C3: Magnetic anomalies produced by simple geological structures

- Remember that objects can acquire both **induced** and **remnant** magnetization.

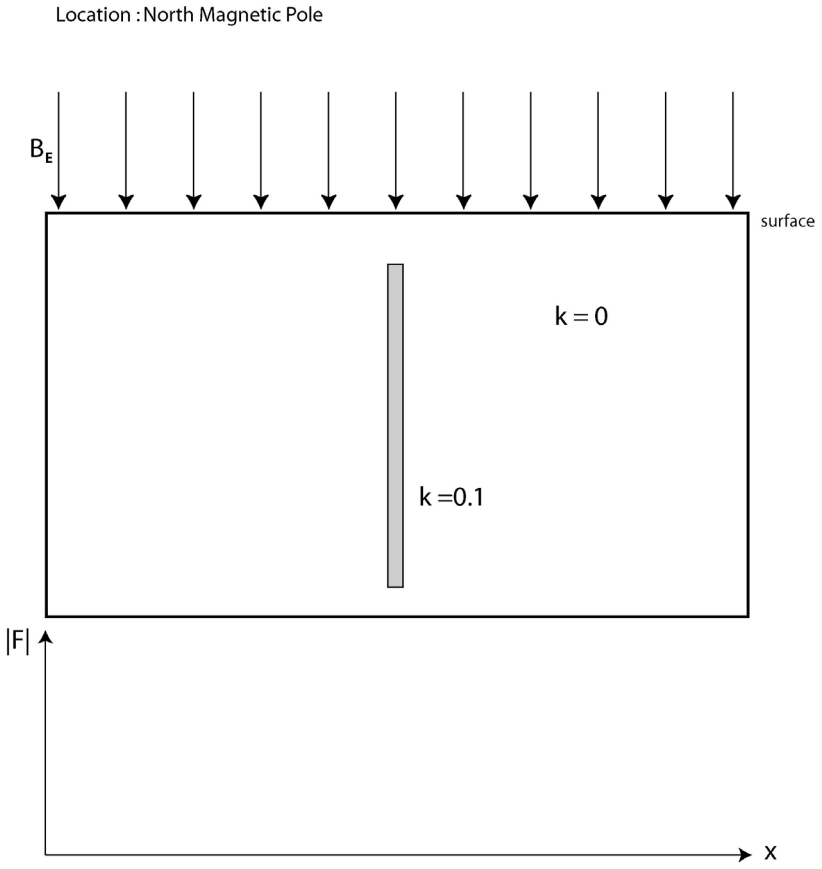
  Induced magnetization will disappear when the applied magnetic field is removed.

  Remnant magnetization is frozen into the material.

- In the following examples, we will consider only **induced magnetization**
- This will be in a direction **parallel** to the Earth's magnetic field.
- Remnant magnetization can be in any direction.

C3.1 Magnetic anomaly of a vertical pipe

- In the presence of the Earth's magnetic field, the pipe develops an **induced magnetic moment**



- Strength of the **magnetic monopole** at the top of the pipe is $m = -kB_E A$

  where k is the magnetic susceptibility of the pipe, A is the cross sectional area and B_E is the strength of the Earth's magnetic field. The vertical distance from top to bottom of the pipe is L. The top of the pipe is at a depth z below the surface.

- The dipole moment (*M*) measures the strength of the magnetization and $M = mL$
- Magnetic field of dipole, *m*, given by $B_r(r) = \frac{\mu m}{4\pi r^2}$

- If the structure extends to depth, then the lower monopole can be ignored since for a monopole, $B_r = \mu m/r^2$

- Compute **total field** at surface by adding B_r and B_E as **vectors.**

- Plot |**F**| since this is routinely measured in field surveys. In this type of survey, the direction of the magnetic field is not measured, which speeds us measurements.

- The anomaly in the total magnetic field (|F|) is the difference between the measured magnetic field and the background magnetic field (B_E).

- Can also compute the anomaly in Z (vertical component of magnetic field).

