ENVIRONMENTAL MAGNETISM
<table>
<thead>
<tr>
<th>Measurement</th>
<th>Sample Properties</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palaeomagnetic</td>
<td>Made upon oriented blocks of 'undisturbed' rock and sediment samples.</td>
<td>Detection of changes in the Earth's magnetic field recorded within the geological record. The geological timing of these changes can be established, allowing palaeomagnetic sequences to be used as a relative dating technique.</td>
</tr>
<tr>
<td>Magnetic Fabric</td>
<td>Made upon oriented blocks of 'undisturbed' sediment samples.</td>
<td>Like other fabric techniques, detection of the direction of flow of the transporting medium responsible for deposition of the sediment.</td>
</tr>
<tr>
<td>Mineral Magnetic</td>
<td>Samples of rock or sediment do not need to be oriented or undisturbed.</td>
<td>Attempts to identify the concentrations and types of magnetic minerals within a sample (analogous to XRD or heavy mineral analysis). No interest in the orientation of grains.</td>
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</tbody>
</table>
Why are iron minerals interesting in an environmental context?

- **Persistant:** The iron oxides which dominate the magnetic properties of most soils, sediments and rocks are both robust (persistent) and yet sensitive to a whole range of environmental processes. Although often present in very small amounts, they are rarely totally absent and, even in small amounts, can play an important role in the chemical behaviour of the material and dominate its colour.

- **Sensitivity:** Mineral magnetic instrumentation is relatively cheap and easy to use. However, and much more importantly, it is very sensitive. For example, in terms of detecting the presence of different iron oxide assemblages within a sample, magnetic measurements can be several orders of magnitude more sensitive the other forms of analysis such as X-ray diffraction.

- **Non-destructive:** Most magnetic measurements are non-destructive. That is, magnetic measurements do not preclude other subsequent forms of analysis on the same samples.
Main types of magnetic behaviour displayed by rock forming minerals

<table>
<thead>
<tr>
<th>Type of magnetic behaviour</th>
<th>Example minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamagnetic</td>
<td>Quartz, Feldspar, Calcite, Water</td>
</tr>
<tr>
<td>Paramagnetic</td>
<td>Olivine, Pyroxene, Garnet, Biotite</td>
</tr>
<tr>
<td>Ferromagnetic group</td>
<td></td>
</tr>
<tr>
<td>Ferri-magnetic</td>
<td>Magnetite, Maghaemite</td>
</tr>
<tr>
<td>Canted anti-ferromagnetic</td>
<td>Haematite, Goethite</td>
</tr>
</tbody>
</table>
# Types of mineral magnetic measurements

<table>
<thead>
<tr>
<th>Type</th>
<th>Properties</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>'In-field'</td>
<td>Sample is placed in a small, artificial magnetic field (larger than the Earth's natural magnetic field) and its response measured.</td>
<td>Magnetic susceptibility ($\chi$).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frequency dependent susceptibility ($\chi_{fd}$).</td>
</tr>
<tr>
<td>Remanence</td>
<td>Sample is placed into a large magnetic field (usually a series of gradually increasing field sizes are used) and then removed from that field. The magnetic response of the sample is then measured (that is, the amount of 'remanence' the sample has of the field).</td>
<td>Saturation Isothermal Remanent Magnetisation (SIRM).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anhysteretic Remanent Magnetisation ($\chi_{ARM}$).</td>
</tr>
</tbody>
</table>
Magnetic susceptibility in archaeology

Features detectable: (dependent on sample interval and depth of archaeology)

Occupational Activity:
- Pits
- Ditched enclosures
- Trackway
- Midden deposits

Industrial Activity:
- Hearths
- Kilns
- Furnaces
Eroded cliffs in the Chinese Loess Plateau

The natural exposures show paler and darker bands that reflect, respectively, alternations between loess deposition ("glacials") and paleosol development ("interglacials").
Luochuan Sequence in China with the dominant 40 and 100 kyr cycles
Variations in the Fed/Fet ratio from the Changwu loess section compared with the magnetic susceptibility values. The timescale is obtained by correlating the susceptibility signals with that of Xifeng.
Tephrochronology

Indicators of volcanic activity in sediment records

- Magnetic minerals
- Glass shard geochemistry
- Colour
Rabaul eruption
Tephrochronology

Crater Mt Rainforest History Project
(landscape ecology: palaeoecology and archaeology)
Tephrochronology

Lake Aguai Ramata, PNG
Magnetic Susceptibility from three cores

Depth below water surface (cm)

Mud-Water Interface Core

Volume Susceptibility (k)

AR_Hole1

Volume Susceptibility (k)

AR_Hole2

Volume Susceptibility (k)

210Pb samples

AMS 14C samples

Lake Muds

Tephra

Long Is tephra (Tibito) AD 1665

Long Is tephra (Olgaboli) 1200 BP

AMS C samples

Volume Susceptibility (k)
Papua New Guinea

Long Island

Markham Valley
Tephrochronology

Lake Wanum, PNG
Magnetic Susceptibility from three cores

Depth below water surface (cm) | Mud-Water Interface Core | Volume Susceptibility (k) | WA_Hole 1 | Volume Susceptibility (k) | WA_Hole 2 | Volume Susceptibility (k)
---|---|---|---|---|---|---
Lake muds | Tephra WA-I | 280 +/- 35 | | 440 +/- 50 | | 1380 +/- 40
Tephra WA-II | | | 2350 +/- 50 | | | 3760 +/- 40
Lake clays | Tephra WA-III | | | 3670 +/- 40 | | 4380 +/- 70

210Pb samples
AMS 14C samples
Human-Landscape Interactions

How can we distinguish disturbance events related to human activity from those related to natural processes?

- The role of regional and global climatic patterns on landscapes
- The significance of human disturbance for landscape changes
The $\chi_{fd}$ and Calluna pollen percentage profiles for Lago di Origlio, Switzerland.

Close correspondence between the profiles indicates the similar overland flow pathways for the two parameters.
Papua New Guinea

Long Island

Tari Basin
Mineral magnetics and human impacts

Tari Basin, PNG
Mineral magnetics and human impacts

Human impacts

- forest loss
- increased burning
- increased erosion
- high Mag susc.