Universidade Federal do Paraná
Programa de Pós-Graduação em Geologia

GEOL7048: Tópicos Especiais em Geologia Exploratória II

Métodos semiquantitativos

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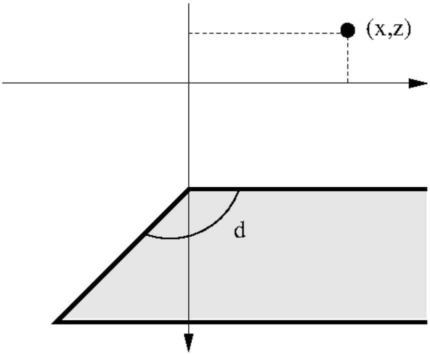
Aula 29

- Anomalia gerada por um contato geológico

- Método tilt depth

Anomalia de um contato

Modelo de anomalia gerada por um contato geológico:



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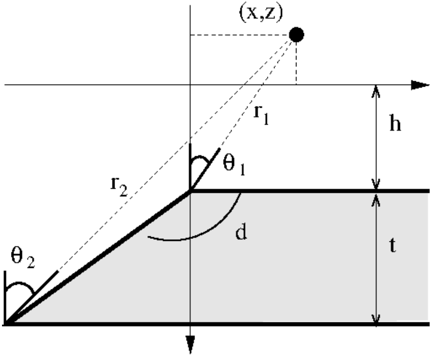

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Anomalia de um contato

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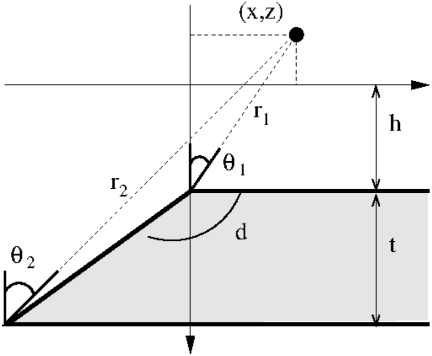
$$M(x,z) = A\left[(\theta_1 - \theta_2)\cos(\phi) + \ln\frac{r_1}{r_2}\,\mathrm{sen}(\phi)\right]$$



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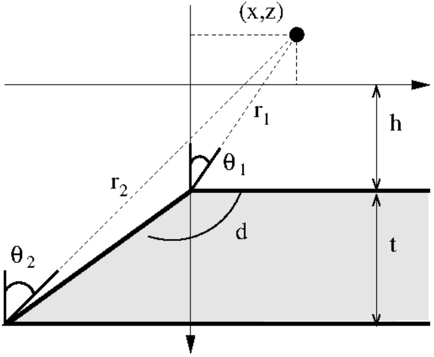
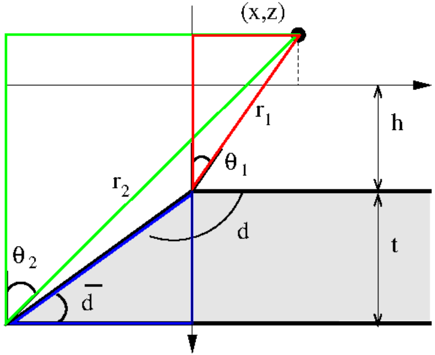


Anomalia de um contato



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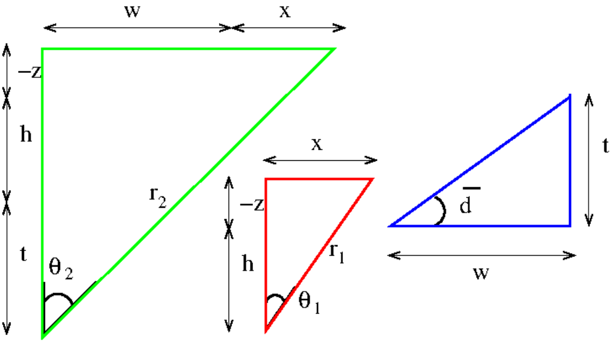

