GPH 201
Part 2

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Magnetic prospecting

- **Magnetic prospecting is used to explore for both oil and minerals.**

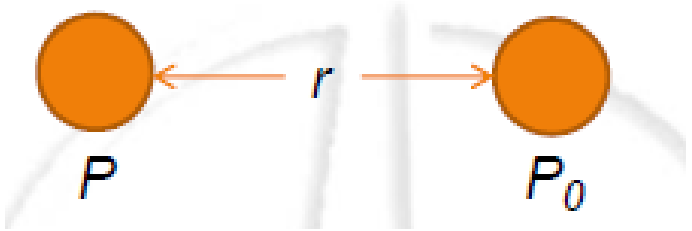
- **It gives information to determine depth to basement rocks, locate and define the extent of sedimentary basins. This information is of importance in previously unexplored areas such as continental shelves newly opened for prospecting.**

- **Sedimentary rocks exert a very small magnetic effect compared to igneous rocks.**

- **Virtually all variations in magnetic intensity result from topographical or lithlogic changes associated with the basement or from igneous intrusive.**
- **Today, all magnetic surveys are done from air or from ships due to speed, economy and convenience.**

Basic concept

Magnetic force



If two poles of strength P0 and P are placed at a distance r apart, the magnetic force between them will be

$$F = \frac{P_0 P}{\mu r^2}$$

The constant μ known as the permeability, depends upon the magnetic properties of the medium in which the poles are situated. μ 1 for air or vacuum

Magnetic field

If $P_0 = 1$

$$F = P/\mu r^2$$

Magnetic field strength at a point is defined as the magnetic force exerted on a pole of unit strength placed at that point.

In cgs system the unit of magnetic field is orested and in mks system it is tesla which is 104Oe.

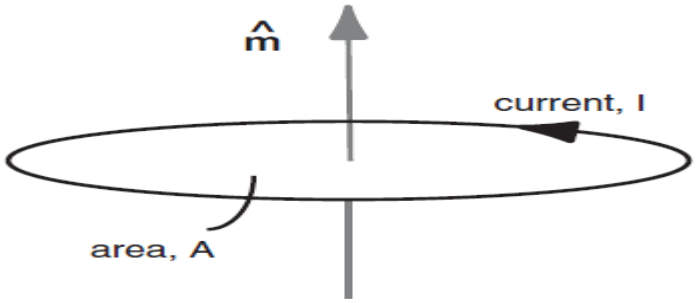
In magnetic prospecting, variation in magnetic field are very small. Therefore, gamma defined as 10-5Oe is most commonly used unit in geophysical work.

Bodies containing magnetic minerals, chiefly Fe–Ti oxides may be viewed as vast assemblages of microscopic aligned magnetic dipoles, which are the elementary building blocks of magnetic sources.

To properly understand magnetic data it is necessary to grasp the concept of an individual magnetic dipole. A magnetic dipole is an infinitesimal loop of area A [units of m2] carrying an electric current I that is measured in amperes [A],

The unit vector mˆ defines the orientation of the dipole and it is directed perpendicular to the plane of the loop, in alignment with the loop axis. The dipole moment m [Am2] is defined as the vector

