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Magnetic anomalies of disjunctive thin-bed structures and their compact magnetic sources

Petar Stavrev[1], *Petya Trifonova*[2]

[1] University of Mining and Geology "St. Ivan Rilski", pstavrev@mail.bg
[2] National Institute of Geophysics, Geodesy and Geography – Bulgarian Academy of Sciences, ptrifonova@geophys.bas.bg

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Short abstract

Models of 2D horizontal semi-infinite in length thin-beds and their discontinuities, like a break or a fault, are under analysis. Magnetic anomalies caused by respective geologic structures appear to be created by an equivalent magnetic source of limited size in the frame of a disjunctive structure. Suppose the vertical and/or horizontal parameters of such source would be taken small with respect to the depth of the thin-bed structure. In that case, the result reaches just the expression of a 2D line-of-dipoles magnetic anomaly. Such patterns are often observed in real case studies of sedimentary basins cut by faults or by breaks of different sizes due to possible earthquakes or river runways along plain terrain or in canyons. They are commonly associated with subtle linear features in high-resolution magnetic maps caused by the tectonic juxtaposition of sedimentary layers with different magnetic properties.

Магнитни аномалии на дизюнктивни тънки пластови структури и техни компактни магнитни източници

*ПетърСтавре*в[1],*ПетяТрифонова*[2]

[1] Минно-геоложки университет „Св. Иван Рилски", pstavrev@mail.bg
[2] Национален институт по геофизика, геодезия и география – БАН, ptrifonova@geophys.bas.bg

Разработени са модели на 2D хоризонтални тънки пластове и техни прекъсвания от нарушения или разломи. Магнитните аномалии, причинени от съответните геоложки структури, наподобяват такива, създадени от еквивалентен тънкослоен магнитен източник с ограничен размер в рамките на дизюнктивната структура. Ако вертикалните и/или хоризонталните параметри на такъв източник се приемат малки по отношение на дълбочината на пластовата структура, резултантното магнитно поле достига израза на магнитна аномалия на 2D-линия от диполи с ограничени размери. Това значително улеснява интерпретацията на подобен род аномалии и позволява определянето на параметрите на смущаващите източници.

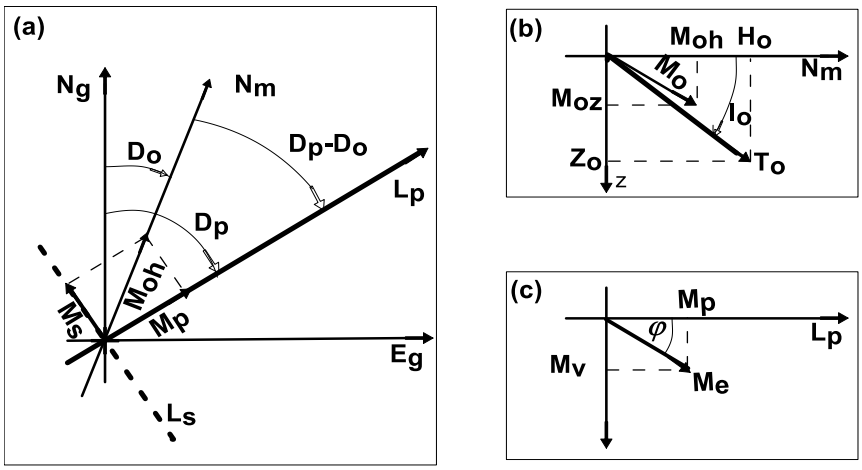


Fig. **1**. (**a**) Line L_p of a magnetic profile across the strike L_s of thin-bed; (**b**) Vertical plane of the magnetic meridian N_m, and (**c**) Vertical plane of the magnetic profile line L_p,

In case of known remnant magnetization, its components in vertical direction and along horizontal profile line L_p should be added to the components M_v and M_p. If the vector of effective magnetization is defined by the magnitude and dip angle, then the anomalous field elements could be calculated from the known expressions (Logachev and Zakharov,1973, see e.g., Dimitrov and Stavrev, 1986) as:

$$Z = 2M_e\, t\,\frac{h\cos\theta - x\sin\theta}{x^2+h^2},\ H = -2M_e\, t\,\frac{h\sin\theta + x\cos\theta}{x^2+h^2}\ ,\quad T_a = \sqrt{H^2+Z^2}\quad , \qquad (1)$$

$$\Delta T = Z\sin I_0 + H\cos I_0\cos(D_P - D_0) \qquad (2)$$

where M_e is the module of effective magnetization vector M_e; angle $\theta = \alpha - \varphi$, where α is the bed dip angle (in our case $\alpha = 0$), φ is the magnetization dip angle; t is the bed thickness; h is the depth of the bed edge; x is the horizontal coordinate of observation point $P(x,0)$ with respect to the bed edge $E(0,h)$ in 2D XOZ coordinate system, where axis x lies from left to write and axis z is pointed downward. Angles α and φ should be taken from the positive direction of axis x clockwise from 0 to 360 degrees. The total magnetic intensity ΔT is calculated here as an additive and quasi-harmonic approximation, acceptable in case of a moderate anomalous field (see e.g. Cady 1980, Blakely 1995),