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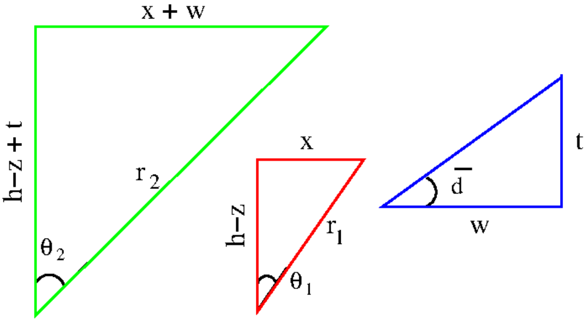
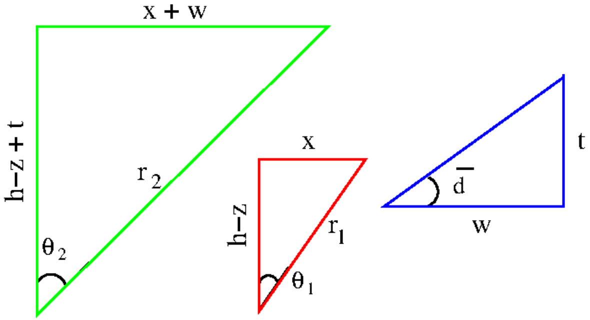


$$M(x, z) = A\left[(\theta_1 - \theta_2)\cos(\phi) + \ln\frac{r_1}{r_2}\,\mathrm{sen}(\phi)\right]$$

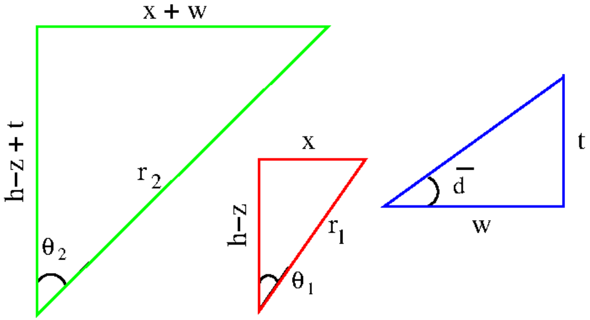
Anomalia de um contato



$$\tan(\theta_1) = \frac{x}{h-z}, \quad \tan(\theta_2) = \frac{x+w}{h-z+t}, \quad \tan(\bar{d}) = \frac{t}{w}$$

$$r_1^2 = (h-z)^2 + x^2, \quad r_2^2 = (h-z+t)^2 + (x+w)^2$$

Anomalia de um contato



$$\tan(\theta_1) = \frac{x}{h-z}, \quad \tan(\theta_2) = \frac{x+w}{h-z+t}, \quad |\tan(d)| = \frac{t}{w}$$

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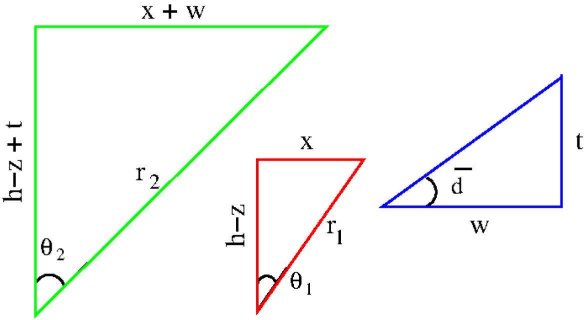
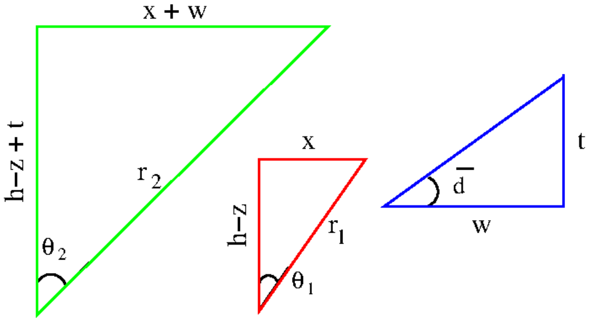
Anomalia de um contato



$$\tan(\theta_1) = \frac{x}{h - z}, \quad \tan(\theta_2) = \frac{x + w}{h - z + t}, \quad w = t|\cot(d)|$$

$$r_1^2 = (h - z)^2 + x^2, \quad r_2^2 = (h - z + t)^2 + (x + w)^2$$

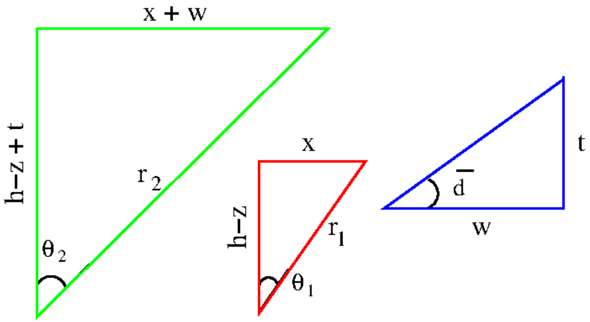
Anomalia de um contato



$$\tan(\theta_1) = \frac{x}{h-z}, \quad \tan(\theta_2) = \frac{x + t|\cot(d)|}{h-z+t},$$

