A Comparison of Two Brunhes Chron Geomagnetic Excursions Recorded by Two Neighbouring North Atlantic Sites (ODP Sites 1062 and 1063)

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1. Introduction

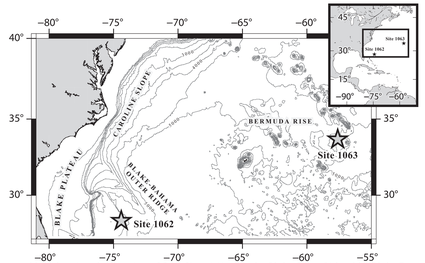
Geomagnetic excursions mark periods of time when the variation in the direction and intensity of the Earth's magnetic field greatly exceeds that of 'normal' secular variation. They are therefore recognised as intrinsic features of the Earth's field. During these events, the field can achieve reversed polarities, accompanied by significant decreases in the intensity of the field. Directional excursions are typically defined as being periods during which the Virtual Geomagnetic Pole (VGP) deviates more than 45° from the geographic poles.

Approximately 7 excursions of the Earth's magnetic field appear to have occurred since the last full geomagnetic reversal at 780 ka, although the absolute chronology of these is uncertain.

Excursions are short duration events (<10 kyr). Attempts to combine high resolution palaeomagnetic studies with accurate chronologies has been limited by the resolution of conventional dating methods - such as oxygen isotope stratigraphy.

Furthermore, there have been relatively few high resolution studies of different excursions from the same or neighbouring sites. This is of particular interest in determining whether different excursions observed in the same locale have similar characteristics. If they do, it may suggest the influence of long-standing thermodynamic features of the core-mantle system.

2. Our Study



Map showing the location of ODP Site 1062 near the Blake Outer Ridge (the Blake Excursion record) and ODP Site 1063 on the Bermuda Rise (the Iceland Basin Record).

Our study presents records for two excursions, the Blake Excursion (~125 ka) and the Iceland Basin Excursion (~185 ka). The records have been obtained from two neighbouring sites in the North Atlantic allowing direct comparison of the local character of the two excursions. Both sites have relatively high sedimentation rates (>10 cm kyr^{-1}) allowing high-resolution study of the excursional behaviour.

Our **Blake Excursion** record is from Ocean Drilling Program (ODP) Leg 172, **Site 1062** on the Blake Ridge (28°14'N, 74°25'W). Three cores were analysed: 1062B, D and E.

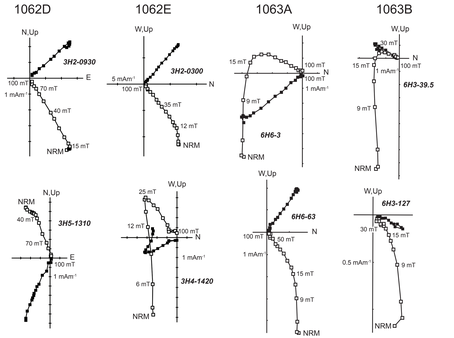
Our **Iceland Basin Excursion** record is from the same ODP Leg 172, **Site 1063** on the Bermuda Rise (33°41'N 57°37'W). Two cores were analysed: 1063A and B.

3. Palaeomagnetic Records

All discrete samples were subjected to a stepwise alternating field (AF) demagnetization of the natural remanent magnetization (NRM) to a peak field of 100 mT using a 2G cryogenic magnetometer in the field-free room at the University of Oxford. Principal component analysis was then used to determine the characteristic remanent magnetization vectors (ChRM).

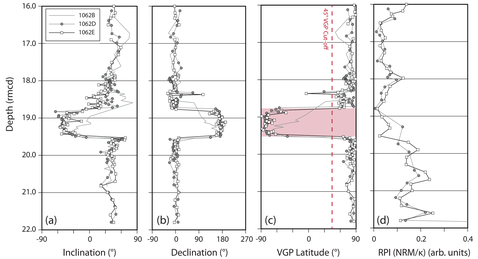
Blake Excursion

Iceland Basin Excursion



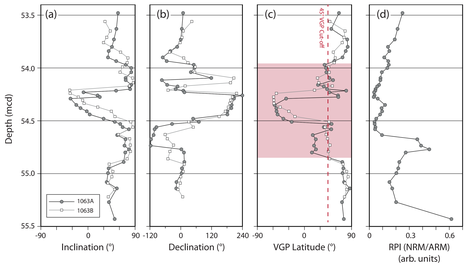
Typical examples of zijderveld diagrams. Solid (open) symbols represent projection of the vector onto a horizontal (vertical) plane. Examples from ODP Site 1062 (Blake Excursion Record) and ODP Site 1063 (Iceland Basin Excursion Record).

