Myths and Misconceptions of the Magnetic Field

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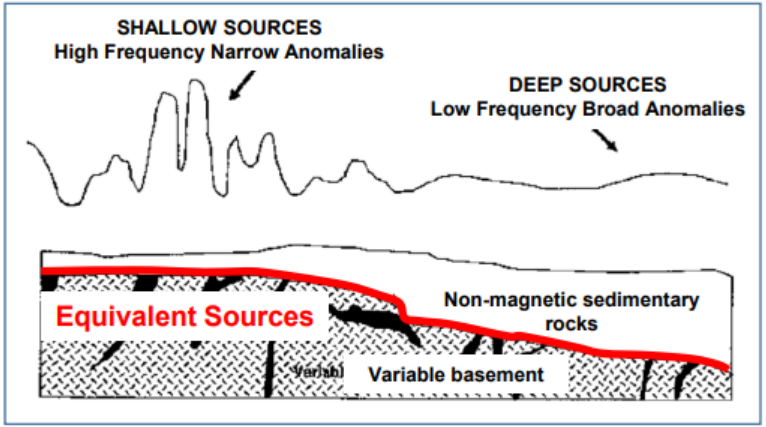
Helmerich & Payne | MagVAR

Motivation

- ISCWSA 57 – Stavanger
- Do magnetic sources in the basement rock hurt our crustal magnetic models?
- What about non-uniqueness?



Math and Physics

$$\nabla \cdot \boldsymbol{B} = 0$$

$$\boldsymbol{B} = -\nabla V$$

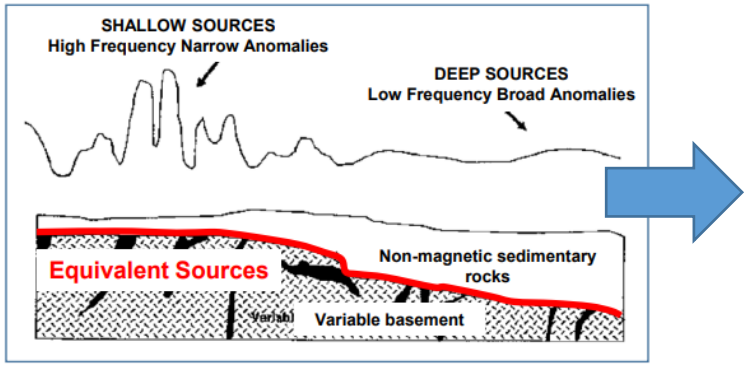
- There are no magnetic monopoles.
- The magnetic field can be expressed in terms of a scalar potential, V.

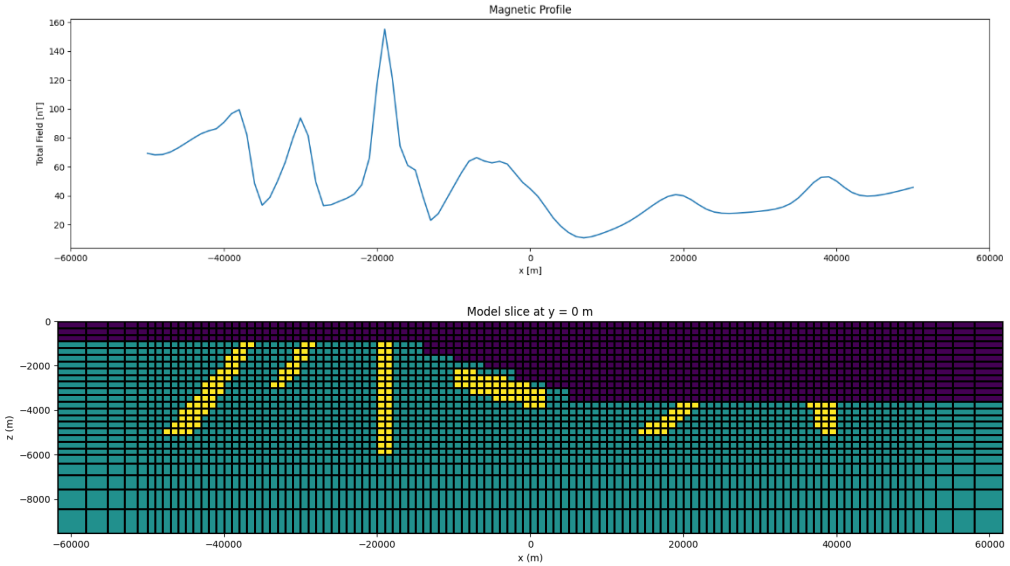
$$\mathbf{B}_A = \frac{\mu_0}{4\pi} \int_V \kappa \mathbf{H}_0 \cdot \nabla\nabla \left(\frac{1}{r}\right) dV$$