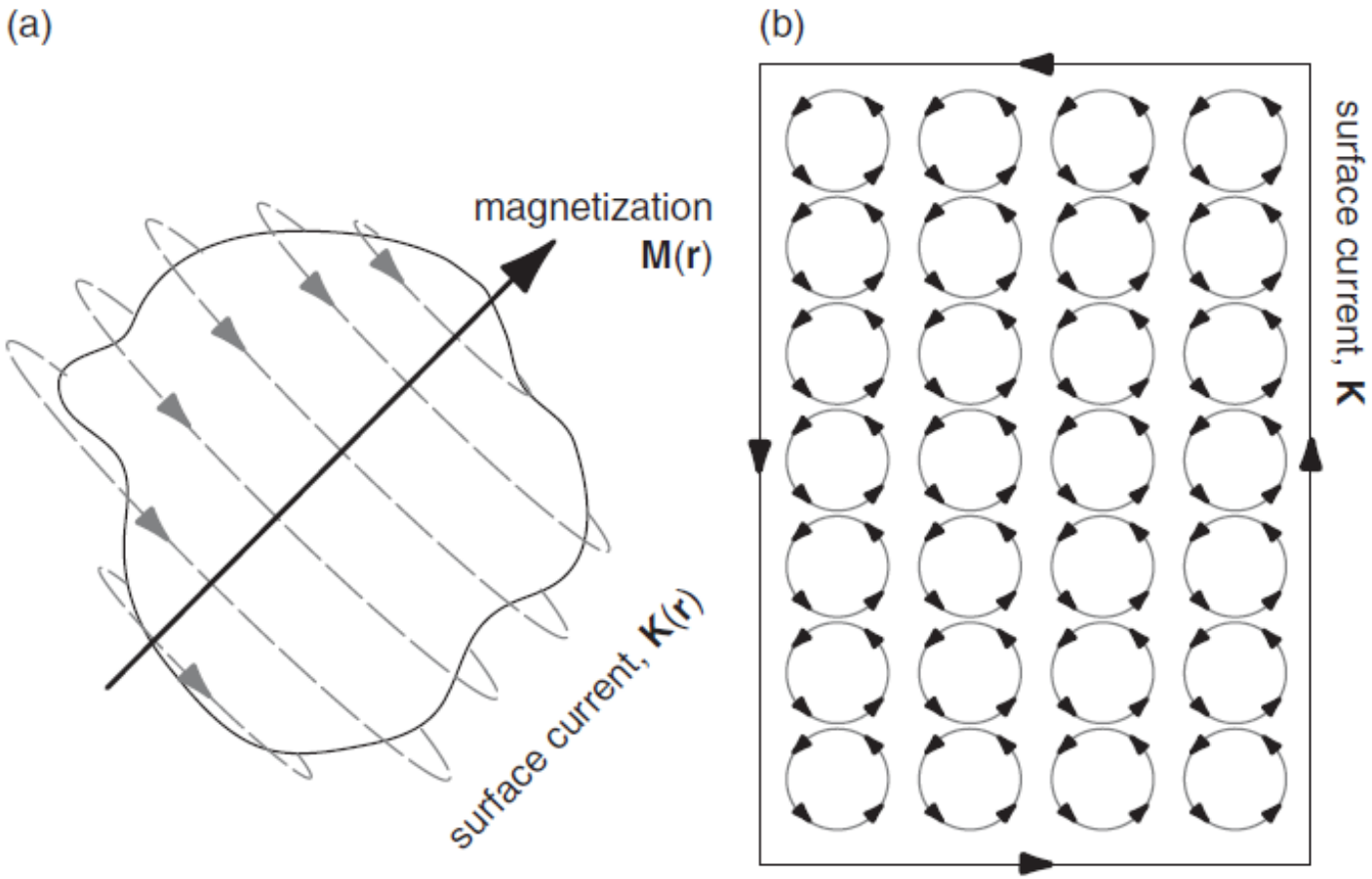
$$\mathbf{m} = IA\,\hat{\mathbf{m}}$$



The magnetization M of a magnetized body is the net dipole moment per unit volume and is given by

$$\mathbf{M} = \frac{1}{V}\sum_{i=1}^{N} \mathbf{m}_i(\mathbf{r}_i),$$

where V is the total volume of the body, while the moments of the N microscopic magnetic dipoles that constitute the body are mi(ri), i ¼ 1,…, N; and ri is the position vector of the ith dipole.
The constituent magnetic dipoles are not perfectly aligned in a single direction.
Various factors, including remnant magnetization, corrosion, random thermal motions, and material heterogeneities contribute to the lack of perfect dipole alignment