Analytical expressions of the magnetic models and their magnetic effects

Break of a 2D horizontal thin bed (Fig. 2) This is the simplest structure for analysis. The anomalous field components Z and H can be represented as a sum of respective components caused by the two thin beds: number '1' from the left and number '2' from the right side of the break structure (Fig. 2b). The zero point of horizontal x-axis we choose in the midpoint of the structure and zero point of downward z-axis – in the line of

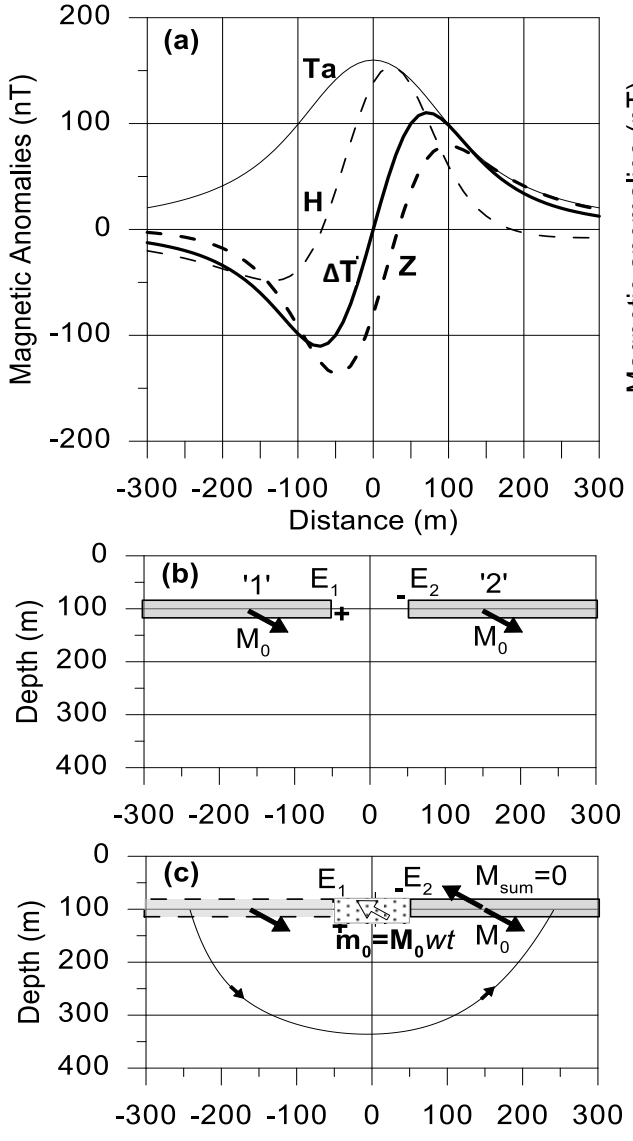


Fig. 2.(**a**) Magnetic anomalies ΔT, Z , H and T_a; (**b**) thin beds with magnetization vector $\mathbf{M}_0$ under angle $\varphi = 30^0$, (**c**) Equivalent source body of limited length (in point raster) with 2D magnetic moment $\mathbf{m}_0$ under angle $\varphi = 180^0+30^0 = 210^0$ after shown geometric displacement of the left bed '1' upon the write one '2'.