$$B \sim \frac{1}{r^3}$$

$\mathbf{B}_A$ = Magnetic field (vector)
μ_0 = magnetic permeability of free space
κ = magnetic susceptibility
$\mathbf{H}_0$ = Inducing Magnetic field (vector)

Magnetic Sources in the Basement





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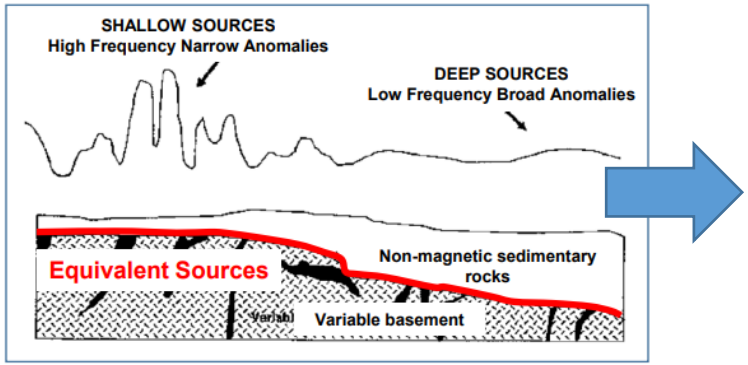
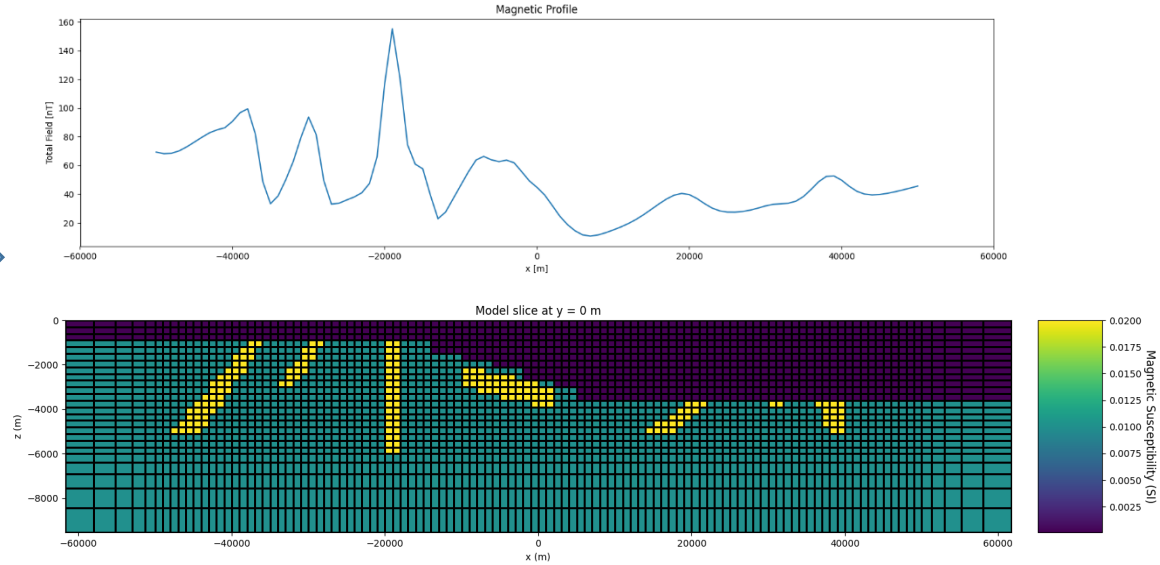
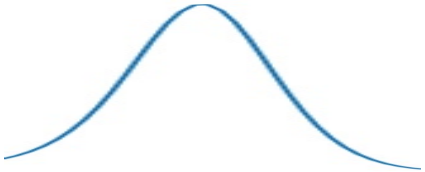
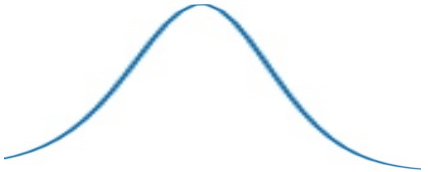


