

Geomagnetism as a Tool for Well-bore Navigation

Navigating towards underground targets when drilling for oil and gas is becoming more challenging. In some areas target sizes are getting smaller and there is an increased risk of collision with existing wells in the congested sub-surface.

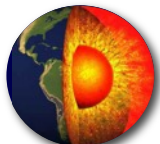
Directional drilling is now a firmly established technique in use within the oil industry. Using magnetic survey instruments to make measurements while drilling (MWD) can reduce drilling time and thus operational costs.

High quality information on the Earth's magnetic field (B) is needed to attain the required levels of accuracy for MWD magnetic surveys.

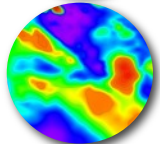
In general, accuracies of 0.1° in declination (D), 0.05° in inclination (I) and 50 nT in total field strength (F) are desired.

Magnetic Field Corrections

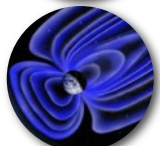
The **BGS Global Geomagnetic Model (BGGM)**, **In-Field Referencing (IFR)** and real-time **Interpolation In-Field Referencing (IIFR)** enable the British Geological Survey to provide accurate estimates of...



The **MAIN FIELD (B_{main})** generated by the fluid motion in the Earth's outer core



Local **CRUSTAL FIELD (B_{crustal})** due to the magnetisation of underlying basement rocks



The **EXTERNAL FIELD (B_{external})** arising from electric currents in the ionosphere and magnetosphere

History and Background

Founded in 1835, the British Geological Survey (BGS) is the world's oldest national geological survey and the United Kingdom's premier centre for earth science information and expertise.

BGS carries out research in strategically important areas including energy and natural resources, vulnerability to environmental change and hazards, and Earth System Science, often in collaboration with the national and international scientific academic community. In this way BGS maintains and develops understanding of earth sciences to improve policy-making, enhance national wealth and reduce risk.

The BGS is part of the Natural Environment Research Council (NERC), which is the UK's main agency for funding and managing research, training, and knowledge exchange in the environmental sciences.



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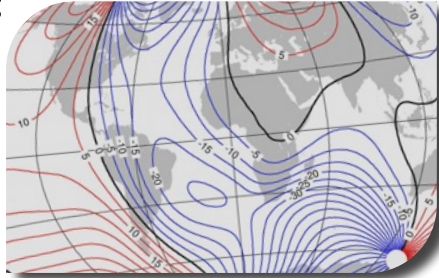
Oil & Gas Industry



Main Field Modelling and Data

BGS Global Geomagnetic Model - B_{main}

The **BGGM** represents a combination of the main field generated in the Earth's fluid outer core and the persistent external field arising from ever-present magnetospheric currents. It is a mathematical model describing these fields and their annual rates of change.



Declination contour map



CHAMP Geoscientific and Atmospheric research satellite

The model is based on data collected from magnetic survey satellites which make accurate observations of the strength and direction of the Earth's magnetic field at altitudes greater than 300 km...

...and from a network of around 160 geomagnetic observatories around the world.



Hartland magnetic observatory UK

The BGGM user licence includes:

- annual updating of the BGGM, maintaining the accuracy of the model.
- stand-alone software and source code

In-Field Referencing IFR

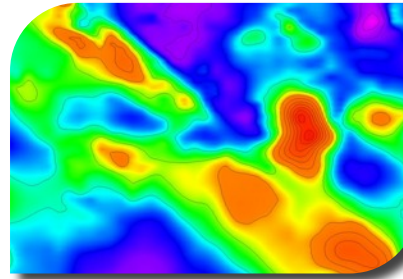
$$IFR = B_{main} + B_{crustal}$$

Crustal field anomalies are often significant for directional drilling (several tenths of a degree).



Aircraft conducting an aeromagnetic survey

The crustal field varies only on geological timescales, and can therefore be considered as a static offset to values derived from global models.



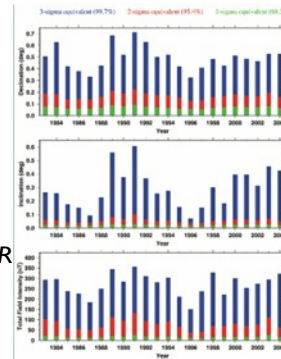
Crustal anomaly map for area of the North Sea (range 1400 nT)

IFR Baseline Values			
	D	I	F
	(°)	(°)	(nT)
P0	-3.522	71.751	50340.1
P1	-3.575	71.766	50382.6
P2	-3.698	71.797	50435.2
P3	-3.770	71.813	50455.0
TVD	-3.828	71.825	50468.0

IFR derived values and estimate of the error associated with the external fields, not included in IFR

The IFR service includes:

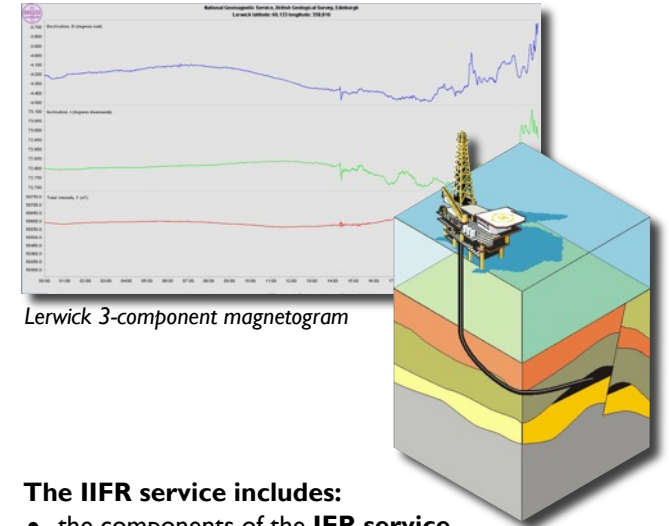
- IFR set-up per field, written report and error estimates
- maintaining the field set-up
- per well requests



Interpolation In-Field Referencing IIFR

$$IIFR = B_{main} + B_{crustal} + B_{external}$$

The **Earth's magnetic field (B)** varies with time due to solar-driven external fields that can be both regular daily variations and irregular disturbances. Even at UK latitudes during solar minimum on an undisturbed day in the winter, the daily range of the magnetic field direction exceeds the desired threshold accuracy of one tenth of a degree. By combining the model results (**IFR**) with the external field as measured at nearby magnetic observatories the sources of **B** are all accounted for. Thus, **IIFR** provides accurate estimates at the drilling site for correction of borehole surveys.



Lerwick 3-component magnetogram

The IIFR service includes:

- the components of the **IFR** service
- derivation of 1-minute values of **D**, **I** and **F** for positions along the well path
- web-based, real-time supply
 - ♦ to dedicated secure pages for each site
 - ♦ showing data and magnetograms
- stop/start data supply as required
- real-time quality control
- back-up systems at various stages
 - ♦ recording at the observatories
 - ♦ communications links, data processing
 - ♦ delivery to customers