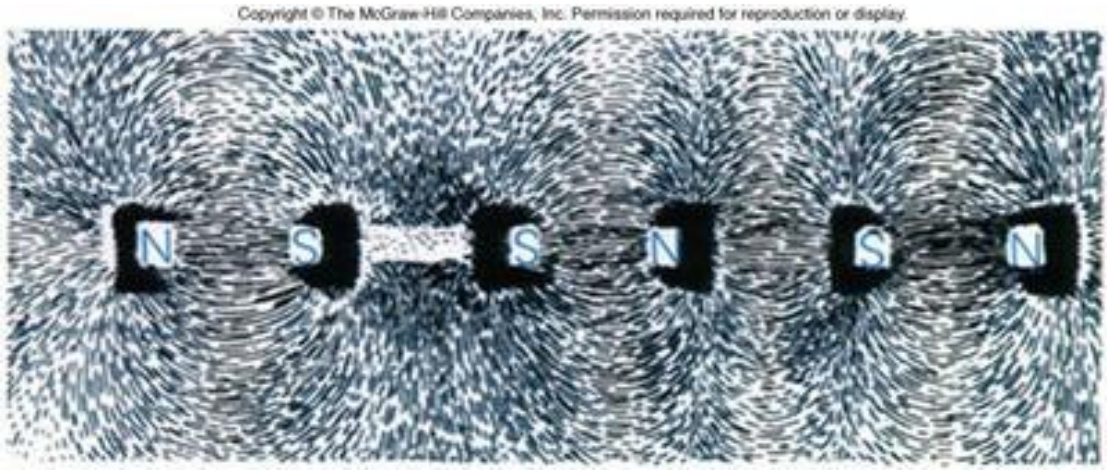


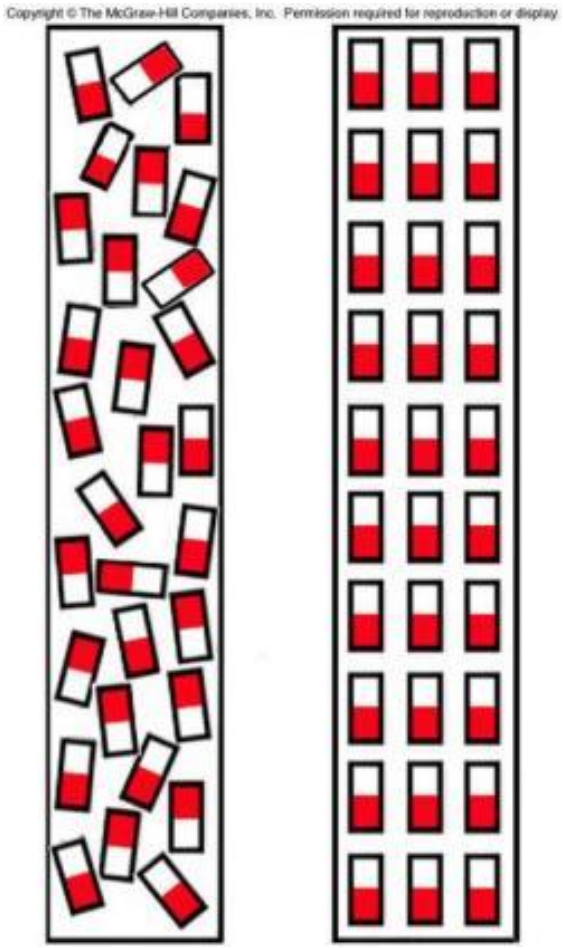
(a) Magnetized (iron, titanium-bearing) rock and its equivalent surface electric current **K(r)** and magnetization **M(r)** vectors. For a heterogeneous rock there is also an equivalent volume current **J(r)**. (b) Cancellation of internal electric currents in the case of a homogeneous magnetization **M**.