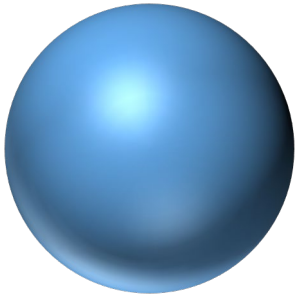


Fields to Sources





- Fundamental ambiguity about the size, strength, and location of the source
- Equivalent Source theory



But…

We care about the field, not the source

- The field can't hide

Upward and Downward Continuation

Mathematically proven that we can project a dataset up or down through source-free regions.

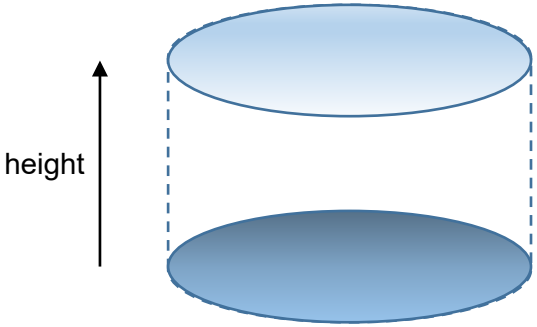
- Let U represent a potential field (i.e. a dataset)

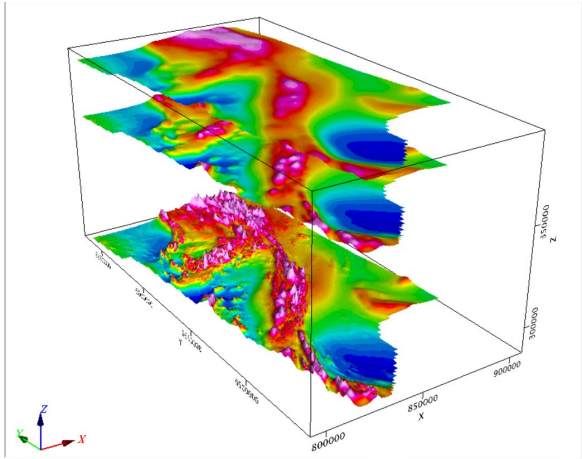
Then,

$$F[U_{upward}] = F[U]e^{-height*|k|}$$

k: wavenumber

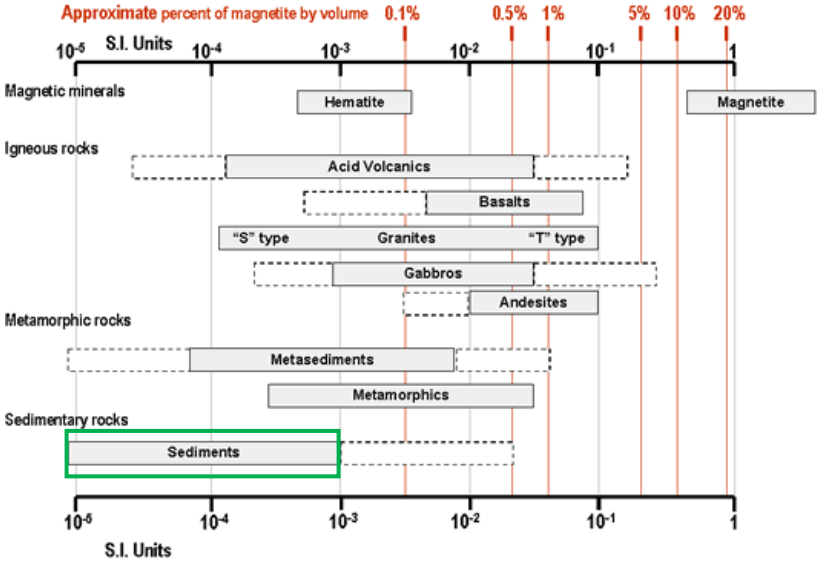
- Upward continuation is a multiplication in the frequency domain.





