magnetic field in tectonic problems.

References

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「地殻ダイラタンシーの複合テンション・クラック・モデル——その変位，重力および地磁気変化」の一部訂正

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上記論文 (SASAI 1986) の一部に誤りが見つかったので，訂正する．それは T33 型クラック・モデルの重力変化の項である．なおこの誤りは，地震研究所の大久保修平博士に指摘して頂いた．単一の T33 型クラックの及ぼす応力場で，半無限弾性体に生ずる密度変化に伴い，重力も変化する．ところがこのタイプの力源では，密度変化による項は，結果としてゼロになることが分かった．原論文における (4.19) 式は，(4.19′) 式に訂正する．これに伴って，原論文では Fig. 8(c) に示した重力変化の例を，Fig. 8′(c) のように改める．同一の最大隆起を示す複合テンション・クラック・モデルのうち，T33 型の重力変化が最も小さく，10 cm 程度の隆起量では，クラック内部を満たす物質の密度の違いを判別できない．なお大久保（準備中）によれば，T33 型の他に，垂直たてずれのせん断型くい違いを表す歪核（W23 型と W31 型）においても，密度変化による重力変化は，地表ではゼロになる．これはピエゾ磁気効果についての同様な結果 (SASAI, 1980) と完全に一致しており，興味深い．この事実の直観的で理解しやすい解釈は，今の所，得られていない．なお，原論文の数式における，いくつかのミスプリントも訂正した．

誤りを指摘した上に，色々議論して頂いた大久保修平博士に，心から感謝します．