- The anomalies in |F| and Z are quite similar in high magnetic latitudes (i > 70°). Remember that $B_E >> B_r$

- Can show that for the negative monopole at the top of the pipe $Z_A = \frac{zkB_E A}{(x^2 + z^2)^{3/2}}$

- Maximum value of $Z_A = Z_A^{\max}$ occurs directly above the pipe and $Z_A^{\max} = \frac{kB_E A}{z^2}$

- Define the distance at which $Z_A = Z_A^{\max}/2$ as the **half-width** where $x = x_{½}$

- Can show that $x_{½} = 0.766z$ (see textbook for derivation)

- This simple equation allows us to compute the depth of the pipe (z) from the measured half-width ($x_{½}$)

$$z = 1.3x_{½}$$

Summary

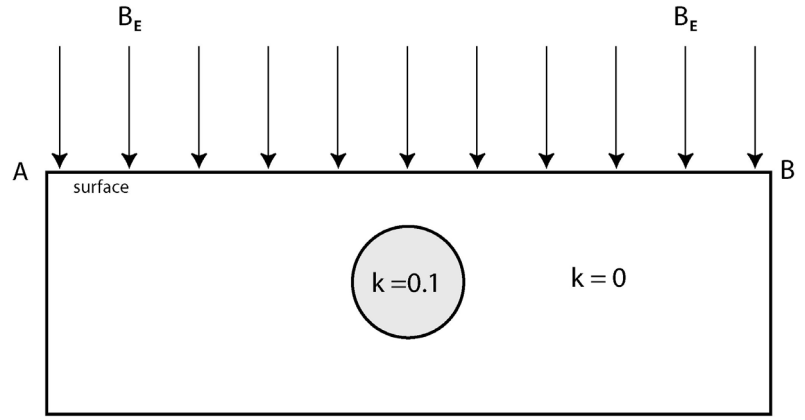
- Width of anomaly depends on depth of pipe (z)

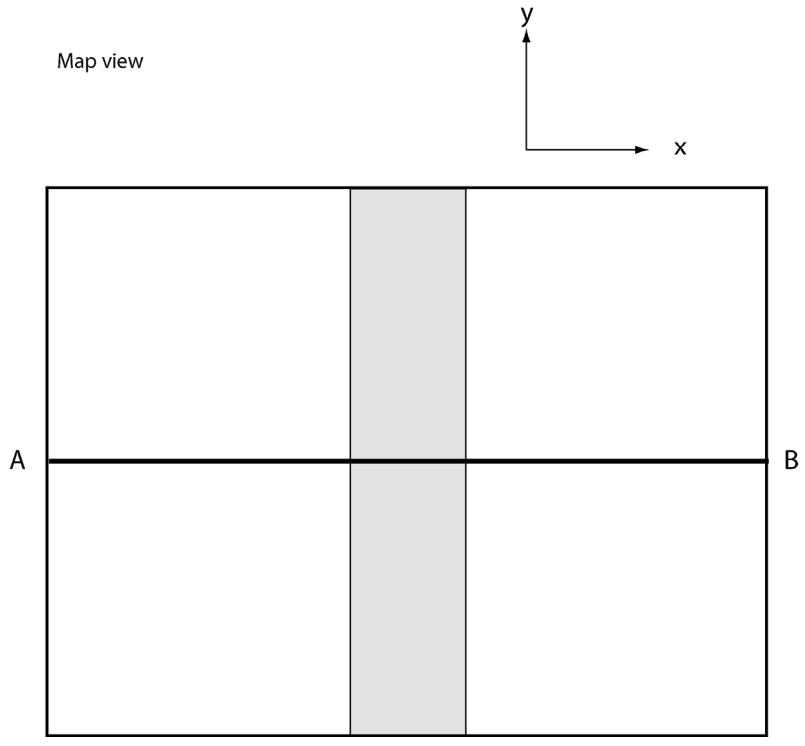
- Magnitude of the anomaly depends on: *k, A, z*