Magnetics in Sedimentary Basins

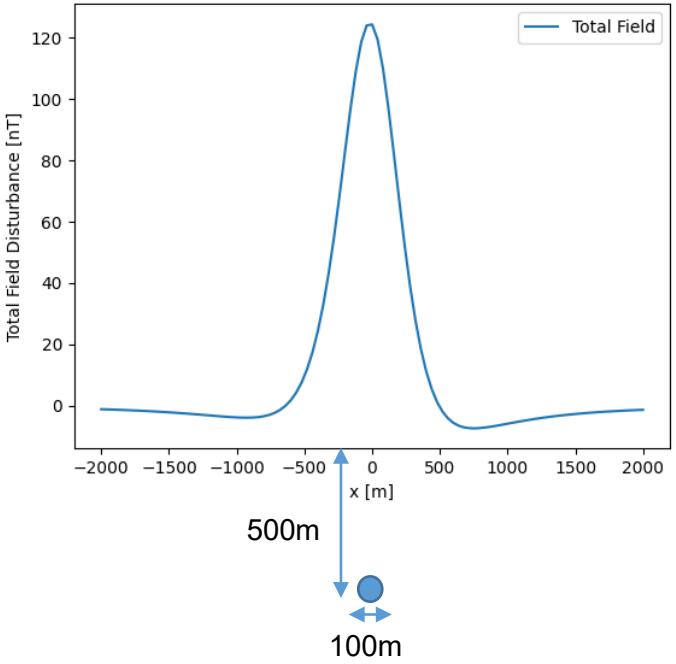
- Sedimentary rocks ***are*** much weaker in susceptibility
- If there is a source in the basin
  - If it is small and powerful, it only affects us over a short distance
  - If it is large and powerful, it affects us over a longer distance, but we probably aren't drilling near it. (Seismic…)

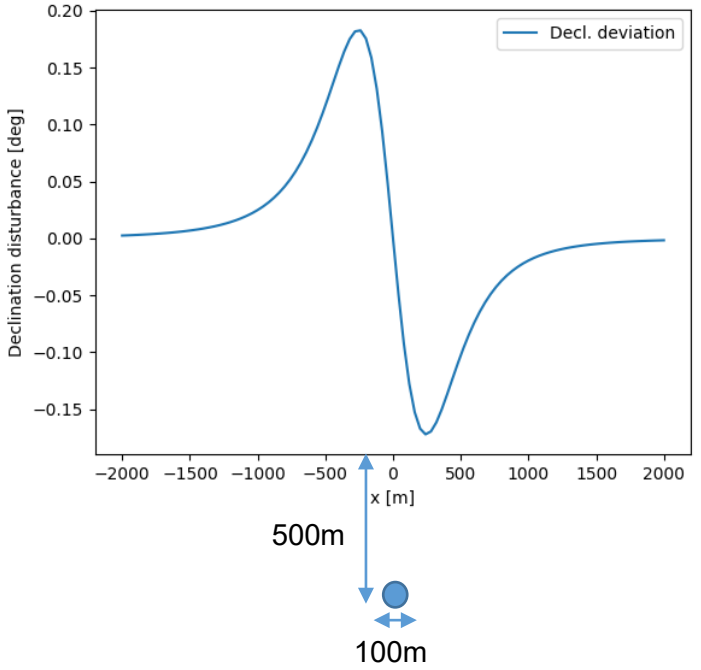


Adapted from Clark and Emerson, Exploration Geophysics, 1991.