Blake Excursion *Site 1062 - (Bourne et al. - in press)*



(a) Inclinations and (b) declinations during the Blake Excursion from ODP Cores 1062D and E. (c) VGP latitudes and the 45° cut-off angle (red dashed line), by which the interval encompassing the Blake (pink shaded area) is defined. (d) Relative palaeointensity (RPI) derived by normalizing the Natural Remanent Magnetization (NRM) by magnetic susceptibility (κ).

Iceland Basin Excursion *Site 1063 - (Knudsen et al., 2006, 2007)*

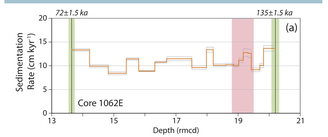


(a) Inclinations and (b) declinations during the Iceland Basin Excursion from ODP Cores 1063A and B. (c) VGP latitudes and the 45° cut-off angle (red dashed line), by which the interval encompassing the Blake (pink shaded area) is defined. (d) Relative palaeointensity (RPI) derived by normalizing the Natural Remanent Magnetization (NRM) by an artificially induced Anhysteretic Remanent Magnetization (ARM).

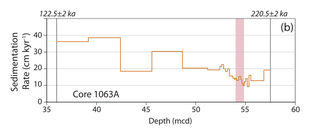
4. Sedimentation Rates

To determine accurate durations for the excursions as defined above, high resolution age models were required. To achieve this end, we conducted investigations using measurements of the concentration of excess thorium-230 ($^{230}Th_{xs}$) to determine relative variations in sedimenation rate with depth (Francois et al., 2004) - *see right*. Two cores were used to determine the durations of the Blake and Iceland Basin Excursions - cores 1062E and 1063A respectively. The stratigraphic boundaries used were determined via independent oxygen isotope stratigraphies for both cores. Isotope measurements were undertaken at Oxford University using a Nu Plasma MC-ICPMS.

Blake Excursion



Iceland Basin Excursion



$^{230}Th_{xs}$ derived sedimentation rates (solid orange lines) for (a) Site 1062E (Blake Record) and (b) Site 1063A (Iceland Basin Record).

Black vertical bars indicate the stratigraphic boundaries used (with uncertainties highlighted in green and ages noted above).

Pink shaded regions in (a) and (b) indicate the intervals encompassing the Blake and Iceland Basin Excursions respectively.

5. Excursion Character

Blake Excursion

The Blake record from Site 1062 shows an almost step change in VGP latitude principally driven by a rapid change in declination. During the excursion, the field direction is fully reversed with VGPs at extreme high latitudes.

The relative palaeointensity shows a steady decrease in field intensity to a broad minimum coinciding with the reversed directions. Field intensity remains low after termination of the inclination anomaly.

Directional Excursion Duration

Using the $^{230}Th_{xs}$ derived sedimentation rates, the duration of the Blake excursion is calculated to be:

6.5 kyr (±1.3 kyr) at Site 1062.

Iceland Basin Excursion

Inclination curves from Site 1063 show two conspicuous inclination "shoulders" on either side of the excursion peak, where the field is very steep. The intial increase to high inclinations is associated with a simultaneous change in declination values.

The drop in palaeointensity did not occur abruptly and was not completely synchronous with the onset and termination of the inclination anomaly.

Directional Excursion Duration

Using the $^{230}Th_{xs}$ derived sedimentation rates, the duration of the Iceland Basin excursion is calculated to be:

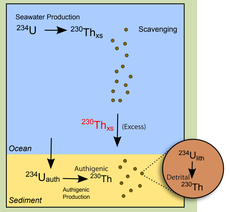
6.8 kyr (+0.4/-0.5 kyr) at Site 1063.

These records have been independently replicated in recent work by Channell et al. (2012) although their duration estimate differs as the result of a different definition for the excursional field.

Thorium Excess Theory

The flux of excess ^{230}Th is only dependent on the depth of the overlying water and the concentration of ^{234}U in seawater, both of which are thought to have stayed relatively constant within the last several hundred thousand years (Henderson and Anderson, 2003).

The activity of $^{230}Th_{xs}$ per gram, corrected for decay, is proportional to the instantaneous sedimentation rate. The sedimentation rate (in cm/kyr) was therefore calculated using the relative variation of the activity of $^{230}Th_{xs}$ with respect to the weighted average activity between bounds of known age obtained from independent stratigraphy.