More details in textbook

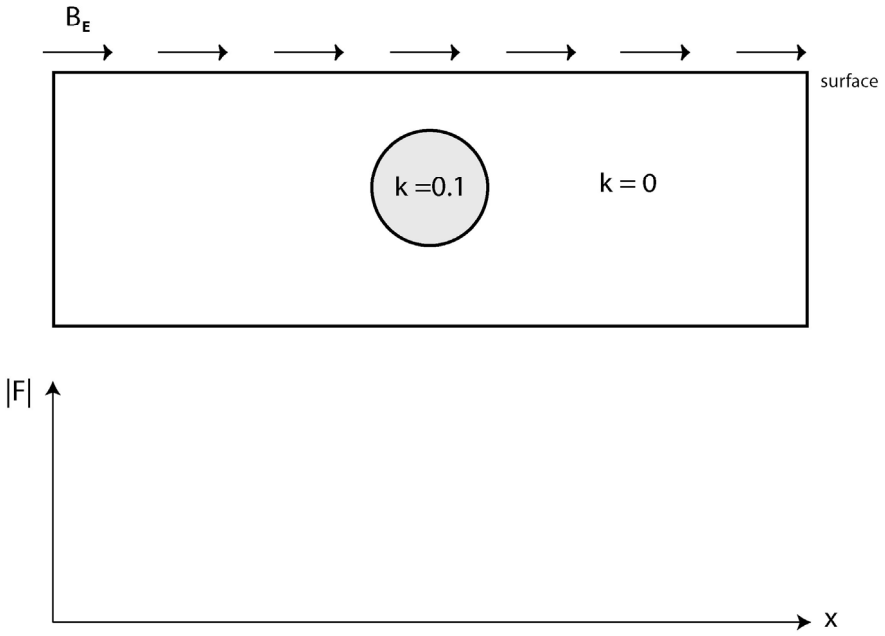
C3.2 Magnetic anomaly of a cylinder

- The cylinder has an **induced magnetization** with negative monopoles on upper surface and positive monopoles on the lower surface.
- Effect is equivalent to a line of dipoles along the axis of the cylinder
- Consider the magnetic field anomaly at the magnetic north pole





- Next consider the magnetic field anomaly at the magnetic equator



C3.3 Magnetic anomaly of a sphere

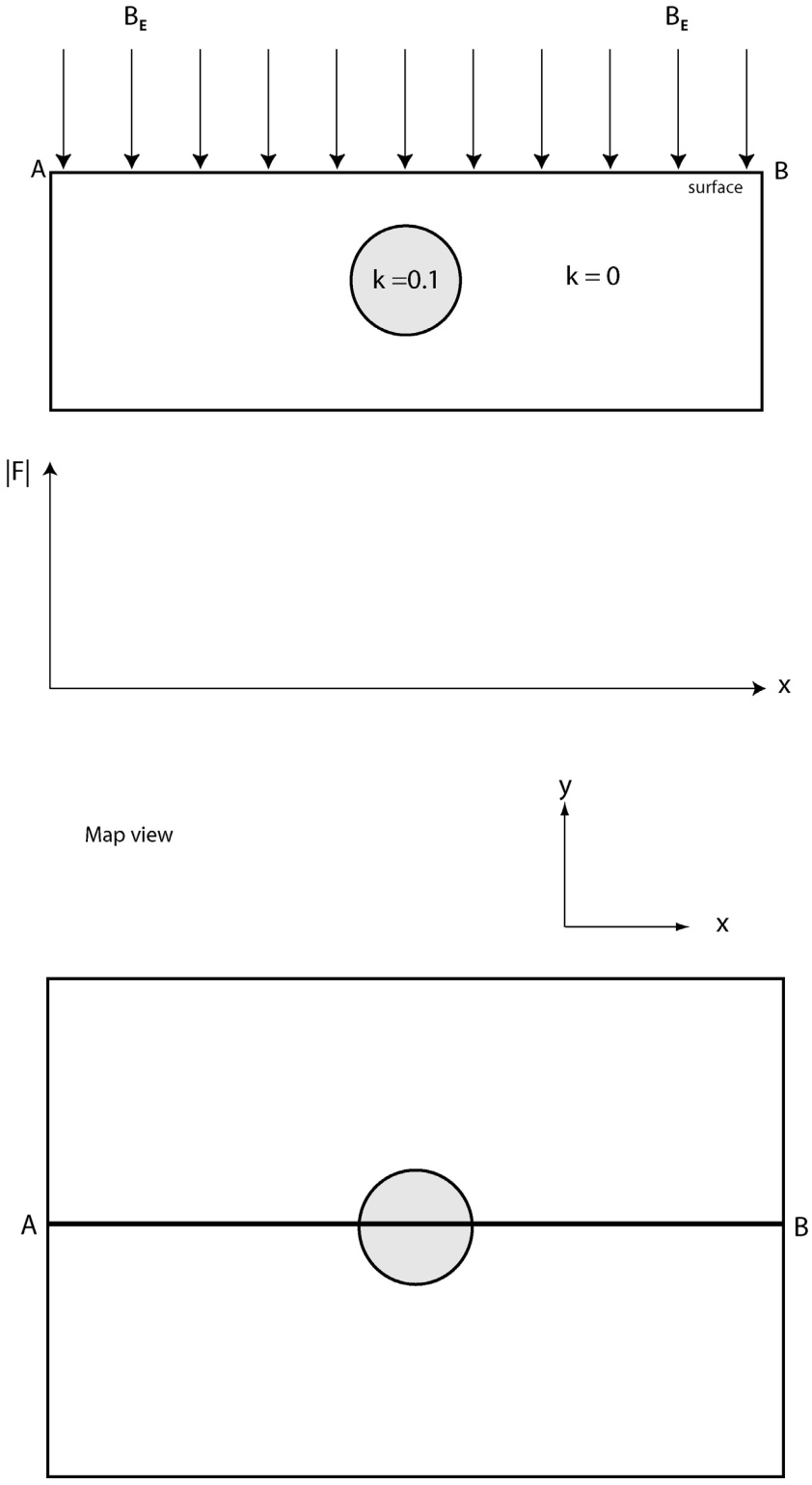
- The sphere develops an **induced magnetic moment**, equivalent to a magnetic dipole located at the centre.