Field Falloff

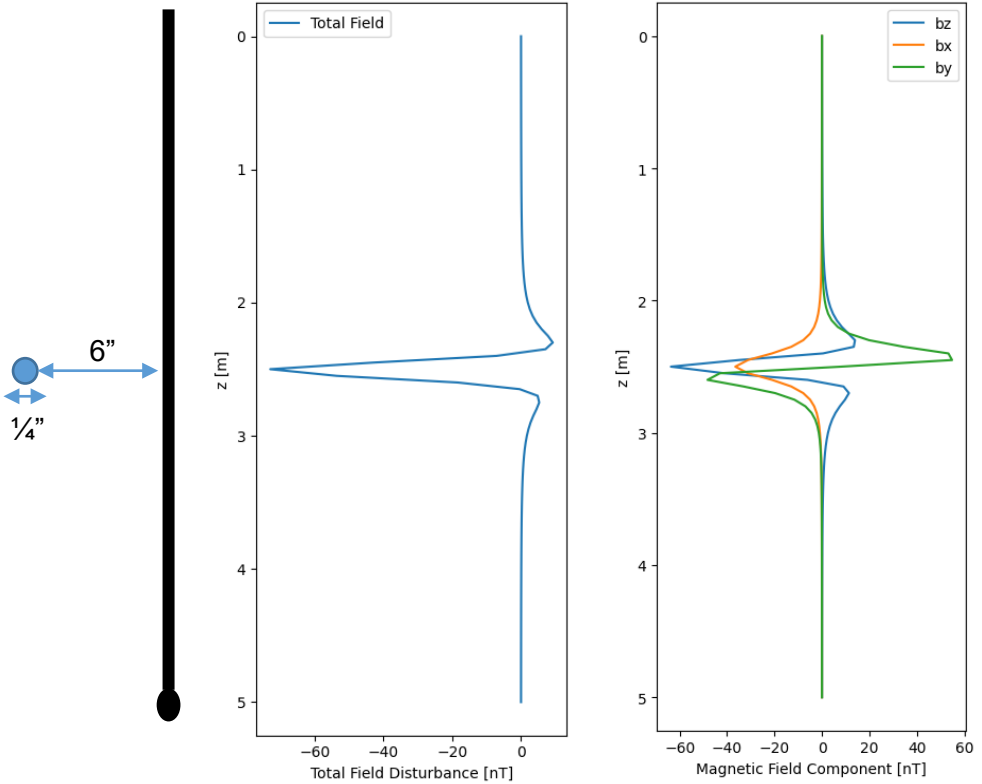
- Simulate a 100m granite intrusion
- What distance does the field propagate?



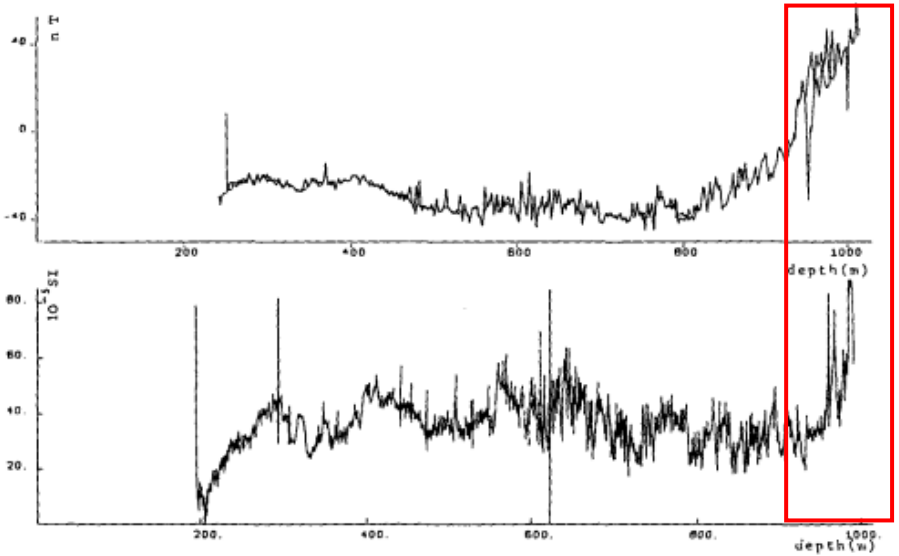


Field Falloff

- What if we are very close?
- Simulate the magnetic response from a magnetic pebble that is close.



