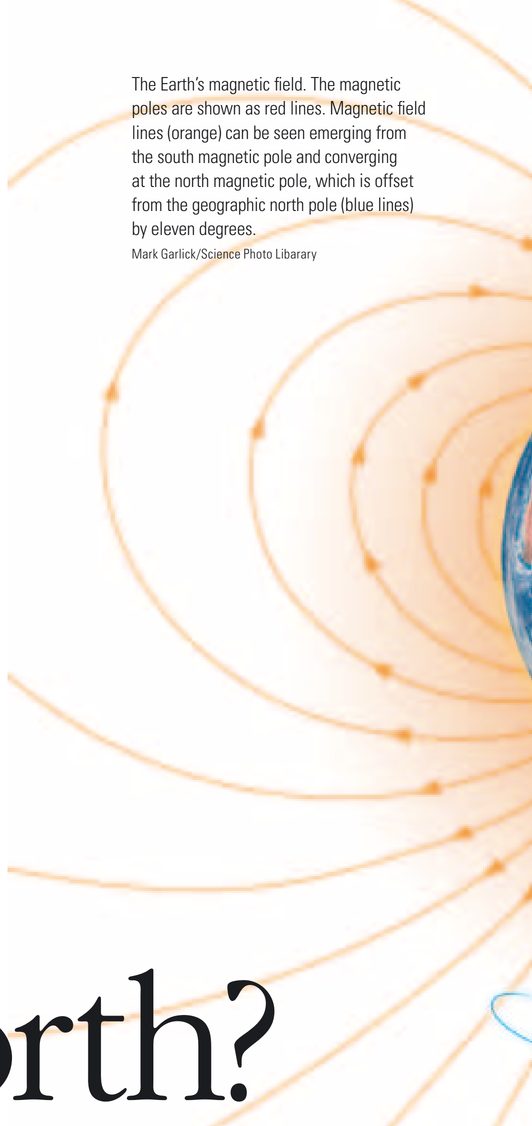

The Earth's magnetic field. The magnetic poles are shown as red lines. Magnetic field lines (orange) can be seen emerging from the south magnetic pole and converging at the north magnetic pole, which is offset from the geographic north pole (blue lines) by eleven degrees.
Mark Garlick/Science Photo Libarary

To go north, you just follow your compass towards magnetic north, right? Not quite. Geophysicists have to work hard so we can continue to navigate with map and compass. Susan Macmillan and Tom Shanahan describe how the UK magnetic repeat station network helps.

Where is North?

To find your way using a magnetic compass with a map, you need to know the difference between magnetic north and map north. This difference is called 'grid magnetic angle', and in the UK it is derived from a model of the Earth's magnetic field, which is updated every year. The variation in grid magnetic angle reflects changes in the Earth's magnetic field arising from sources in the Earth's fluid outer core. We don't yet understand these changes well enough to make good forecasts, so we need to monitor them continuously.

Some of the data we need has been provided by an important, UK-wide network of magnetic survey stations that has been operating since the early 20th century.

At these 'repeat stations', very accurate measurements are made of the magnetic field strength and direction over a whole day, every few years, at exactly the same place. The readings are influenced by different sources of magnetism (see explanations to the right) and all these need to be carefully considered when making and processing magnetic field observations.

For example, in the UK the horizontal direction of the main field is currently changing by about 0.2° each year. But we can also see this much variation between sites just a few metres apart because of variations in the crustal fields. Taking repeated measurements at exactly the same spot lets us measure the core magnetic field signal without the risk of distortions from changes in the crustal field.

Likewise, variations in the magnetosphere surrounding the Earth cause the overall magnetic field to fluctuate by about 0.2° each day in the UK, and by considerably more during a magnetic storm. During a storm in October 2003 the magnetic field direction was observed in the UK to change by over 5° in six minutes. Fortunately these variations are short-lived compared to those from the core. We measure them at the three UK magnetic observatories, and can then subtract them from the repeat station data.