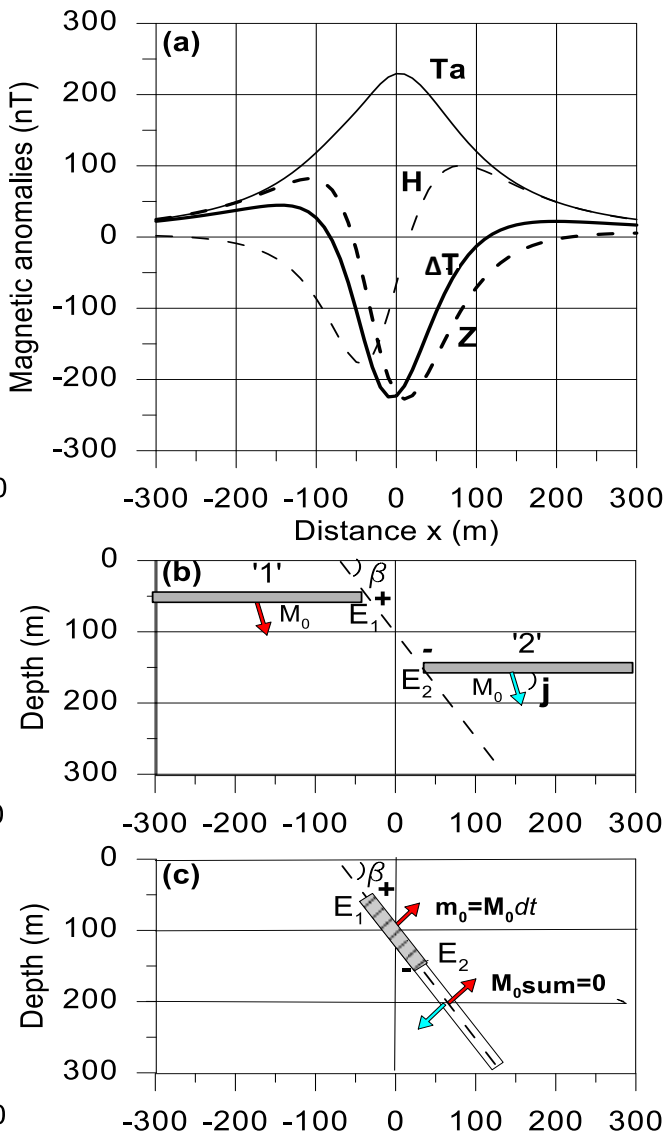


Fig. 3.(**a**) Magnetic anomalies ΔT , Z , H and T_a (**b**) dipping fault structure consisting of two thin beds with magnetization $\mathbf{M}_0$; (**c**) Equivalent source body (in cross lines raster) with 2D magnetic moment $\mathbf{m}_0 = \mathbf{M}_0 dt$ after geometric rotation of the left bed and right bed to the dipping position under angle β, t is the thickness and d is the source length between edge points E_1 and E_2; the coinciding parts of the two beds under point E_2 compensate each other ($\mathbf{M}_0$sum=0) so they are not magnetically active.

The possibility for such equivalent replacement is found in Equation 1, where components Z and H depend on angle $\theta = \alpha - \varphi$ only, but not on angles α and φ individually. Angle α is of given value as it corresponds to

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the horizontal beds under consideration, while angle φ we may accept one and the same for the two beds like it is the case before the break geological event. If the difference angle θ states constant along with the edge coordinates and magnetization module, then the anomalous magnetic profiles Z, H, ΔT T_a are also constant after a geometrical rotation from center E_1 like shown in Figure 2c. The magnetization vector of this equivalent source body has an effective angle $\varphi' = \varphi+180^0$, i.e. its direction is in opposition to the original bed's magnetization orientation as it should be.

If the width w of the structure is of a small negligible size with respect to the distances between the thin-bed source and observation points, we obtain the geomagnetic components:

$$Z = 2m_0 \frac{(x^2-h^2)\sin\varphi + 2xh\cos\varphi}{(x^2+h^2)^2}, \quad H = -2m_0 \frac{(x^2-h^2)\cos\varphi - 2xh\sin\varphi}{(x^2+h^2)^2}, \qquad (3)$$

$$\Delta T = 2m_0 \frac{(x^2-h^2)S_w + 2xhC_w}{(x^2+h^2)^2}, \qquad T_a = \sqrt{Z^2+H^2} = 2m_0 \frac{1}{x^2+h^2}. \qquad (4)$$

These expressions (Eq. 3 and Eq. 4) coincide with the well-known equation for the anomalous field caused by a 2D line of point dipoles having magnetic moment m_0. The example in Figure 2c treats inclined magnetic moment and magnetization. Coefficients S_w and C_w depend on the angles φ, I_0, D-D_0.

Dipping fault structure consisting of two 2D thin beds (Fig. 3). We can obtain an equivalent source (in the raster of cross lines) with 2D magnetic moment $\mathbf{m}_0 = \mathbf{M}_0 dt$ after geometric rotation of the left bed and right bed to the dipping position under angle β, t is the thickness and d is the source length between edge points E_1 and E_2; the coinciding parts of the two beds under point E_2 compensate each other ($\mathbf{M}_0$sum=0) so they are not magnetically active.

The shown above approach to the analysis of a break or a fault structure and respective anomalous magnetic fields has been applied to other disjunctive structures, including to thick beds of a small throw. Similar kinds of total magnetic anomalies can be seen in Grauch, Hudson, Minor and Caine (2006).

Conclusions

The magnetic effect from disjunctive thin beds of semi-infinite horizontal extension can be explained by an equivalent compact source of limited size between the edge points of the beds.

The form of a compact equivalent source is useful in the process of forward modeling and can be useful for inversion models like Euler deconvolution.

The shown above analytical expressions and Figures have been compounded and calculated using the author's special PC programs for the creation of forward magnetic models.

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