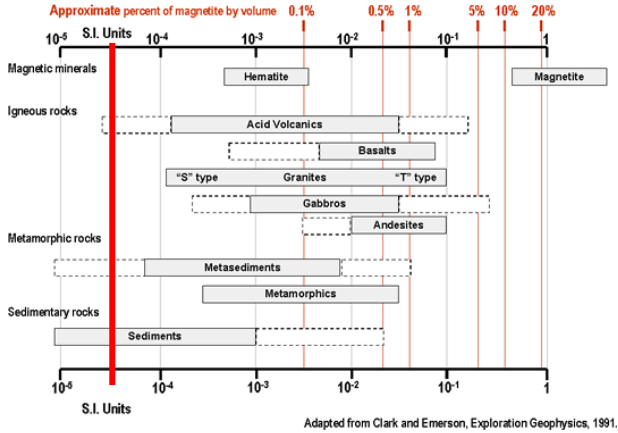
Geothermal Drilling and Magnetics



sedimentary rocks **basement rocks**

Magnetic logging at Couy, France

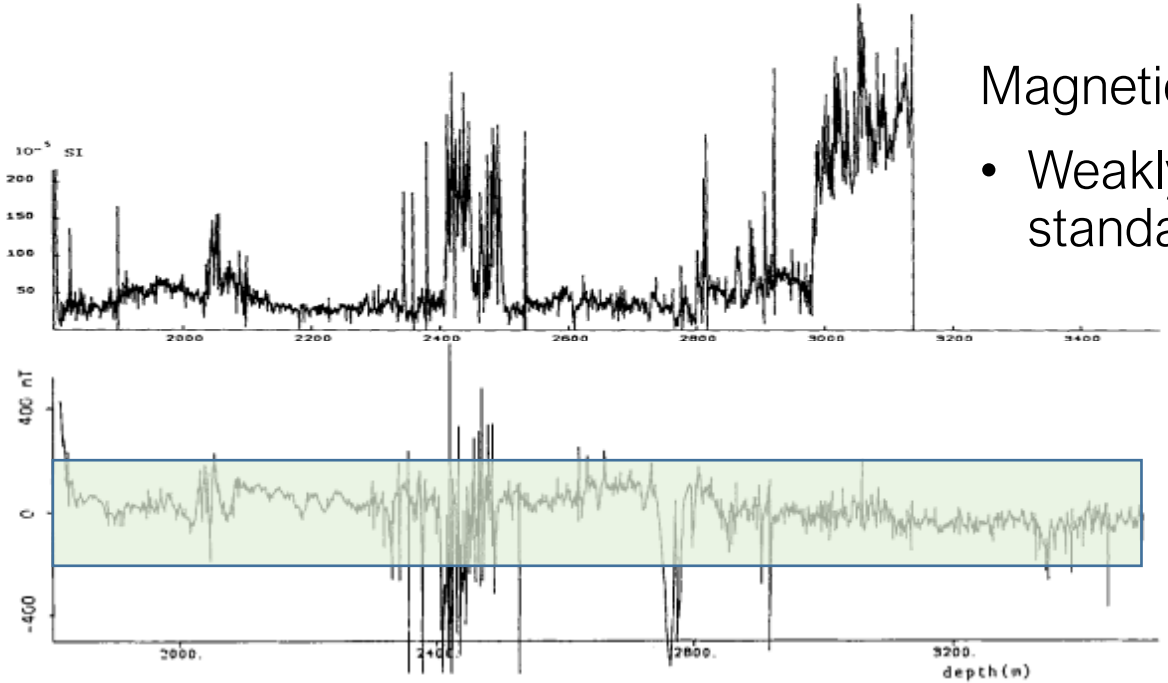
- Weakly magnetic by basement rock standards



Adapted from Clark and Emerson, Exploration Geophysics, 1991.

*Tabbagh, A., et al.(1990). Magnetic field and susceptibility logging in GPF3 borehole at Couy (France) between 0 and 3500 m.

Geothermal Drilling and Magnetics



basement rocks

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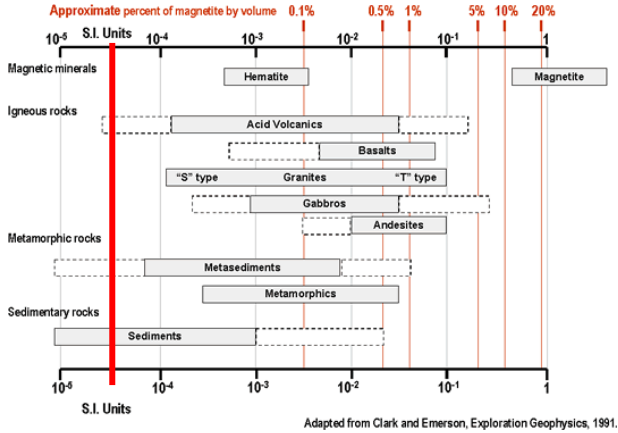

