Interpretação inicial

Que informações da fonte de massa anômala podemos obter de um perfil ou de um mapa de anomalia gravimétrica?

Yara Marangoni, 2020

Estimativa de alguns parâmetros da fonte em perfis

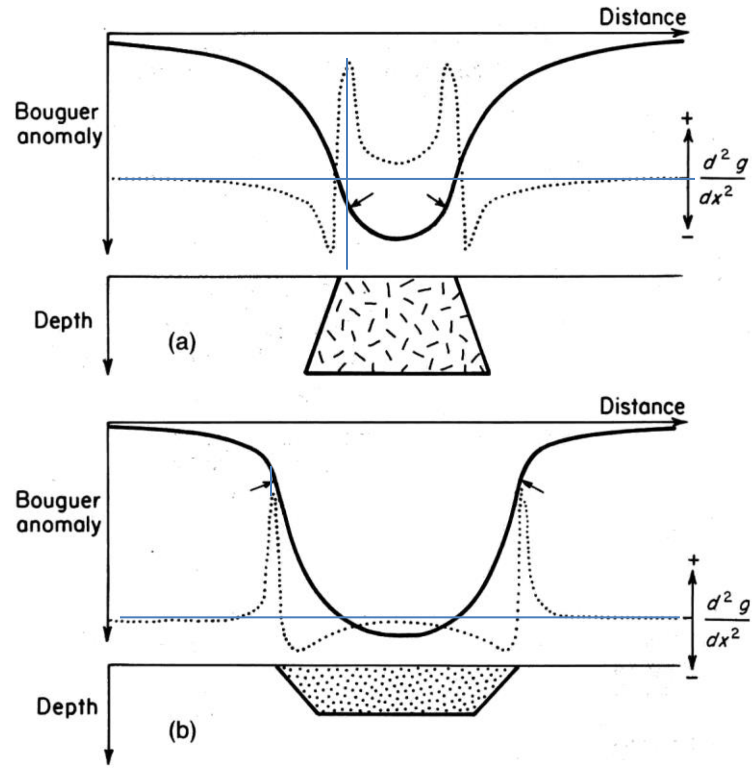
- **Tamanho lateral da fonte** através das segundas derivadas horizontais da anomalia.
- **Inclinação dos contatos da fonte** através de um perfil de anomalia e da derivada segunda.
- **Máxima profundidade do topo da fonte** (estima a profundidade do centro de massa da fonte) usando apenas um perfil da anomalia.

Tamanho lateral da fonte

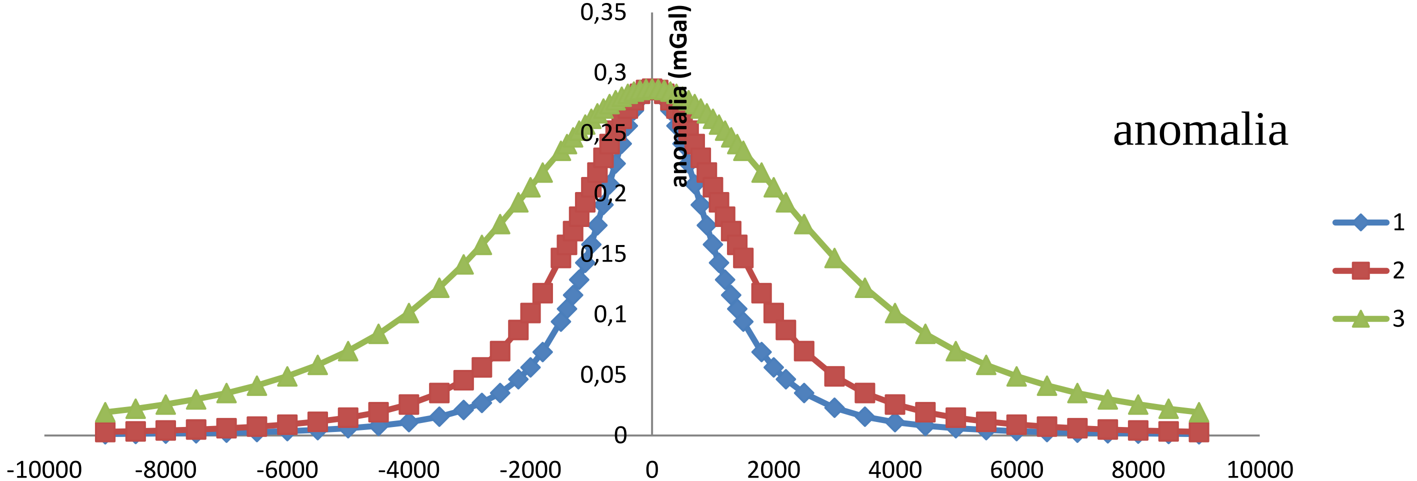
- **Tamanho lateral da fonte** através das segundas derivadas horizontais da anomalia.
- Se for um perfil, teremos apenas uma direção para a derivada. Se for um mapa podemos fazer a derivada nas duas direções de forma independente.

