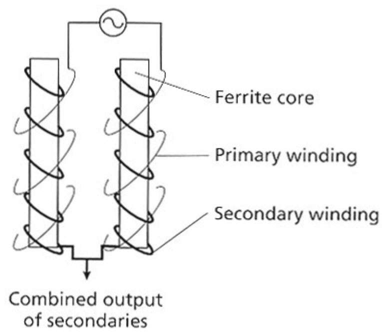
224 D4 Instrumentation and data collection techniques for magnetic exploration

D4.1 Instrumentation

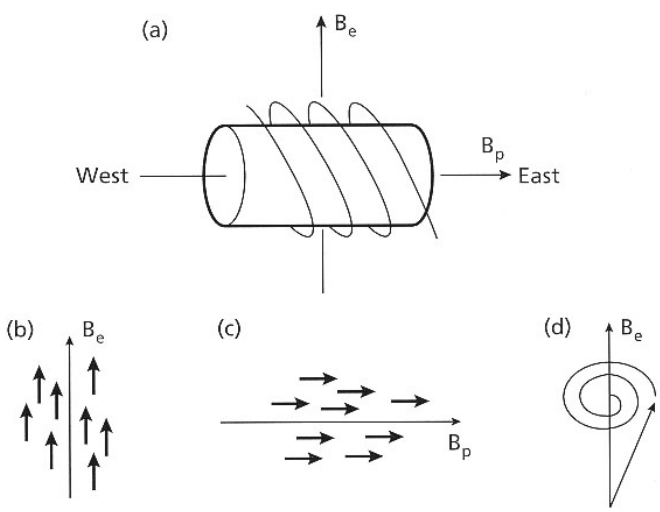
D4.1.1 Flux gate magnetometer

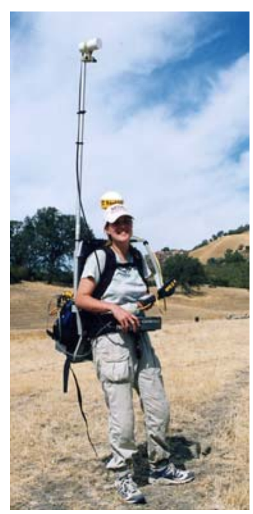


● Details of operation are described in Keary and Brooks

● Measures the **component** of magnetic field **along the axis** of the ferrite cores

D4.1.2 Proton precession magnetometer





● cylinder contains a proton (hydrogen) rich liquid

● protons have a magnetic moment and act as small magnets

● they align with the Earths magnetic field, B_E
● when a stronger magnetic field (B_P) is applied, the protons are re-aligned

● when B_P is switched off, the protons return to be being aligned with B_E

● as this happens, they presses at a characteristic frequency, ω, that is proportional to B_E

● this frequency is measured by the weak radio signal emitted by the precessing protons

● measures **total magnetic field**, so no alignment of the instruments is needed

D4.1.3 Alkali vapour magnetometer

● These magnetometers use **changes in the frequency splitting** of optical spectral lines of elements such as rubidium, caesium or potassium to measure the magnetic field. This is governed by the Zeeman effect.

● Typically measure 10 times per second with precision of 0.01 nT or lower.

● Now the most widely used magnetometer in airborne surveys.

● Errors in survey limited by positioning errors rather than magnetic field measurements.

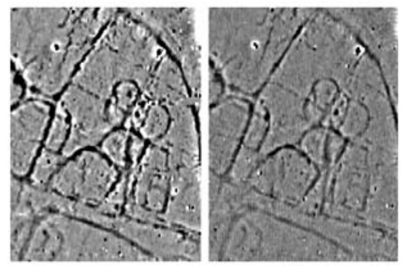
● Typical HRAM (High resolution aeromagnetic surveys) use these instruments. Elevation is 40-80 m and line spacing 200-500 m. This has allowed aeromagnetic exploration to be used in studies of the subtle magnetic anomalies generated by sedimentary rocks with small (but variable) magnetite contents. See examples in D6 from North Slope of Alaska, Canadian Cordillera and Weyburn, Saskatchewan. Example from Finland below.