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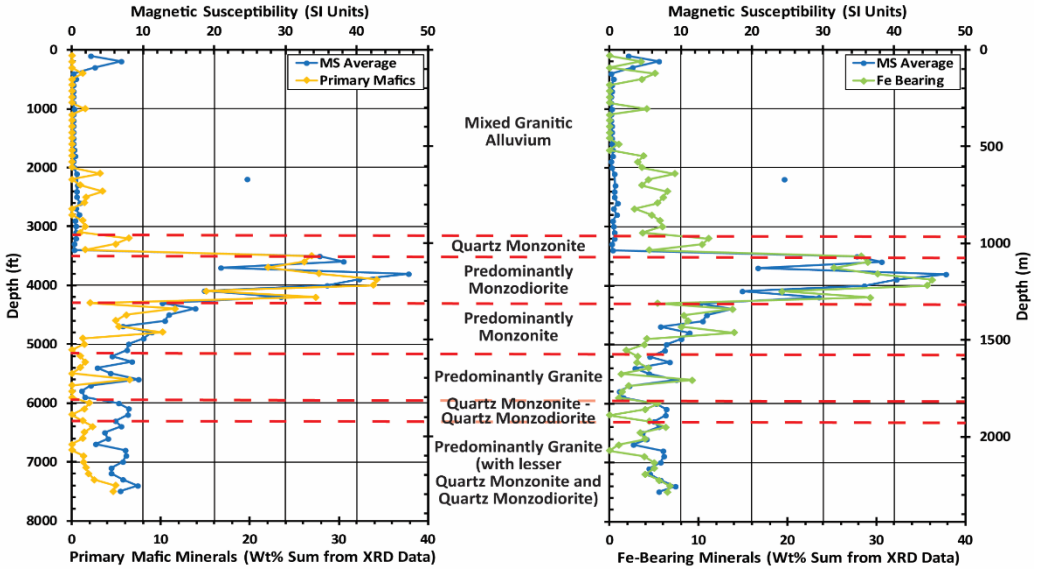
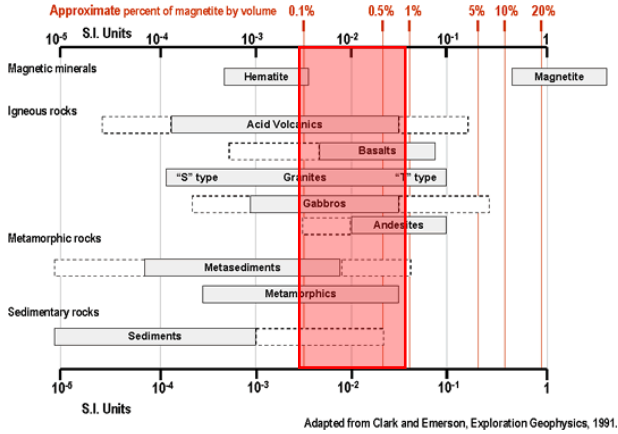
Utah FORGE Geothermal Project



Utah FORGE Geothermal

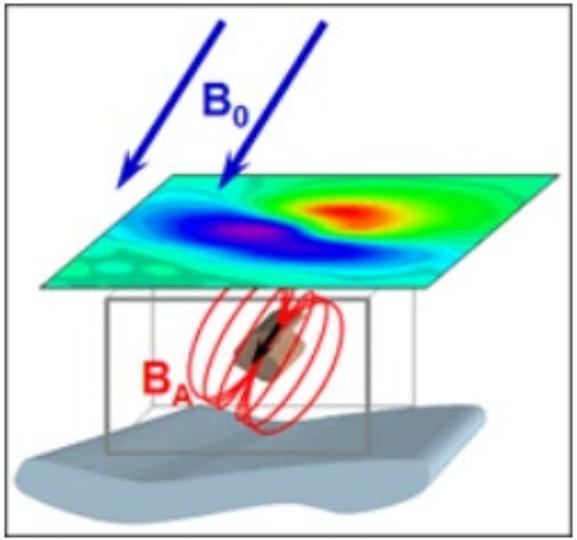
- 100x the values at Couy



*Gwynn, M., et al. (2018). Rock properties of FORGE well 58-32, Milford, Utah. *Transactions*.

Questions?

Magnetic Response of a Buried Object



- Inducing field induces magnetization in a body that has magnetic susceptibility
- Secondary field opposes inducing field
- Observed magnetic field is the sum of both
- Inclination and declination of the inducing field determines the asymmetry of the response

Field Falloff

- What if we are very close?
- Simulate the magnetic response from a magnetic pebble that is close.