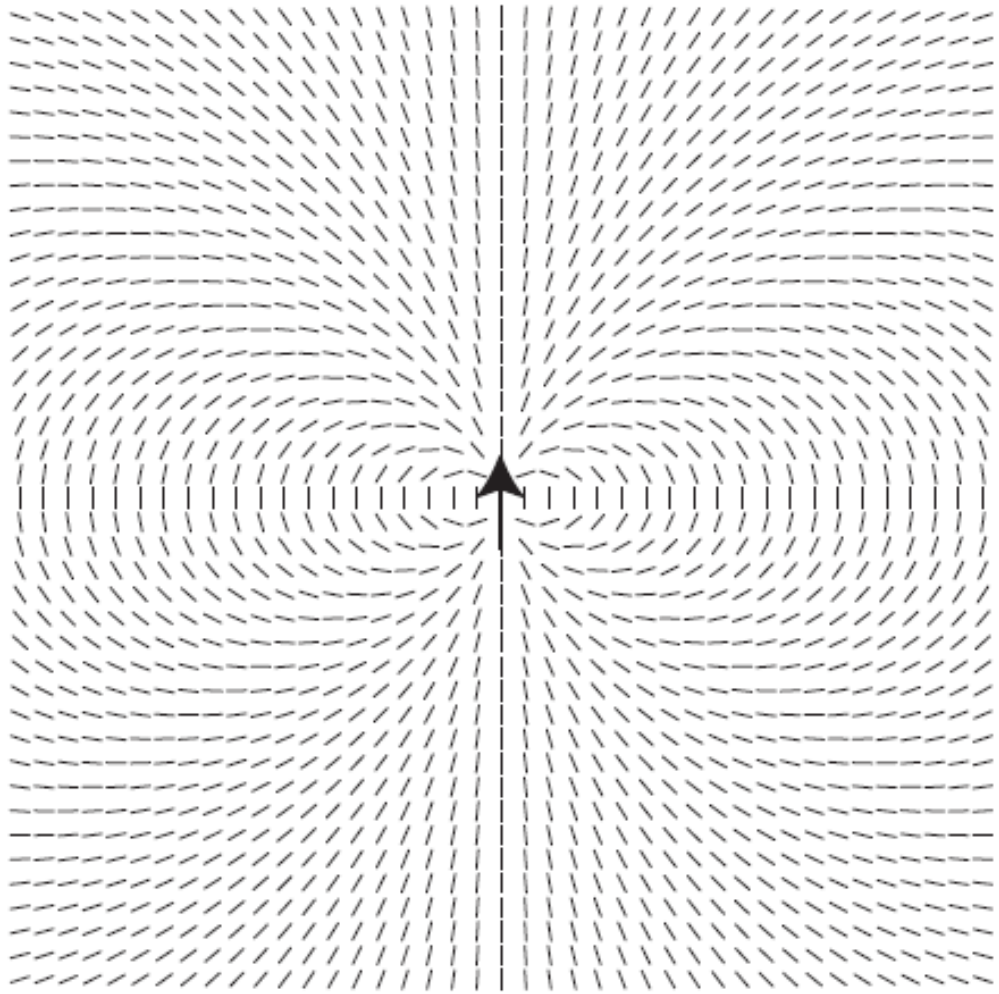
How to make a steal bar a magnet:

Heat it in a magnetic field and then let it cools gradually.

Magnetic force lines.







Lines of force of a magnetic dipole.

Magnetization of rocks

Magnetic rocks have almost always acquired their polarization from the earth's field.

If the rock is igneous, its direction of magnetization will be that of the earth's field at the time it cooled from its initial molten state to a temperature below the Curie point. This is called thermo remnant magnetization.

If the rock is sedimentary, any orientation of its magnetic grains during deposition would have been in alignment with the field that existed when the deposition occurred. This is depositional remnant magnetization.

Remanent magnetization is the permanent magnetization that remains after an applied field is removed.

The total magnetization of an iron-bearing geomaterial is the vector sum of the Induced MI and remanent MR magnetizations.

The Induced magnetization is acquired by the rook during their geologic time after their origin due to the ambient field.