Inclinação das paredes da fonte

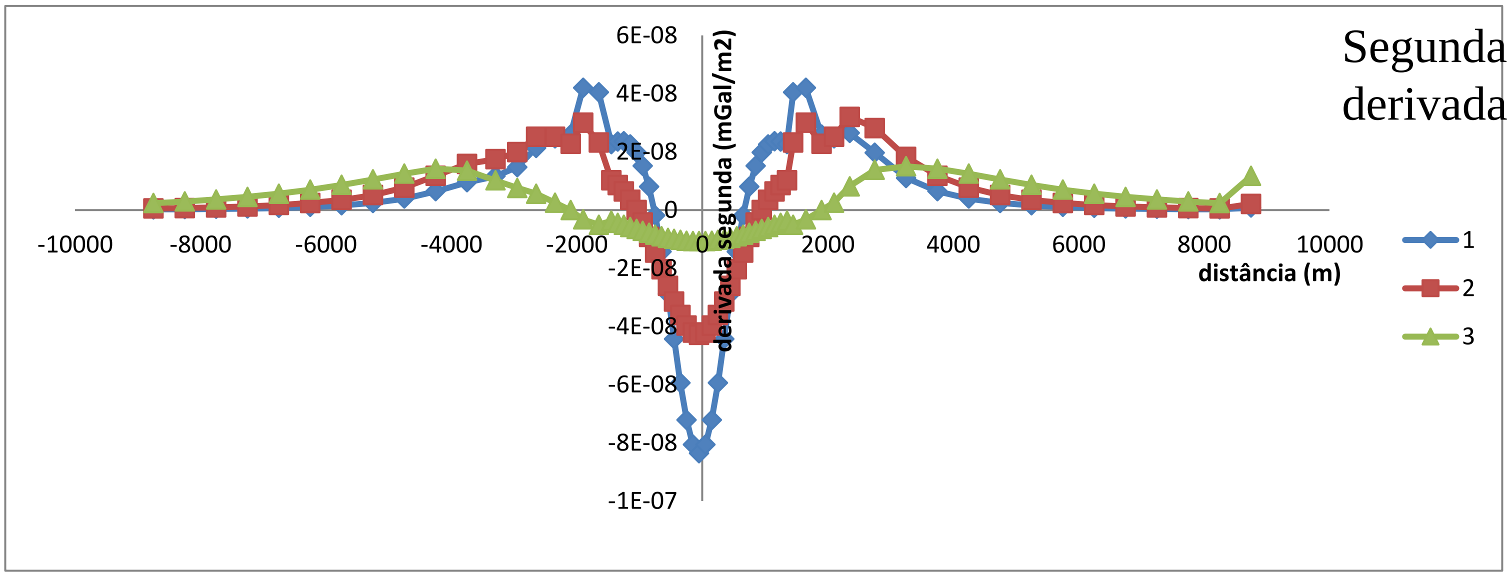
- A localização dos pontos de inflexão (pontos da curva onde a segunda derivada é igual a zero) dos perfis gravimétricos pode fornecer uma informação útil sobre a natureza das fronteiras da fonte.
- contatos inclinados para fora (a): os pontos de inflexão (identificados pelas setas) situam-se na base da anomalia
- contatos inclinados para dentro (b): (caso de bacias sedimentares) os pontos de inflexão situam-se nas bordas da anomalia.