D4.1.4 Magnetic gradiometers

● By placing one magnetometer above another, the vertical gradient of the magnetic field (dF/dz) can be measured. The high precision of modern instruments means the spacing only needs to be 1-2 m. This has several advantages

● By computing (dF/dz)/F, temporal variations in the external magnetic field can be effectively removed from the data. This is illustrated in the data example below (panel f), and this provides an alternative way to remove time variations (if the base station fails!)

● dF/dz can be more sensitive to dipole anomalies in the Earth than long wavelength features in the regional magnetic field.



1m gradiometer 0.5m gradiometer

D4.2 Field techniques for magnetic exploration

D4.2.1 Ground-based magnetic surveys

● typically use a proton precession magnetometer (~ 1nT sensitivity) or an alkali vapor magnetometer (~ 0.01 nT sensitivity)

● operator must be liberated of all metal objects (especially their keys and money!)

● survey along a profile or grid

● locate profiles with surveying, or with an instrument with integrated GPS (above)

Spatial corrections

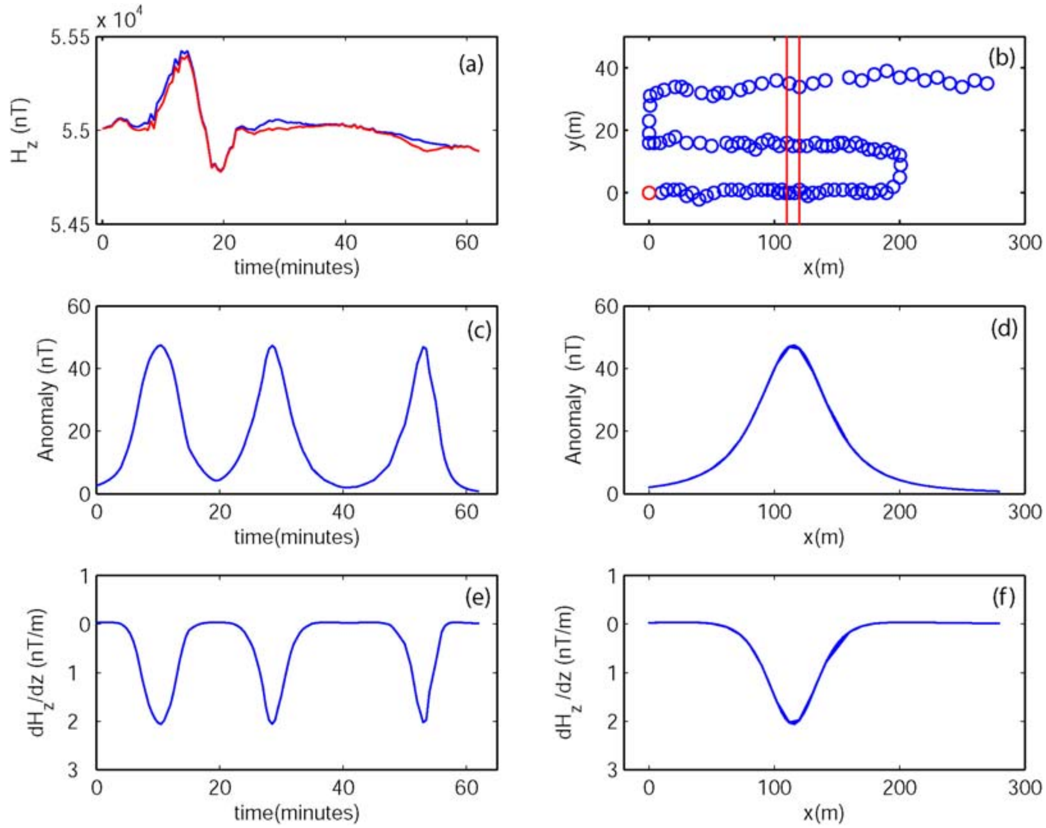
● It is possible to correct magnetic data for latitude and elevation but these corrections are generally much smaller than magnetic field anomalies. They are only important if the survey has a large spatial extent.

- Topography is important, such as when measurements are made in a narrow valley or canyon.

Time corrections

- A simple magnetic survey could use a single magnetometer that is carried along a profile. Since the magnetic field of Earth changes with time, it is unclear if changes in magnetic field are due to (1) temporal changes or (2) subsurface structure.