- Dipole moment induced in the sphere is $M = \frac{4}{3}\pi R^3 k B_E$

  where R is the radius of the sphere, k susceptibility and B_E the Earth's magnetic field

- Centre of sphere is at a depth z

- Consider again the case of the North magnetic pole

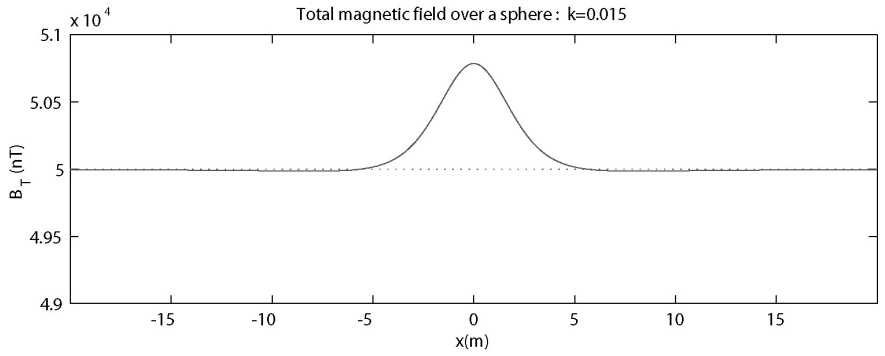


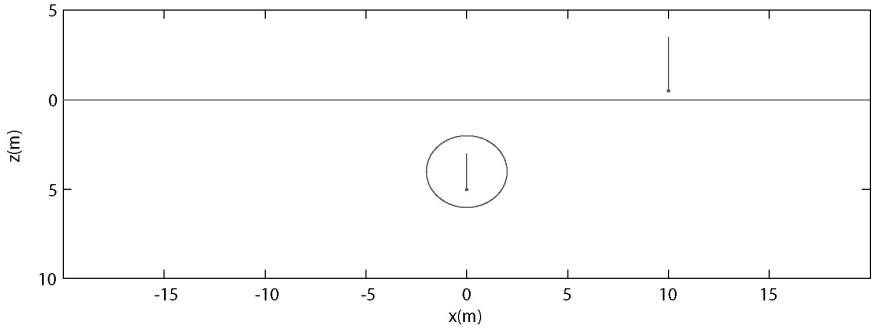
- At high magnetic latitude can show that $x_{1/2} = 0.5z$ and can find depth as $z = 2x_{1/2}$
- At high magnetic latitude (i > 70°) anomalies in Z and F are similar (see Figure 7-17)

