# Geomagnetic Reversal in Brunhes Normal Polarity Epoch

Abstract. *The magnetic stratigraphy of seven cores of deep-sea sediment established the existence of a short interval of reversed polarity in the upper part of the Brunhes epoch of normal polarity. The reversed zone in the cores correlates well with paleontological boundaries and is named the Blake event. Its boundaries are estimated to be 108,000 and 114,000 years ago ± 10 percent.*

Theoreticians have speculated on the possible presence of short intervals of reversed polarity within the Brunhes epoch of normal polarity. The las-Champ event, the first such interval to be reported (*1*), was based on evidence derived from magnetic measurements of Quaternary volcanic rocks. The radiometric-$C^{14}$ method places the las-Champ event between 7000 and 9000 years ago. Cox (*2*) suggested a geomagnetic reversal model that predicted short reversals of polarity within the Brunhes epoch of normal polarity (700,000 years ago to present).

The purpose of this study was to investigate the possibility of short reversals in polarity during the Brunhes epoch of normal polarity. Cores with expanded upper Pleistocene sections and high sedimentation rates were selected as most likely to contain an easily detectable record of such mag-

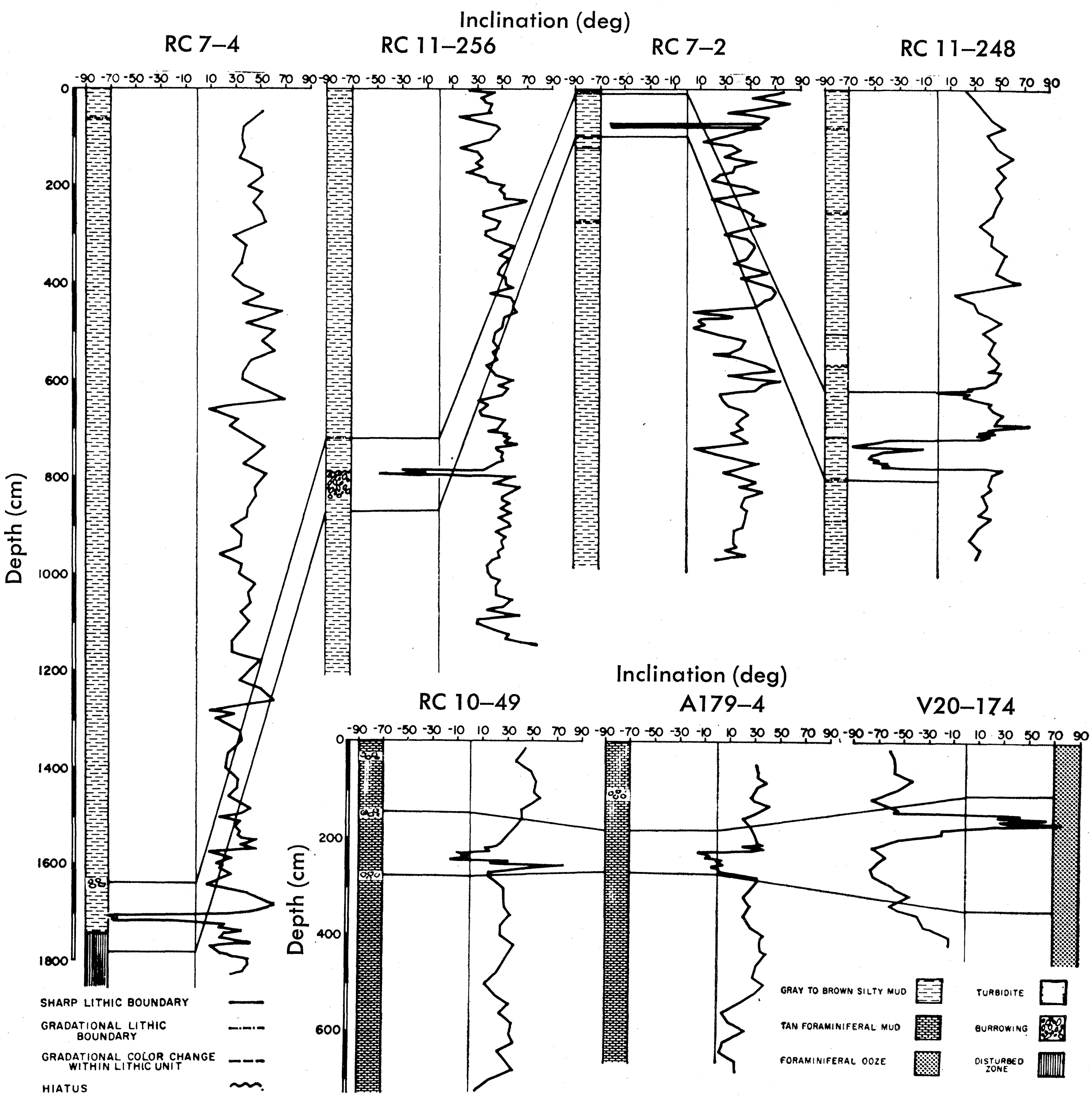


Fig. 1. Inclination angle of remanent magnetism versus depth and stratigraphic sections. Correlation lines define the boundaries of the X zone.