Their relative contributions are described by the Koenigsberger ratio Q =MR/MI

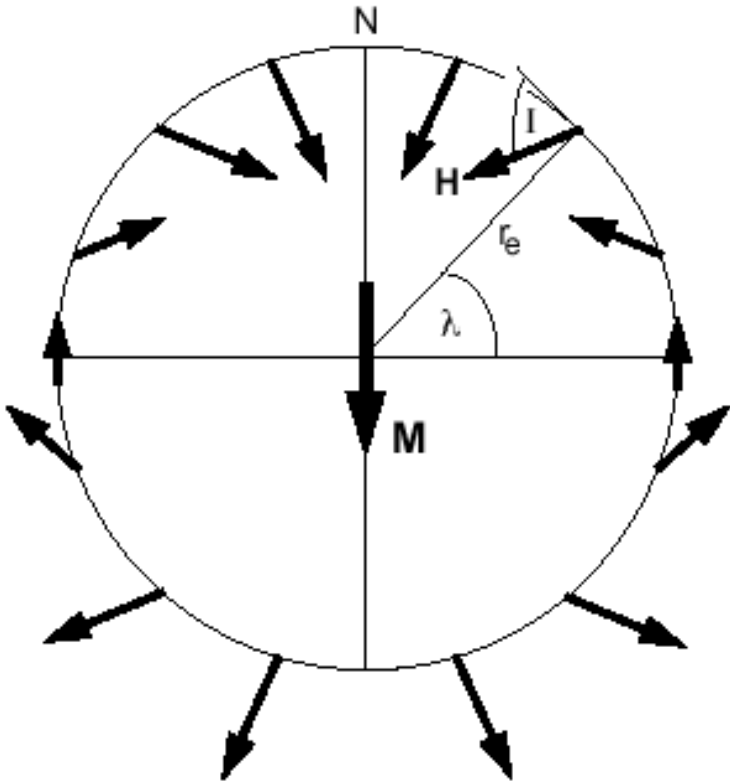
Total magnetization M consists of

- **Remnant magnetization Mr**
- **Induced magnetization Mi**

$$M = Mr + Mi$$

Earth magnetic field

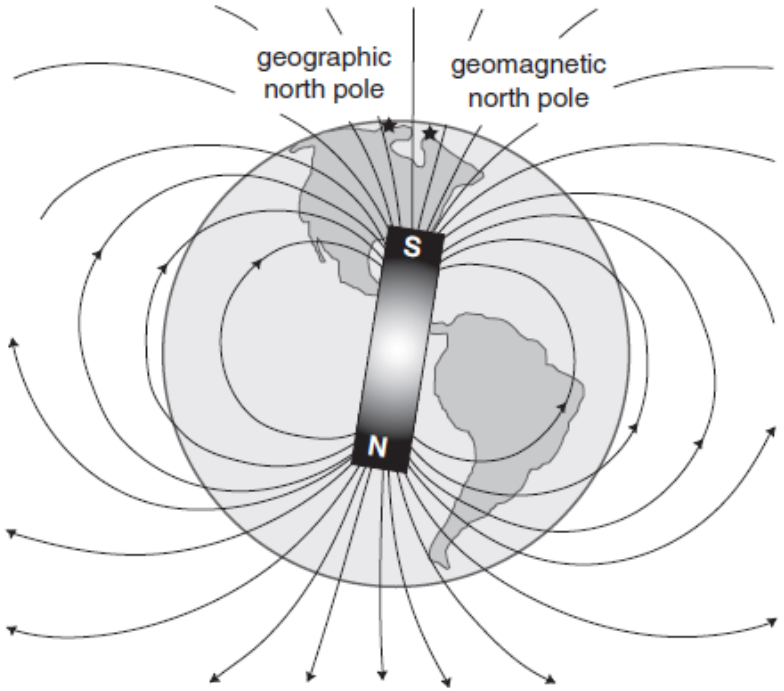
We know that the earth is a magnetic dipol, with magnetic north and south. The magnetic field varies in both intensity and orientation, but over time (10^5yr) the magnetic poles coinside with the rotation poles i.e. geographical north and south poles. Consequently the magnetic Field is vertical near the poles and horisontal near equator!



Magnetic field of earth depends on

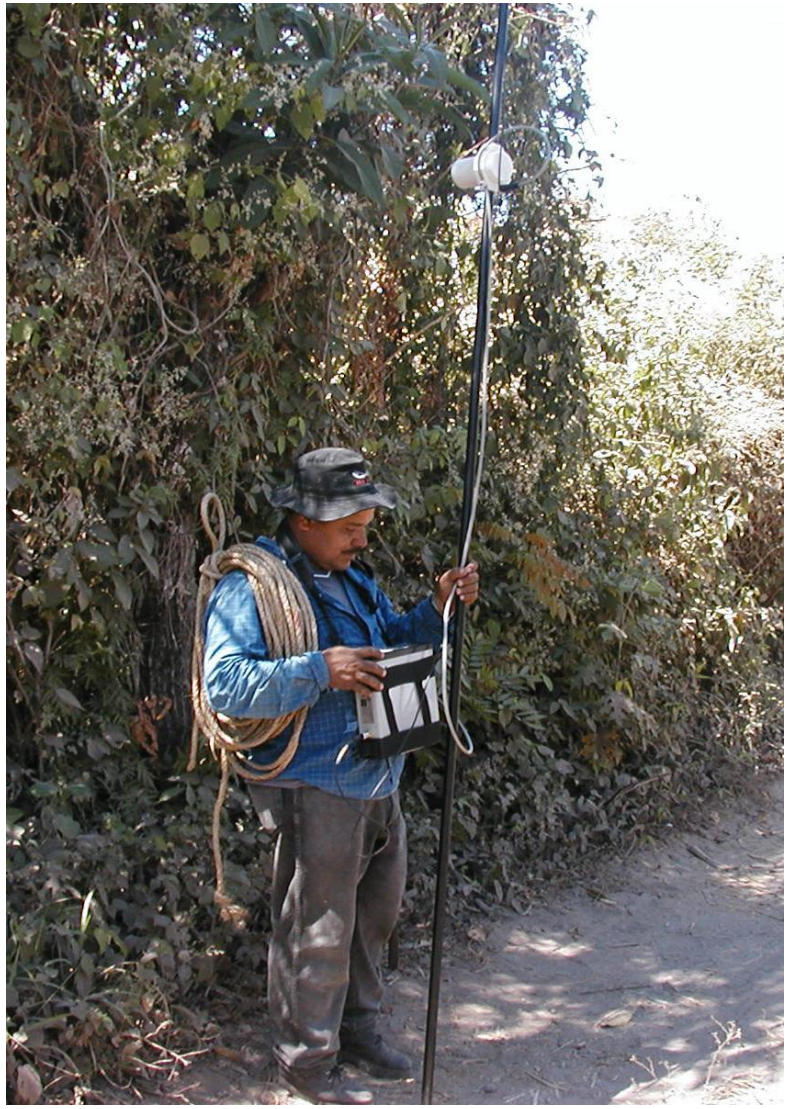
- **Latitude**
- **Longitude**
- **Time**