Estimativa da extensão lateral da fonte

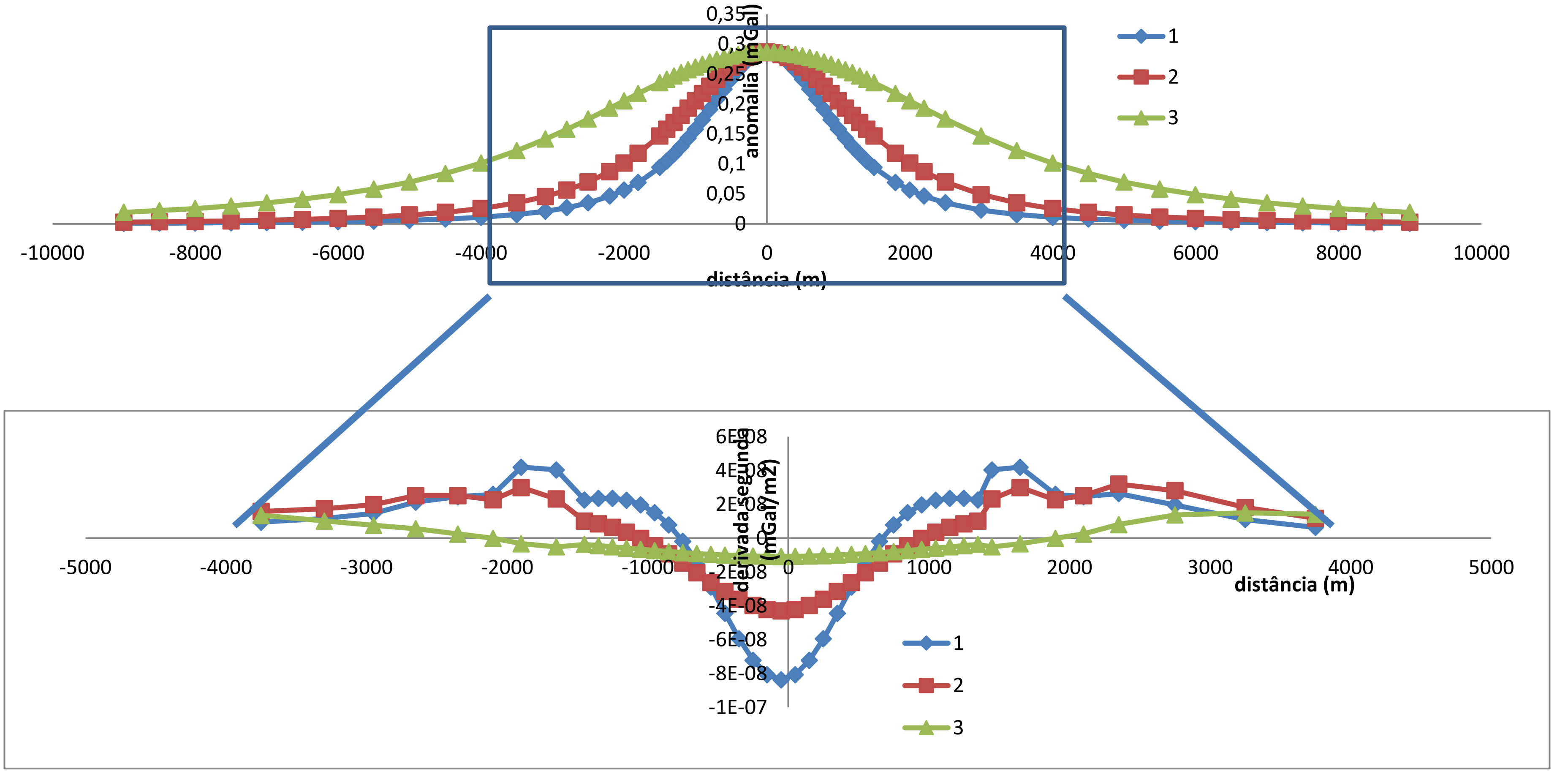


anomalia



Segunda derivada em x

Estimativa da extensão lateral da fonte



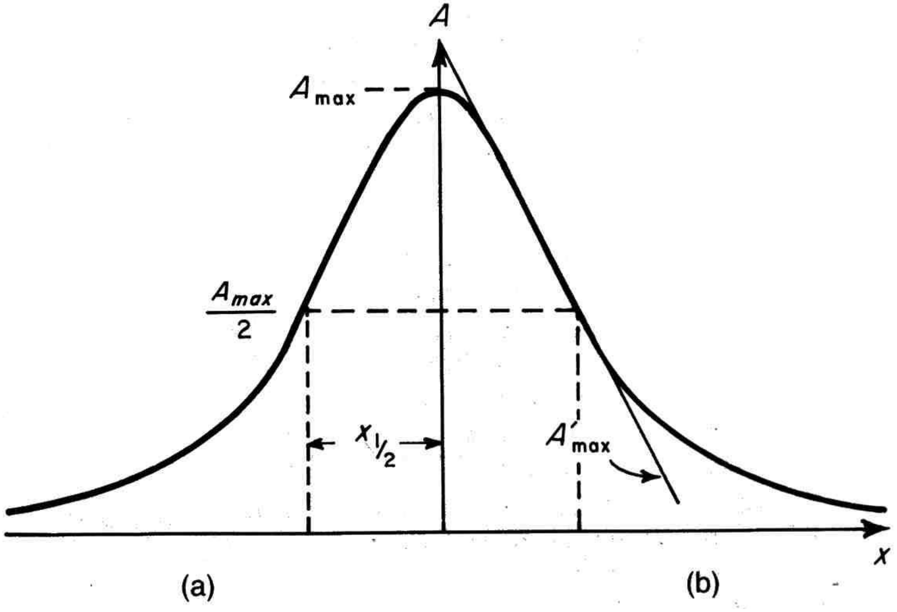
Curva 1: 0 da segunda derivada entre -900 e -800 m e 600 e 700 m
Curva 2: 0 da segunda derivada entre -1200 e -1100 e 900 e 1000 m
Curva 3: 0 da segunda derivada entre -2500 e -2300 e 1800 e 2000 m

Estimativa da máxima profundidade da fonte

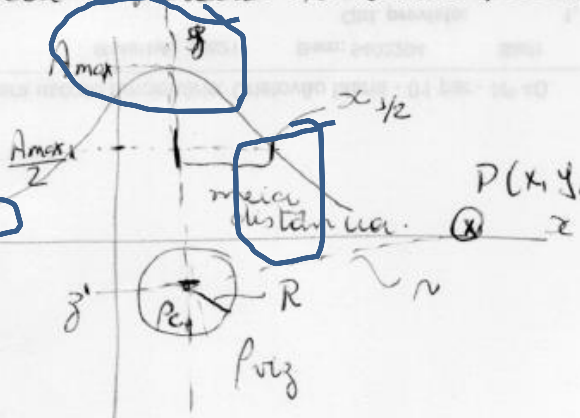
- Método da meia largura
- Anomalia 3D
- Esfera: $z < \frac{x_{1/2}}{(4^{1/3}-1)^{1/2}}$

- Anomalia 2D
- Linha de massa:

$z < x1/2$



meia-largura → que é igual à distância entre os pontos no qual a anomalia cai à metade do valor máximo da anomalia



A anomalia precisa decair para zero.
Preciso conhecer é:
Valor da anomalia máxima
Posição x onde g é a metade do valor máximo

anomalia de uma esfera com centro $(0,0,z)$

$$g = G\,\frac{4}{3}\,\pi\,R^3\,\Delta\rho\,\frac{z}{(x^2+z^2)^{3/2}}$$

máximo da anomalia → centro da esfera.

$$g_{max} = G\,\frac{4}{3}\,\pi\,R^3\,\Delta\rho\,\frac{z}{z^3} = G\,\frac{4}{3}\,\pi\,R^3\,\Delta\rho\,\frac{1}{z^2}$$