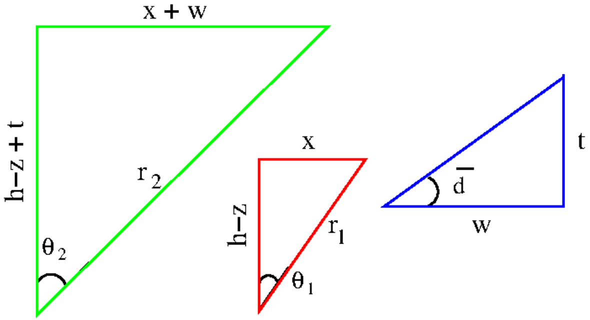
$$r_1^2 = (h-z)^2 + x^2, \quad r_2^2 = (h-z+t)^2 + (x + t|\cot(d)|)^2$$

Anomalia de um contato



$$
\begin{aligned}
M(x,z) \quad &= \quad A\left[\left(\tan^{-1}\frac{x}{h-z} - \tan^{-1}\frac{x+t|\cot(d)|}{t+h-z}\right)\cos(\phi) + \right. \\
&+ \quad \left. \ln\frac{\sqrt{(h-z)^2+x^2}}{\sqrt{(h-z+t)^2+(x+t|\cot(d)|)^2}}\operatorname{sen}(\phi)\right]
\end{aligned}
$$

Anomalia de um contato



$$M(x,z) = A\left[\left(\tan^{-1}\frac{x}{h-z} - \tan^{-1}\frac{x+t|\cot(d)|}{t+h-z}\right)\cos(\phi) + \right.$$
$$\left. + \frac{1}{2}\left[\ln((h-z)^2 + x^2) - \ln((h-z+t)^2 + (x+t|\cot(d)|)^2)\right]\operatorname{sen}(\phi)\right]$$

Anomalia de um contato

$$M(x,z) = A\left[\left(\tan^{-1}\frac{x}{h-z} - \tan^{-1}\frac{x+t|\cot(d)|}{t+h-z}\right)\cos(\phi)+\right.$$

$$\left.+\,\frac{1}{2}\left[\ln((h-z)^2+x^2) - \ln((h-z+t)^2+(x+t|\cot(d)|)^2)\right]\operatorname{sen}(\phi)\right]$$

Derivada com respeito a x

$$\begin{aligned}\frac{\partial M}{\partial x}(x,z) &= A\left[\frac{(h-z)\cos(\phi)}{(h-z)^2+x^2} - \frac{\cos(\phi)}{(h-z+t)\left[\left(\frac{x+t|\cot(d)|}{h-z+t}\right)^2+1\right]}\right.\\ &+ \left.\frac{x\operatorname{sen}(\phi)}{(h-z)^2+x^2} - \frac{(x+t|\cot(d))\operatorname{sen}(\phi)}{(x+t|\cot(d)|)^2+(h-z+t)^2}\right]\end{aligned}$$

Anomalia de um contato

$$M(x,z) = A\left[\left(\tan^{-1}\frac{x}{h-z} - \tan^{-1}\frac{x+t|\cot(d)|}{t+h-z}\right)\cos(\phi) + \right.$$
$$\left. + \frac{1}{2}\left[\ln((h-z)^2+x^2) - \ln((h-z+t)^2+(x+t|\cot(d)|)^2)\right]\operatorname{sen}(\phi)\right]$$

Derivada com respeito a x, com a espessura $t \to \infty$

$$\frac{\partial M}{\partial x}(x,z) = A\left[\frac{(h-z)\cos(\phi)}{(h-z)^2+x^2} + \frac{x\operatorname{sen}(\phi)}{(h-z)^2+x^2}\right]$$

Anomalia de um contato

$$M(x,z) = A\left[\left(\tan^{-1}\frac{x}{h-z} - \tan^{-1}\frac{x+t|\cot(d)|}{t+h-z}\right)\cos(\phi) + \right.$$
$$\left. + \frac{1}{2}\left[\ln((h-z)^2 + x^2) - \ln((h-z+t)^2 + (x+t|\cot(d)|)^2)\right]\operatorname{sen}(\phi)\right]$$

Derivada com respeito a x, com a espessura $t \to \infty$

$$\frac{\partial M}{\partial x}(x,z) = A\left[\frac{(h-z)\cos(\phi) + x\operatorname{sen}(\phi)}{(h-z)^2 + x^2}\right]$$