- To separate effects (1) and (2) two magnetometers must be used in fieldwork. An example of this procedure is illustrated below. One magnetometer is placed at a fixed location (the base station) and the other is carried along the profiles (b). Data recorded here are shown in red and measurements at the moving station are shown in blue (a).

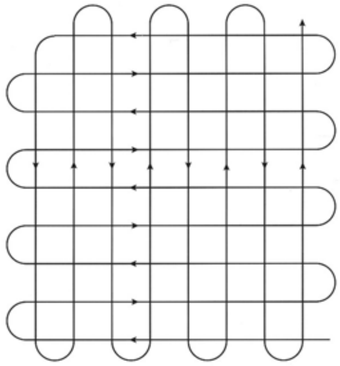


- Variations at the base station instrument are **subtracted** from those on the moving instrument to determine variations along the profiles (c)

- Note that the three crossings of the target are **virtually identical** when the time variations are removed (d,f)

- Unlike gravity exploration, instrument drift is not a serious problem

D4.2.2 Aeromagnetic surveys



- Profiles flown with line spacing 100 m to several kilometers. Elevation 100-1000 m.

- Alkali vapour magnetometer. Accuracy 0.01 nT or less

- Continuous recording base station used to remove temporal variations.

- Cross lines used as internal check that temporal variations have been consistently removed.

- Need a non-magnetic aircraft or put the magnetic sensor in a towed bird. Compensation used to remove residual magnetic effects of aircraft.

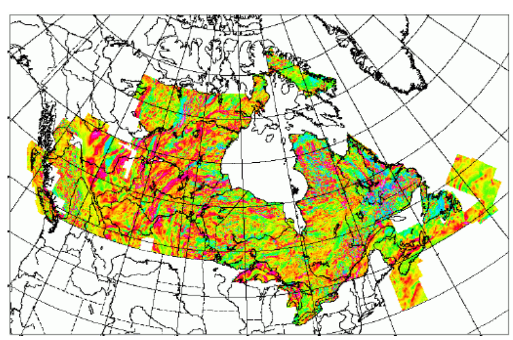
- Flight path can be located with radar, altimeter or by taking aerial photos. GPS now makes this much more accurate and simpler.

- Magnetic field data is usually corrected to a common elevation with **upward or downward continuation**

- Draped surveys flown at constant elevation above the surface (need helicopter)

- With total magnetic field measurements the motion of the aircraft or bird is not serious.

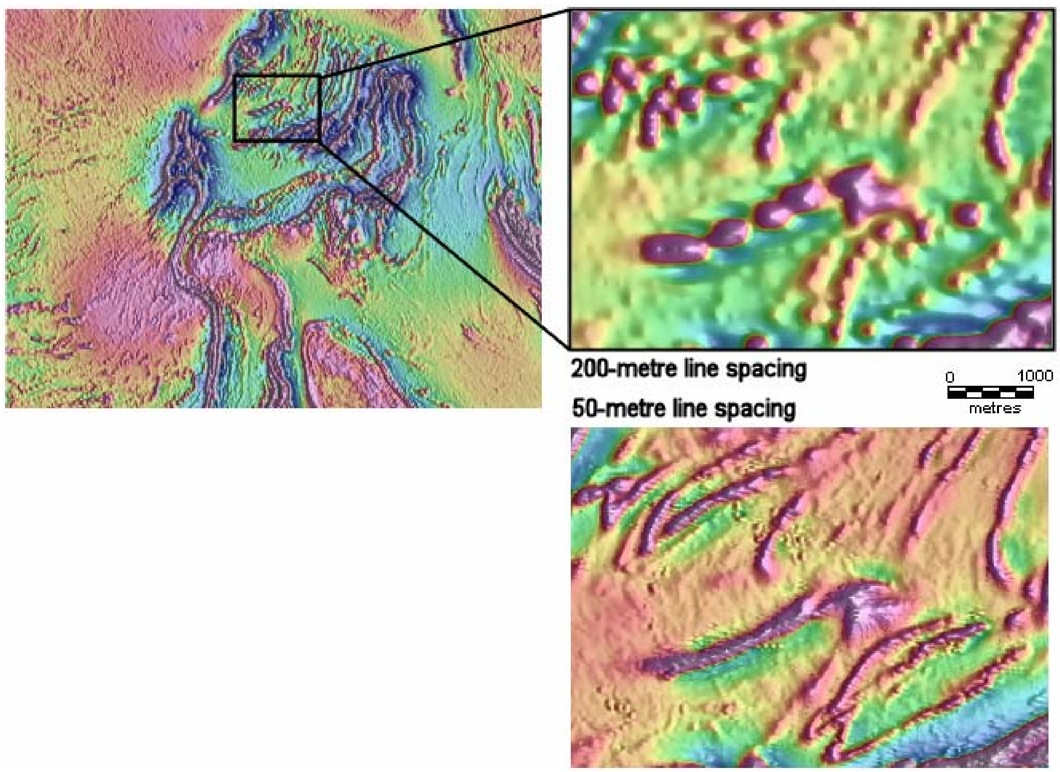
- Gives rapid coverage and works well in areas where access is difficult on ground (both in remote wilderness areas or urban environment)