Having processed and modelled the data,

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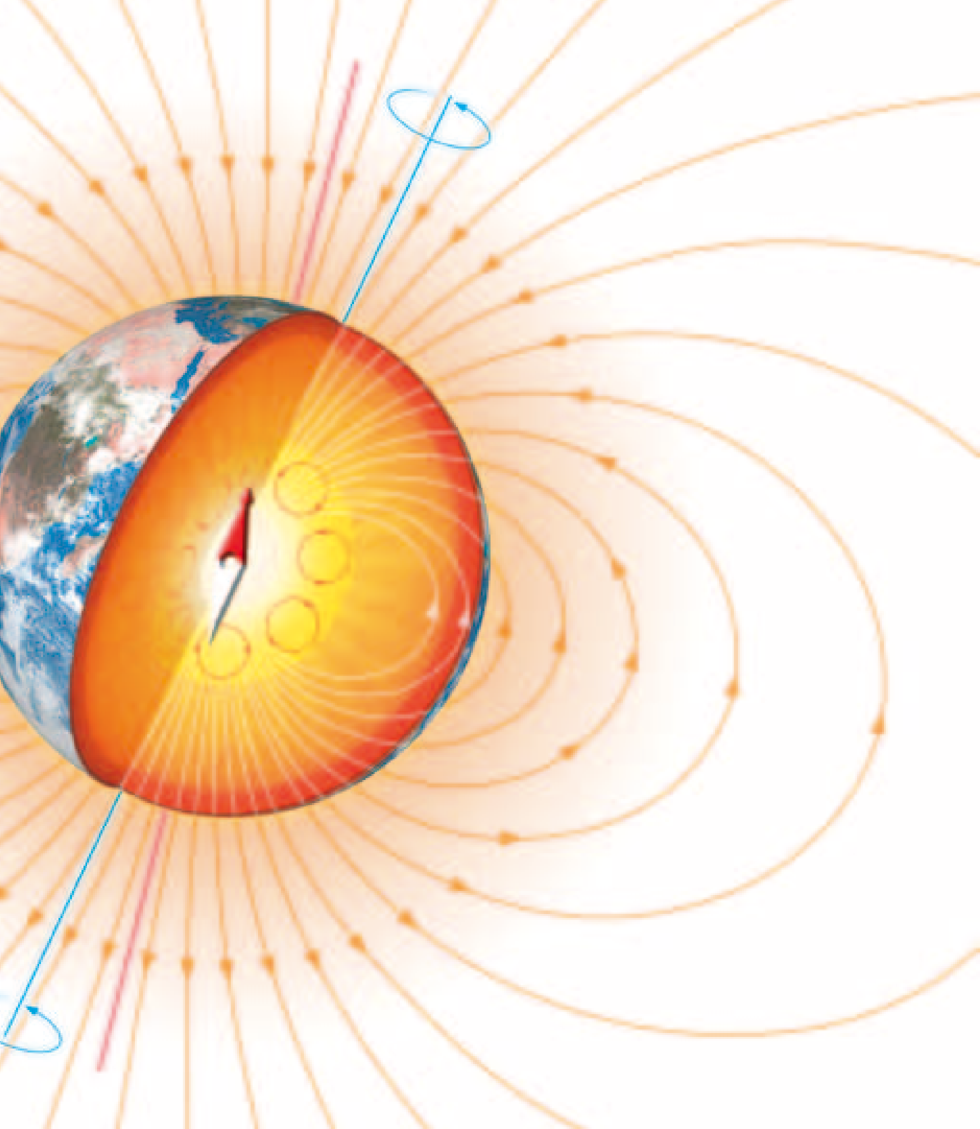

MAGNETIC FIELD SOURCES

- The Earth's magnetic field mostly arises from the motions of fluid in the Earth's outer core region, and changes slowly with time.
- Weaker fields from magnetic material in local rocks (the 'crustal field') vary significantly over the surface of the Earth – often aiding geological interpretation – but not so much with time.
- The Earth's magnetosphere – where the planet's magnetic field interacts with charged particles from space – causes variations in the observed magnetic field. These are affected by the Sun's activity, and are relatively rapid compared to those from the core.

we can update the magnetic charts. We can see that the correction we need to apply to a compass bearing to convert it to a map bearing – and vice versa – varies both in space and in time. The models are then used to supply the Ordnance Survey with the magnetic north data they need for their maps.

East is least, west is best

The earliest observations of the geomagnetic field in the UK were made in and around London in the late 16th century. At that time magnetic north was east of map north. However it was not until the early 20th century that we had a genuine repeat station network covering the whole of the UK with sites that could be revisited at regular intervals.

Several magnetic surveys were made before this, though. Perhaps the most noteworthy were the efforts of Major Edward Sabine between 1834 and 1838. At that time, magnetic north was more than 20° west of map north. Later he was to declare that this survey 'deserves to be remembered as having been the first complete work of its kind planned and executed in any country as a national work, coextensive with the limits of the state or country, and embracing the three magnetic elements'.

Sabine also pointed out that such surveys are able 'by their repetition at stated intervals to supply the best kind of data for the gradual elucidation of the laws and source of the secular change in the distribution of the Earth's magnetism'. These early magnetic surveys were major undertakings, given the delicate but sizeable instruments available at that time and the challenges of travelling across the country.

Nowadays the instruments used are a 'fluxgate-theodolite', allowing us to measure the direction of the magnetic field, and a 'proton precession magnetometer', for measuring its strength. We determine the direction of true north using a north-seeking gyroscope. Each site is marked by a buried slab of concrete, and detailed site plans allow us to set up our equipment in exactly the same place each time.

The data we get from these stations can also help us understand the crustal magnetic field. By measuring the magnetic field at the same locations very accurately over long periods of time, we should be able to distinguish between the different types of crustal magnetisation. This can be either 'remanent magnetisation', which is 'embedded' in rocks when they form, or 'induced magnetisation', which rocks take on when exposed to the Earth's ambient magnetic field.

As the core field changes with time, there should also be small changes in the crustal magnetic field if there is induced magnetisation present – although detecting these very small signals in measurements that contain signals from a variety of sources is quite a challenge.

But for the foreseeable future, the main and most crucial application of the data is likely to be navigation. You'll be making use of magnetic field data next time you use a map and compass to find the next destination. However it's also used whenever something needs to be set up to point in a precise direction with the help of a compass. This includes everything from aligning sundials and satellite dishes, to making sure mosques face towards Mecca.

MORE INFORMATION

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FURTHER READING

Jackson A, Studies of crustal magnetic anomalies of the British Isles. *Astronomy & Geophysics*, 2007.