Assumindo que o CM da esfera está em (0,0, z)

$$\frac{g_{max}}{2} = G\,\frac{4}{3}\,\pi\,R^3\,\Delta\rho\,\frac{z}{(x_{1/2}^2+z^2)^{3/2}}$$

Substitui o valor de gmax

$$\frac{G\,\frac{4}{3}\,\pi\,R^3\,\Delta\rho}{2\,z^2} = G\,\frac{4}{3}\,\pi\,R^3\,\Delta\rho\,\frac{z}{(x_{1/2}^2+z^2)^{3/2}}$$

6.3

$$\frac{1}{2 z^2} = \frac{z}{\left(x_{1/2}^2 + z^2\right)^{3/2}}$$

~~des~~conhecido ⇒ meio de um perfil.

⇒ desconhecido ⇒ profundidade do CM da esfera

$$z^3 = \frac{1}{2}\left(z^2 + x_{1/2}^2\right)^{3/2} \quad \times \text{ eleva a } (2/3)$$

$$2^{2/3} z^{3 \cdot 2/3} = z^2 + x_{1/2}^2$$

$$4^{1/3} \cdot z^2 - 1\, z^2 = x_{1/2}^2$$

$$\left(4^{1/3} - 1\right) z^2 = x_{1/2}^2$$

$$z = \frac{x_{1/2}}{\left(4^{1/3} - 1\right)^{1/2}} = \frac{x_{1/2}}{0{,}7664}$$ ⇒ máxima profundidade do topo.

$$z \simeq 1{,}3048\, x_{1/2} \qquad z \simeq \frac{4}{3} x_{1/2}$$

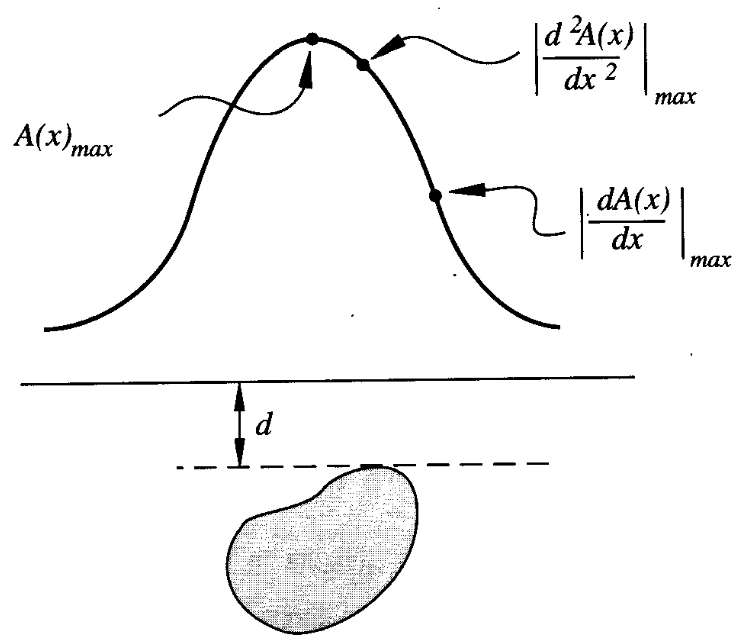
Estimativa da máxima profundidade da fonte