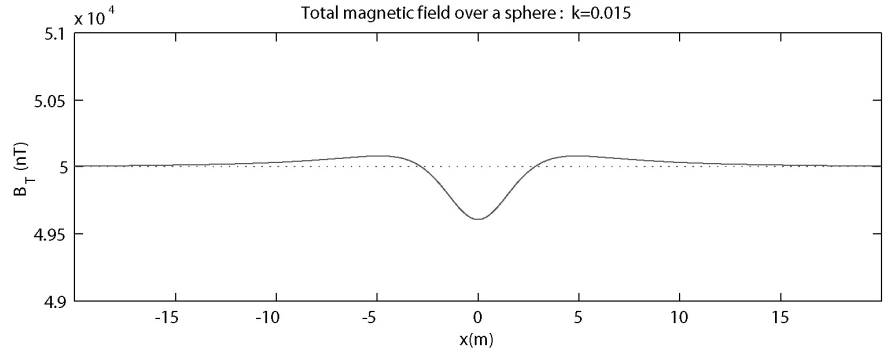
Summary

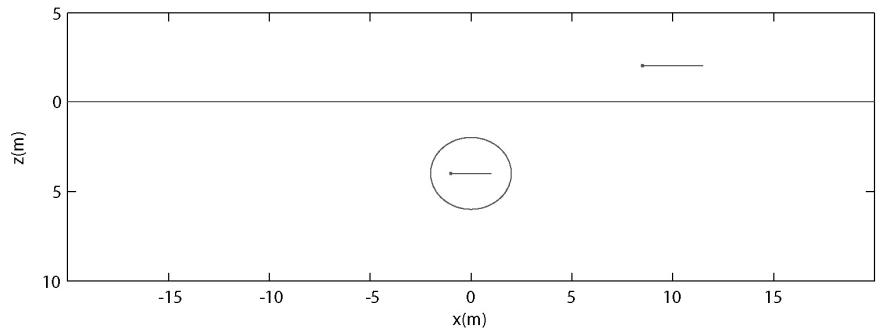
- Width of anomaly depends on depth of the sphere (z)
- Magnitude of the anomaly depends on: k, R and z