Thorium-230 has three principal components in ocean sediments:

Detrital ^{230}Th : *Derived from a detrital, lithogenic fraction. Uranium supported.*

In-grown ^{230}Th : *Produced by the decay of authigenic uranium incorporated into the sediment from seawater.*

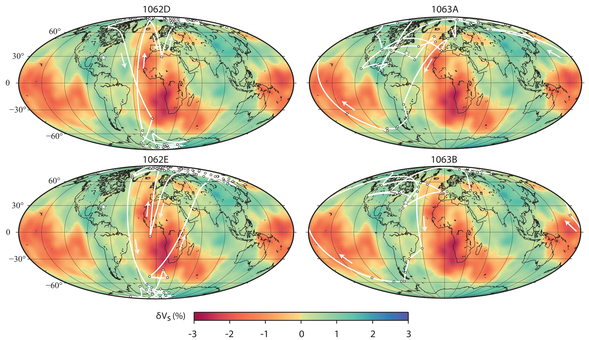
Scavenged or `excess' thorium : *Derived from thorium-230 that adsorbed from seawater onto the surface of descending particulates.*

The detrital and in-grown ^{230}Th components are subtracted from the total ^{230}Th concentration to obtain the concentration of $^{230}Th_{xs}$.

6. Virtual Geomagnetic Pole Paths

Blake Excursion

Iceland Basin Excursion



VGPs during the Blake excursion and the Iceland Basin Excursion. The observation site is indicated by a star. The background map is a tomographic model (SMEAN) of shear-wave velocity anomalies (δV_s) at the CMB (2850 km depth), based on global intermediate wavelength shear-wave tomography models (Becker and Boschi, 2002). Positive (red) values indicate lower than average shear-wave velocities corresponding to regions with hotter than average mantle material.

VGPs from Site 1062 show that the excursional field during the Blake Excursion was characterised by rapid transitions with few transitory VGPs at low latitudes. There is little evidence for any stop-and-go behaviour.

VGPs from Site 1063 indicate that the excursional field during the IB Excursion was dominated by seemingly metastable patches of vertical flux over North America and the tip of South America. The field appears to have experienced some stop-and-go behaviour between these flux patches which correspond reasonably well with zones of high seismic velocity in the lower mantle.

7. Conclusions

Although of similar duration (6.5 and 6.8 kyr respectively), the Blake and Iceland Basin excursions, observed at neighbouring ODP Sites 1062 and 1063 respectively, exhibit different directional character.

The 'long duration' of the Iceland Basin Excursion is principally the result of broad 'inclination' shoulders and stop-and-go behaviour: features that are not seen in the Blake Excursion which is characterised by rapid transitions to reversed directions.

Persistent long-standing thermodynamic features of the core-mantle system appear to have little influence over the directional character of the excursional fields.

References: **Becker and Boschi** (2002), A comparison of tomographic and geodynamic mantle models. G^3, 3, 2001gc000,168. **Bourne et al.,** 'Rapid directional changes associated with a 6.5 kyr–long Blake geomagnetic excursion at the Blake–Bahama Outer Ridge', EPSL. **Channell et al.,** (2012). ODP Site 1063 (Bermuda Rise) revisited: Oxygen isotopes, excursions and paleointensity in the Brunhes Chron. G3, 13(1), p.Q02001. **Francois, R. et al.,** (2004) 230Th normalization: An essential tool for interpreting sedimentary fluxes during the late Quaternary. Paleoceanography, 19(1), p.PA1018 . **Gubbins** (1999) The distinction between geomagnetic excursions and reversals. Geophys. J. Int. 137, F1–F4. **Henderson and Anderson** (2003) The U-series Toolbox for Paleoceanography. Rev. Mineral. Geochem., 52(1), p.493–531. **Knudsen et al.,** (2006) High-resolution data of the Iceland Basin Excursion from ODP sites 1063 and 983. EPSL 251, 18–32. **Knudsen et al.,** (2007) Seven thousand year duration for a geomagnetic excursion constrained by 230thxs. Geophys. Res. Lett. 34, 1–6. **Lund, S.P. et al.**, (2006). A summary of Brunhes paleomagnetic field variability recorded in ODP cores. PEPI 156, p.194–204. **Shipboard Scientific Party** (1998) Ocean Drilling Program (ODP) Leg 172.

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