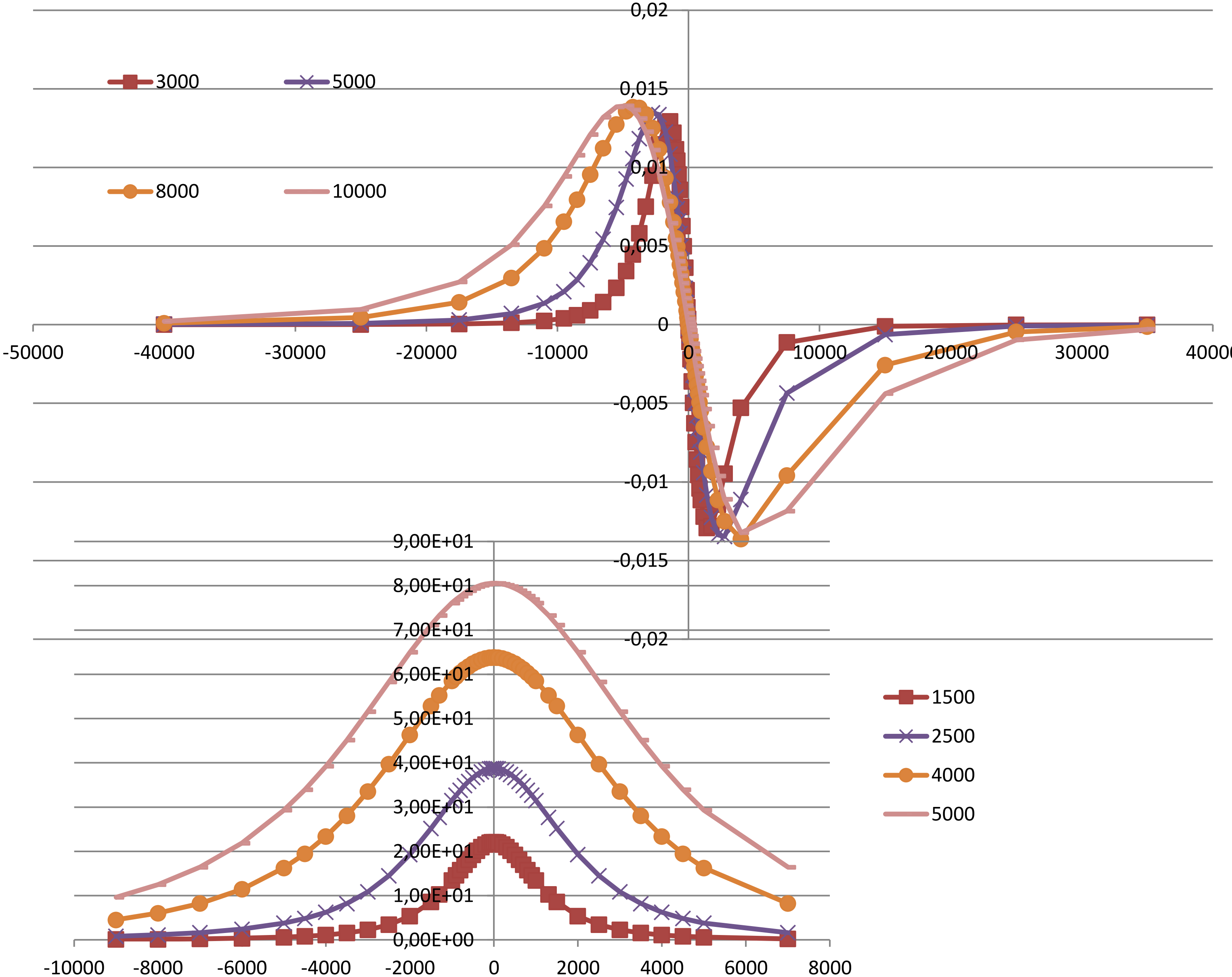
- Método da razão gradiente-amplitude
- Anomalia 3D