Anomalia de um contato

$$M(x,z) = A\left[\left(\tan^{-1}\frac{x}{h-z} - \tan^{-1}\frac{x+t|\cot(d)|}{t+h-z}\right)\cos(\phi) + \right.$$
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Derivada com respeito a x, com a espessura $t \to \infty$

$$\frac{\partial M}{\partial x}(x,z) = A\left[\frac{(h-z)\cos(\phi) + x\operatorname{sen}(\phi)}{(h-z)^2+x^2}\right]$$

Derivada com respeito a z com $t \to \infty$

$$\frac{\partial M}{\partial z}(x,z) = A\left[\frac{x\cos(\phi) - (h-z)\operatorname{sen}(\phi)}{(h-z)^2+x^2}\right]$$

Anomalia de um contato

Derivada com respeito a x, com$t \to \infty$:

$$\frac{\partial M}{\partial x}(x,z) = A\left[\frac{(h-z)\cos(\phi) + x\,\mathrm{sen}(\phi)}{(h-z)^2 + x^2}\right]$$

Derivada com respeito a z com $t \to \infty$:

$$\frac{\partial M}{\partial z}(x,z) = A\left[\frac{x\cos(\phi) - (h-z)\,\mathrm{sen}(\phi)}{(h-z)^2 + x^2}\right]$$

Parâmetros: $A = 2kF[1-\cos^2(i)\sin^2(\alpha)]\,\mathrm{sen}(d)$ e $\phi = 2I - d - 90^{\circ}$,

- k: contraste de susceptibilidade
- F: intensidade do campo magnético terrestre
- i: inclinação do campo magnético terrestre
- α: ângulo entre o norte magnético e o eixo x
- I: ângulo definido por $\tan(I) = \tan(i)/\cos(\alpha)$

Anomalia de um contato

No polo, $\alpha = 0^{\circ}$ e $i = 90^{\circ}$, de modo que

$$A = 2kF[1 - \cos^2(i)\sin^2(\alpha)]\,\mathrm{sen}(d), \quad \phi = 2I - d - 90^{\circ}, \quad \tan(I) = \frac{\tan(i)}{\cos(\alpha)}$$

Anomalia de um contato

No polo, $\alpha = 0^\circ$ e $i = 90^\circ$, de modo que

$$A = 2kF[1-\cos^2(90^\circ)\sin^2(0^\circ)]\,\mathrm{sen}(d), \quad \phi = 2I-d-90^\circ, \quad \tan(I) = \frac{\tan(90^\circ)}{\cos(0^\circ)}$$

Anomalia de um contato

No polo, $\alpha = 0º$ e $i = 90º$, de modo que

$$A = 2kF[1 - 0]\,\mathrm{sen}(d), \quad \phi = 2I - d - 90º, \quad \tan(I) = \frac{\tan(90º)}{1}$$

Anomalia de um contato

No polo, $\alpha = 0^{\circ}$ e $i = 90^{\circ}$, de modo que

$$A = 2kF\,\mathrm{sen}(d), \quad \phi = 2I - d - 90^{\circ}, \quad I = 90^{\circ}$$

Anomalia de um contato

No polo, $\alpha = 0$º e $i = 90$º, de modo que

$$A = 2kF\,\mathrm{sen}(d), \quad \phi = 90^{\circ} - d$$

Anomalia de um contato

No polo, $\alpha = 0^o$ e $i = 90^o$, de modo que

$$A = 2kF \operatorname{sen}(d), \quad \phi = 90^o - d$$

Assumindo ainda que o contato é vertical $d = 90^o$, obtemos

$$A = 2kF \operatorname{sen}(90^o), \quad \phi = 90^o - 90^o$$

Anomalia de um contato

No polo, $\alpha = 0^o$ e $i = 90^o$, de modo que

$$A = 2kF\,\mathrm{sen}(d), \quad \phi = 90^\text{o} - d$$

Assumindo ainda que o contato é vertical $d = 90^o$, obtemos

$$A = 2kF, \quad \phi = 0^\text{o}$$

Anomalia de um contato

No polo, $\alpha = 0^{\circ}$ e $i = 90^{\circ}$, de modo que

$$A = 2kF\,\mathrm{sen}(d), \quad \phi = 90^{\circ} - d$$

Assumindo ainda que o contato é vertical $d = 90^{\circ}$, obtemos

$$A = 2kF, \quad \phi = 0^{\circ}$$

Nestas condições,

$$\frac{\partial M}{\partial x}(x,z) = 2kF\left[\frac{(h-z)\cos(0^{\circ}) + x\,\mathrm{sen}(0^{\circ})}{(h-z)^2 + x^2}\right]$$

$$\frac{\partial M}{\partial z}(x,z) = 2kF\left[\frac{x\cos(0^{\circ}) - (h-z)\,\mathrm{sen}(0^{\circ})}{(h-z)^2 + x^2}\right]$$