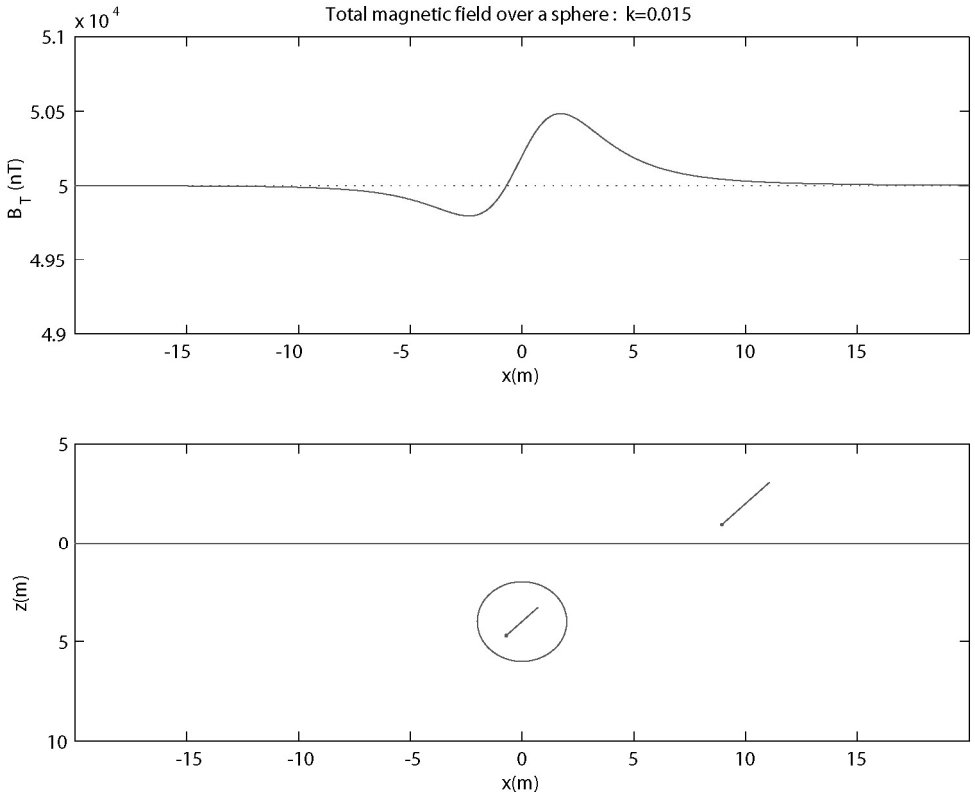
Exact calculations with MATLAB script





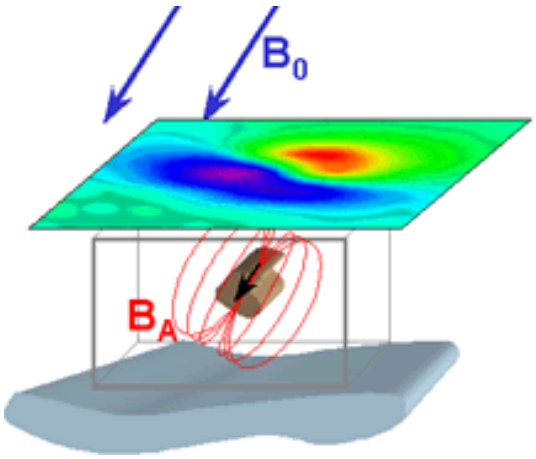






Map view when i = 45°

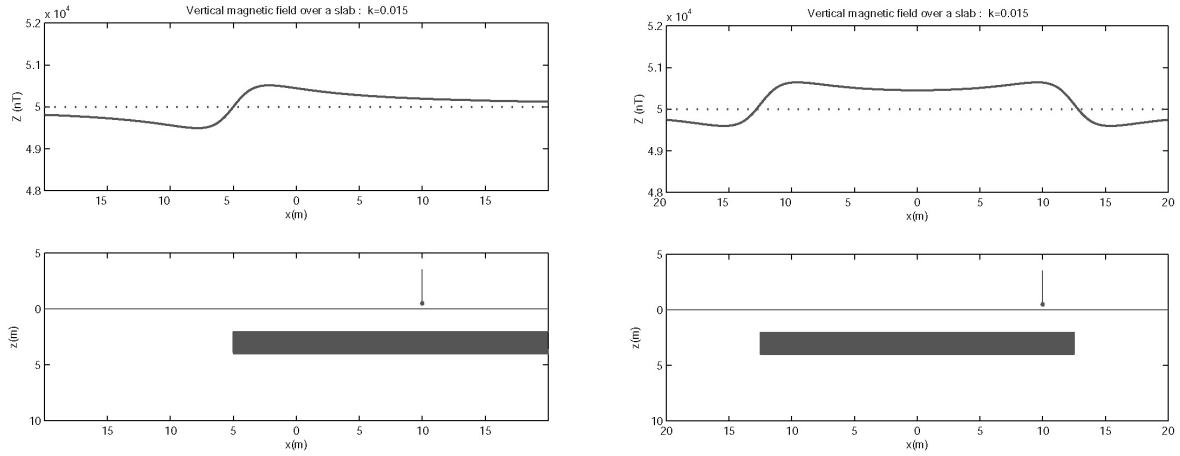
- Positive anomaly $B > B_0$ (red)
- Negative anomaly $B < B_0$ (blue)
- At the magnetic poles the positive anomaly is above the magnetic body.
- When i = 45°, that positive anomaly is not directly above the target.

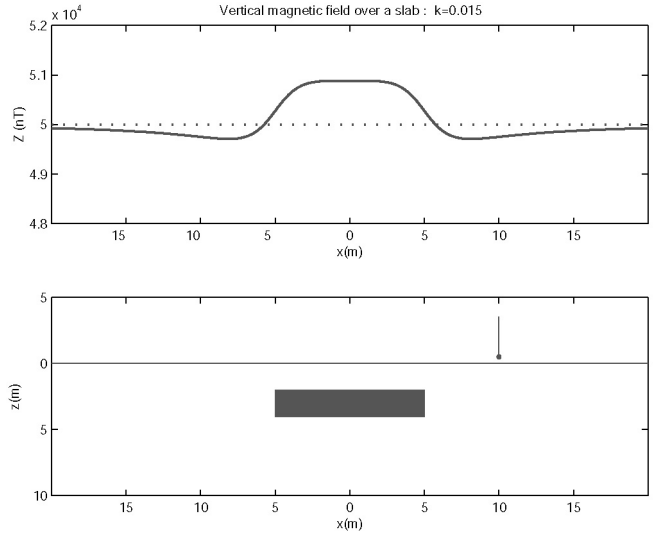


From *http://www.gif.ubc.ca*

C3.4 Thin sheet or slab

- An infinite sheet develops negative poles (South poles) on the upper surface and positive poles (North) poles on the lower surface.
- If the sheet is thin in the vertical direction, then the magnetic fields due to the upper and lower surfaces cancel to give no net magnetic field at the surface.
- When the sheet is finite in horizontal distance, the magnetic poles near the edge do not cancel and a positive-negative anomaly is observed.
- The magnetic anomaly is sensitive to the edges of structures





C3.5 Basement topography See class notes

C3.6 Basement with variable susceptibility See class notes

C3.7 Cave See class notes