The geomagnetic poles are the locations at which the geocentric dipole axis intersects Earth's surface. Notice that the convention for labeling the geomagnetic poles is opposite to that of the bar magnet, so that the geomagnetic north pole resides in the northern hemisphere close to the geographic north pole.



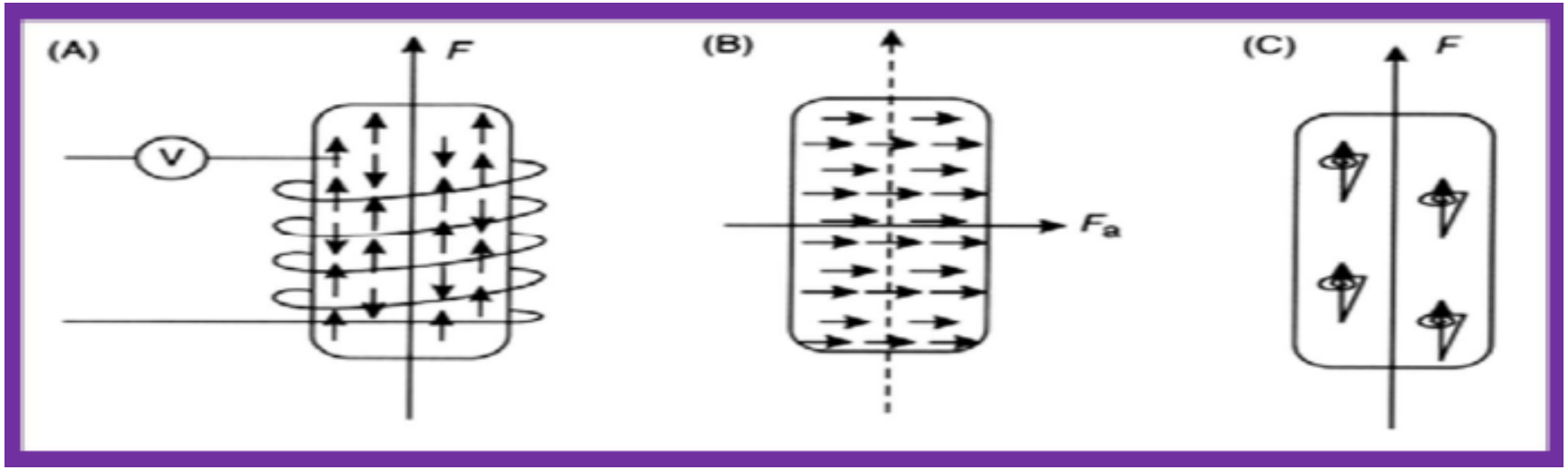
The geocentric dipole as a bar magnet.