$$z < 0{,}86 \left| g_{zmax}/(dg/dz)_{max} \right|$$

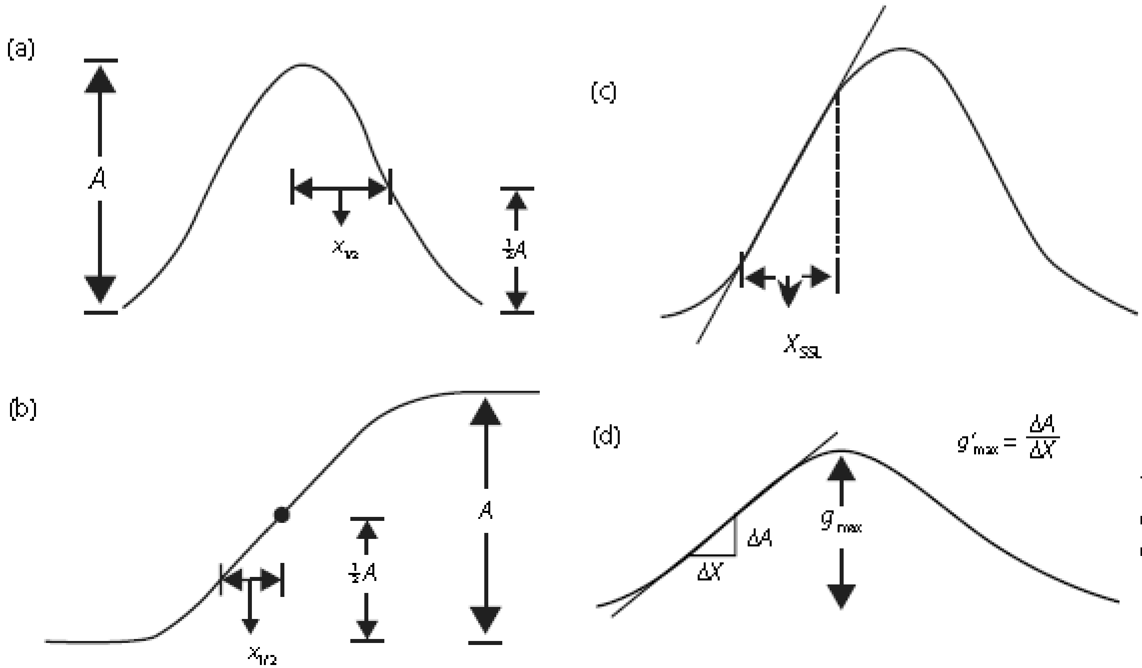
- Anomalia 2D

$$z < 0{,}65 \left| g_{zmax}/(dg/dz)_{max} \right|$$




0,02
0,015
0,01
0,005
0
-0,005
-0,01
-0,015
-0,02
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
3000
5000
8000
10000
9,00E+01
8,00E+01
7,00E+01
6,00E+01
5,00E+01
4,00E+01
3,00E+01
2,00E+01
1,00E+01
0,00E+00
-10000
-8000
-6000
-4000
-2000
0
2000
4000
6000
8000
1500
2500
4000
5000

Estimativa da máxima profundidade da fonte



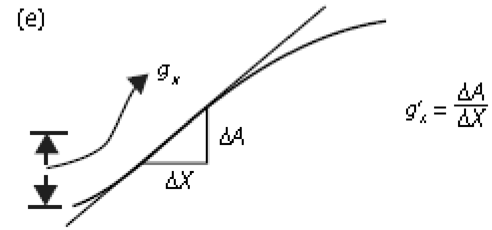


FIGURE 7.16 Measurements used in estimating source depth from gravity anomalies. (a) Half-width method based on a spherical source. (b) Half-width method applied to an anomaly derived from a fault. (c) Straight-slope method. (d) Smith method based on the entire anomaly. (e) Smith method based on a partial anomaly. In these estimates, A is the maximum amplitude of the anomaly, X is horizontal distance, and $\Delta A/\Delta X$ is the change in amplitude (ΔA) over the horizontal distance change (ΔX). See text for further descriptions.

TABLE 7.1 Gravity half-width depths either to the tops (z_t) or the centers (z_c) of various idealized sources in terms of one-half the width of the anomaly at one-half the amplitude, $X_{1/2}$, or the horizontal distance from one-half the amplitude to either one-quarter or three-quarters the amplitude, $X^{\ddagger}_{1/2}$. The complementary magnetic half-width depths for these sources are given in Table 13.1.

Source	Gravity depth
Sphere	$z_c \leq 1.3 \times X_{1/2}$
Thin horizontal cylinder	$z_c \leq 1.0 \times X_{1/2}$
Deeply extending vertical cylinder	$z_t \leq 0.58 \times X_{1/2}$
Narrow vertical dike	
if depth extent $\approx Z_t$	$z_t \approx 0.7 \times X_{1/2}$
if depth extent $\gg Z_t$	$z_t \approx 1.0 \times X_{1/2}$
Vertical fault	$z_c \leq 1.0 \times X^{\ddagger}_{1/2}$

Hinze et al., 2013

Estimativa da máxima profundidade da fonte

(A) Half-width method The half-width method of depth determination (Nettleton, 1940, 1942) has been widely used in gravity interpretation. It is based on equating the gravity effect of an idealized geometric source to half of its amplitude and solving for the source's depth in terms of the horizontal distance between the anomaly peak and one-half of the peak amplitude.