Anomalia de um contato

No polo, $\alpha = 0^{\circ}$ e $i = 90^{\circ}$, de modo que

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Assumindo ainda que o contato é vertical $d = 90^{\circ}$, obtemos

$$A = 2kF, \quad \phi = 0^{\circ}$$

Nestas condições,

$$\frac{\partial M}{\partial x}(x,z) = 2kF\frac{(h-z)}{(h-z)^2 + x^2}, \qquad \frac{\partial M}{\partial z}(x,z) = 2kF\frac{x}{(h-z)^2 + x^2}$$

Método tilt depth

Aplicando correção de altitude, podemos considerar $z = 0$:

$$M_x(x,0) = 2kF\frac{(h-0)}{(h-0)^2 + x^2}, \qquad M_z(x,0) = 2kF\frac{x}{(h-0)^2 + x^2}$$

Salem et al (2007) Tilt-depth method: A simple depth estimation method using first-order magnetic derivatives.
The Leading Edge, 26, 1502-1505

Método tilt depth

Aplicando correção de altitude, podemos considerar $z = 0$:

$$M_x(x,0) = 2kF\frac{h}{h^2+x^2}, \qquad M_z(x,0) = 2kF\frac{x}{h^2+x^2}$$

Salem et al (2007) observaram que

$$\frac{M_z(x,0)}{M_x(x,0)} = \frac{2kF\frac{x}{h^2+x^2}}{2kF\frac{h}{h^2+x^2}}$$

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Salem et al (2007) observaram que

$$\tan^{-1}\left(\frac{M_z(x,0)}{M_x(x,0)}\right) = \tan^{-1}\left(\frac{x}{h}\right)$$

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Método tilt depth

Aplicando correção de altitude, podemos considerar $z = 0$:

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Salem et al (2007) observaram que

$$ISA(x=0,0) = \tan^{-1}\left(\frac{0}{h}\right), \qquad ISA(x=h,0) = \tan^{-1}\left(\frac{h}{h}\right)$$

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Método tilt depth

Aplicando correção de altitude, podemos considerar $z = 0$:

$$M_x(x,0) = 2kF\frac{h}{h^2 + x^2}, \qquad M_z(x,0) = 2kF\frac{x}{h^2 + x^2}$$

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Método tilt depth

Aplicando correção de altitude, podemos considerar $z = 0$:

$$M_x(x,0) = 2kF\frac{h}{h^2 + x^2}, \qquad M_z(x,0) = 2kF\frac{x}{h^2 + x^2}$$

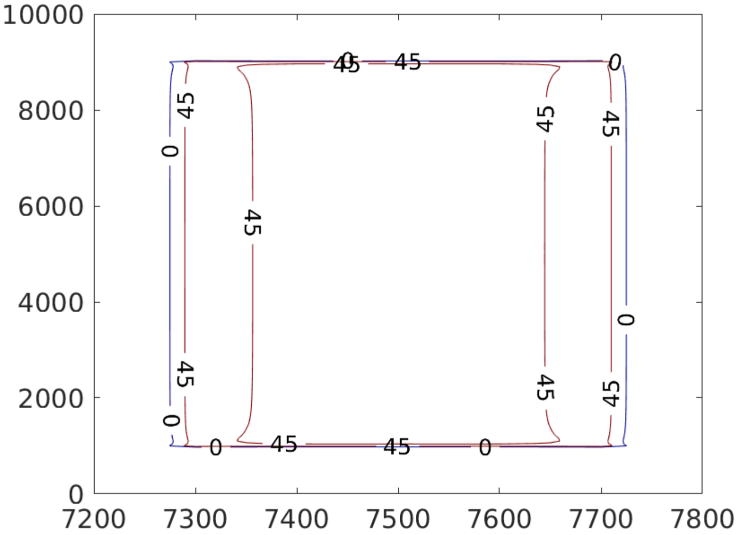
Salem et al (2007) observaram que

$$ISA(x = 0, 0) = 0^\circ, \qquad ISA(x = h, 0) = 45^\circ$$

O método tilt depth consiste em estimar h pela distância entre as isolinhas $ISA = 0^\circ$ e $ISA = 45^\circ$:

Salem et al (2007) Tilt-depth method: A simple depth estimation method using first-order magnetic derivatives. The Leading Edge, 26, 1502-1505

Método tilt depth



Método tilt depth