The proton magnetometer has a sensor which consists of a bottle containing a proton-rich liquid, usually water or kerosene, around which a coil is wrapped, connected to the measuring apparatus. Each proton has a magnetic moment M and, as it is always in motion, it also possesses an angular momentum G, rather like a spinning top. The Figure shows examples of field measurements with a magnetometer



Measurement of magnetic field

A: Protons of atom originally aligned with natural field
B: External coil is energized with a DC current resulting in a strong field that aligns protons.
C: Current turned off and protons precess back to alignment with external field, generating AC current in coil
Larger fields → higher frequencies

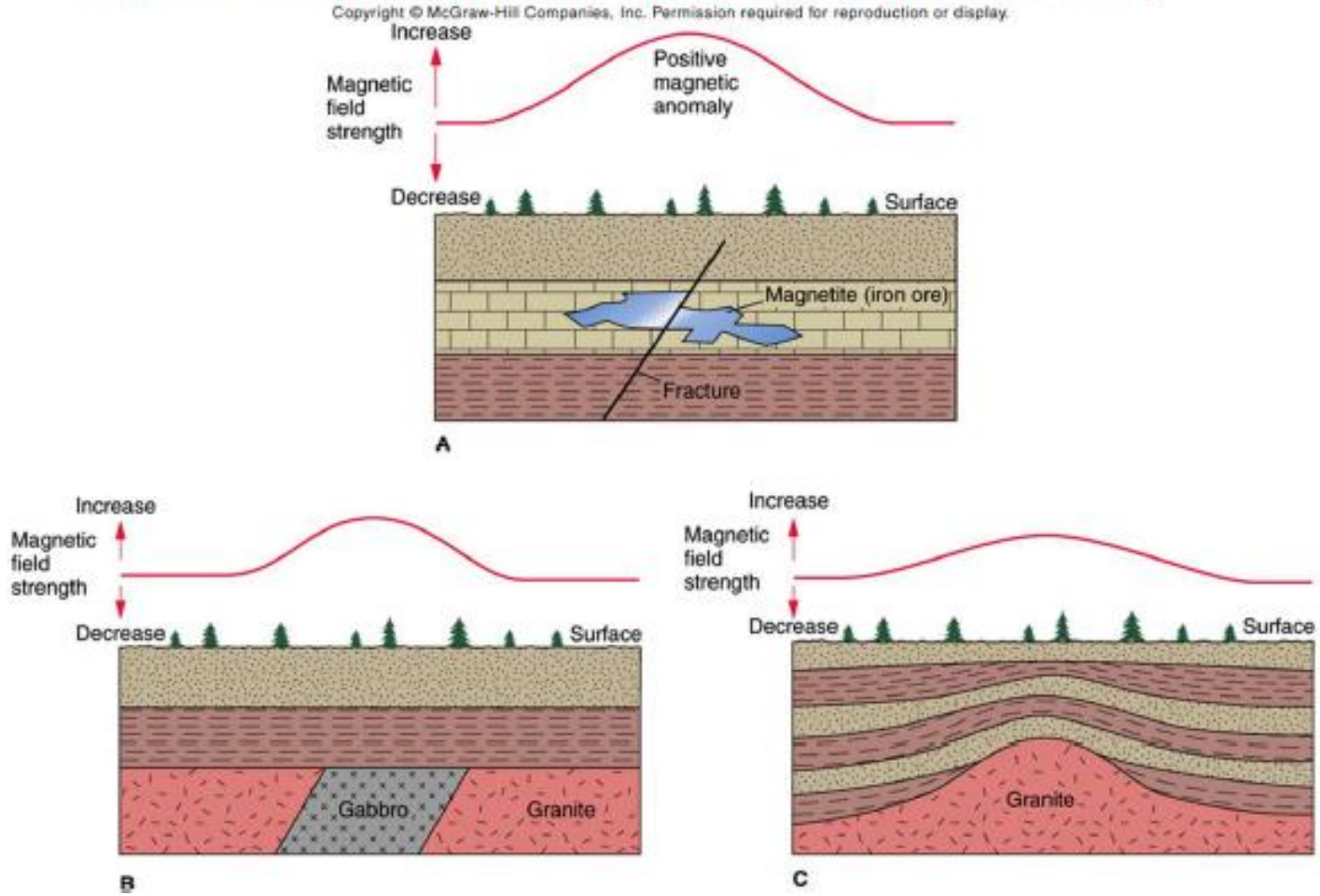


Instruments for measuring magnetic field

Proton-precession magnetometer

Earth's magnetic field

magnetic anomalies occur in local field from magnetic rock below surface (similar to gravity anomalies)



Earth's magnetic field

removal of magnetic material from near surface
causes negative anomaly (example is normal faulting)