- The magnetometer is further from target than in ground surveys, so the sensitivity is slightly lower. However, with alkali vapour magnetometers small ore deposits and features in sedimentary rocks can be mapped..

- High resolution aeromagnetic (HRAM) surveys are now the standard field technique and they use a **dense line spacing** and **low flight elevation** to give detailed information about subtle, sub-nanotesla magnetic field anomalies. See examples from Geological Survey of Finland at

  http://www.gsf.fi/aerogeo/eng0.htm

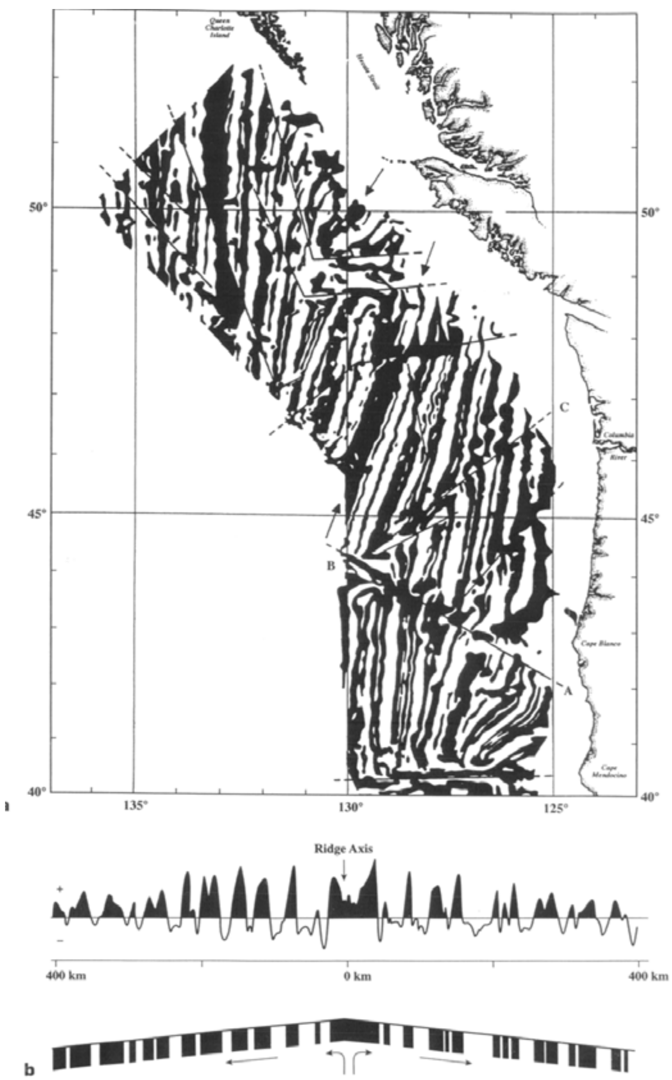


D4.2.3 Marine magnetic surveys

- The proton precession magnetometer needs to be as far from a metal ship as possible. This is usually in a plastic fish that is towed behind the ship.

- Marine surveying is slower and more expensive than airborne surveying, so not widely used in commercial offshore exploration.

- However, magnetometers are routinely towed behind survey ships and have revealed many details of the structure of ocean basins (*e.g.* magnetic stripes produced by seafloor spreading)



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