The method is based on simplification of the theoretical gravity effect from an idealized geometry assumed in the application of the method. The horizontal distance from the center of the anomaly to one-half of its amplitude is called the anomaly half-width (Figure 7.16(a)). The half-width distance for the vertical edge of the horizontal slab, that is the vertical fault anomaly, is measured somewhat differently. It is the horizontal distance from the center of the fault anomaly that is one-half of its total amplitude to either the one-quarter or three-quarters anomaly value (Figure 7.16(b)). For various idealized sources with simple geometric forms, Table 7.1 lists the relationships between the anomaly half-width distance, $X_{1/2}$, and the depth either to the top, z_t, or the center, z_c, of the source.

(B) Straight-slope method Anomaly source depths also may be estimated from the horizontal distance over which the maximum gradient of the anomaly remains essentially constant. The method is sometimes easier to perform on the computed vertical derivative of the gravity anomaly, rather than the gravity anomaly itself where the flat spots at the peaks and troughs are measured. This is the so-called straight-slope distance method because it is based on the distance over which the slope at the inflection point of the anomaly profile remains straight or the gradient is constant. This method is not based on theoretical formulations, but rather on empirical evidence from case histories or anomalies calculated from idealized sources. Dampney (1977) found that the relationship $z_c \approx 2 \times X_{SSL}$ is useful in determining the depth z_c to the center line of a vertical fault from the straight slope length, X_{SSL} (Figure 7.16(c)). Ram Babu *et al.* (1987) found a similar relationship and developed other straight-slope length relations for additional geometric forms including $z_c \approx 2 \times X_{SSL}$ for spheres and horizontal cylinders, and $z_c \approx 1.22 \times X_{SSL}$ for thin horizontal plates.

Hinze et al., 2013

Estimativa da máxima profundidade da fonte

(C) Smith rules SMITH and BOTT (1958) and SMITH (1959, 1960) developed several depth determination rules based on horizontal derivatives of gravity. These rules, commonly referred to as the Smith Rules, are independent of source geometry, and thus are potentially useful where the geometry of the source is unknown or cannot be approximated with a simple shape. Where the entire anomaly is isolated, the approximate depth, z_t, to the top of the source is

$$z_t \leq K \times (g_{max}/g'_{max}), \tag{7.1}$$

where $K = 0.65$ for the 2D source and 0.86 for the 3D source, g_{max} is the peak or maximum anomaly value, and g'_{max} is the absolute maximum horizontal derivative (i.e. slope) of the gravity anomaly in gravity anomaly unit per depth unit (Figure 7.16(d)). Where only a portion of the anomaly is mapped and isolated (Figure 7.16(e)), the depth approximation is

$$z_t \leq K' \times (g_x/g'_x), \tag{7.2}$$

where $K' = 1.0$ for the 2D source and 1.5 for the 3D source, and g_x is the gravity anomaly value where the absolute horizontal derivative (slope) is g'_x.

If the absolute maximum density contrast $\Delta\sigma_{max}$ occurring within the source can be specified as well as the absolute maximum second horizontal derivative of the gravity anomaly g''_{max}, then the depth to the top of the source is

$$z_t \leq 5.4 \times G(\Delta\sigma_{max}/g''_{max}), \tag{7.3}$$

where G is the gravitational constant and all the variables must be consistent units. If the depth to the source can be estimated from other sources, Equation 7.3 can be inverted to determine the maximum density contrast. The results can also be improved if the density contrast within the source is positive throughout. In this case, $\Delta\sigma_{max}$ is replaced by $\Delta\sigma_{max}/2$.

Porque falamos em máxima profundidade do topo da fonte?

Hinze et al., 2013