Table 1. Location of cores, length of X zone, rate of sedimentation in X zone, length of event, age of event, and age of lower boundary of X zone.

| Lamont core number | Latitude | Longtitude | Geographic location | Length of X zone (cm) | Sedimentation rate in X zone (cm/1000 years) | Length of event (years) | Age of event (years) | Age of lower X zone boundary (years ago) |
|---|---|---|---|---|---|---|---|---|
| RC 10-49 | 16°34'N | 79°31.5'W | Caribbean | 130 | 3.4 | 5,000 | 117,000–111,000 | 126,000 |
| A 179-4 | 16°36'N | 74°48'W | Caribbean | 90 | 2.4 | 7,000 | 111,000–105,000 | 126,000 |
| *Cores with unreliable sedimentation rates* | | | | | | | | |
| RC 11-248 | 16°36'N | 74°48'W | W. No. Atlantic | 180 | 4.7 | 12,000 | 120,000–114,000 | ? |
| RC 11-256 | 30°25'N | 74°22.5'W | W. No. Atlantic | 150 | 4.0 | 2,500 | 107,000–101,000 | ? |
| RC 7-4 | 29°15'N | 74°14'W | W. No. Atlantic | 145 | 3.8 | 6,700 | 112,000–106,000 | ? |
| RC 7-2 | 32°15'N | 74°48'W | W. No. Atlantic | 85 | 2.2 | 3,200 | 115,000–109,000 | ? |
| V 20-174 | 28°08'S | 68°46'E | Indian | 235 | 6.2 | 4,900 | 100,000–094,000 | ? |

netic events. The magnetic stratigraphy of seven cores of deep-sea sediment (Table 1) was determined with use of the spinner magnetometer described by Foster (*3*), by the method of Opdyke and co-workers (*4*). Plots of inclination of the remanent magnetism against depth for the seven cores investigated show a consistent zone of reversed polarity within the X zone of Ericson and colleagues (*5*) (Fig. 1). Following the precedent established by Cox, Doell, and Dalrymple (*6*), we named this the Blake event because it was originally discovered in deep-sea sediments of the Blake Outer Ridge. Cores RC 11-248 and A 179-4 have disturbed zones at about 600 and 245 cm, respectively, which are probably a result of mechanical distortion at the end of a core pipe (600 cm) and the end of a storage tray (245 cm). Since the 1966 cruise of R.V. *Vema* and the 1967 cruise of R.V. *Conrad*, cores have been handled specifically to preserve relative declination to assist in paleomagnetic interpretation. Thus, cores RC 11-248 and RC 11-256 are presented in Fig. 2 as examples of the change in declination angle that accompanies a complete polarity reversal.

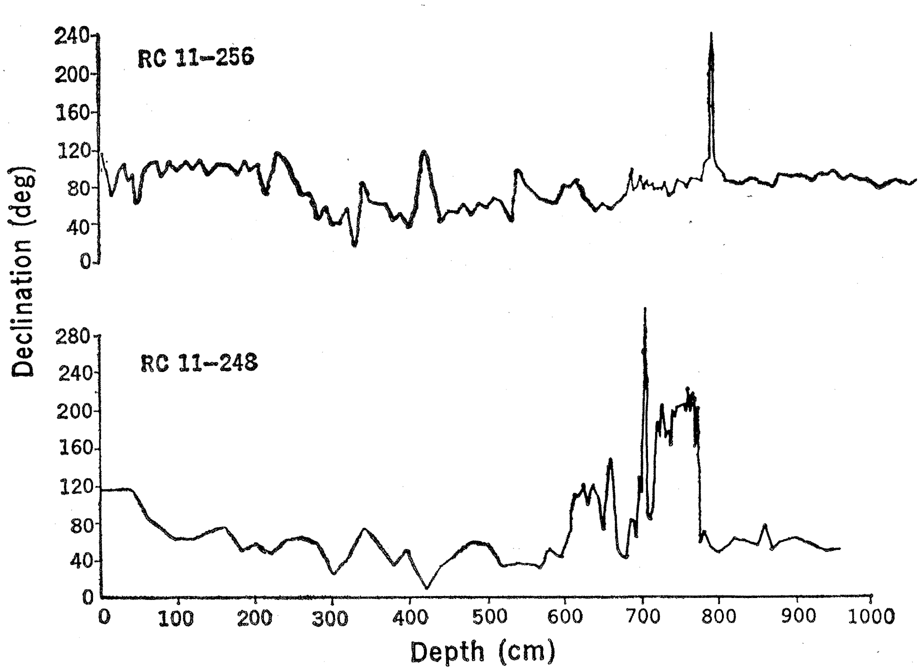

Fig. 2. Declination angle of remanent magnetism plotted against depth.

The X zone established by Ericson and co-authors (*5*) is based on the presence or absence of certain warm-water species of planktonic foraminifera, specifically defined as a biozone characterized by the presence of abundant *Globorotalia menardii* and *Globorotalia flexuosa*. The X zone in core A 179-4 was originally defined by Ericson and co-authors (*5*). The X zones in cores RC 7-4 and RC 7-2 were originally defined by Heezen, Hollister, and Ruddiman (*7*). Because *Globorotalia flexuosa* (Koch) was also reported in Ericson's V zone (*5*) and in older sediments (*8*), the uppermost zones in the cores RC 10-49, RC 11-248, RC 11-256, and V 20-174 that contained abundant *Globorotalia flexuosa* were chosen as the X zone. In cores taken from the Atlantic Ocean and the Caribbean Sea, lithology was an aid in delimiting the X zone. In the Blake-Bahama Basin and outer ridge cores, the tan to brown foraminiferal muds of the X zone are overlain and underlain by gray muds of the Y and Z zones, respectively. These contain cold-water faunas and have been interpreted to indicate a greater terrigenous influence of sedimentation during these periods (*5*).

In the Caribbean cores, the sediments of the X zone are not as easily distinguished on the basis of lithology, but in general they appear to be slightly more calcareous, as evidenced by their lighter tan color relative to underlying and overlying sediments. The core taken from the Indian Ocean is uniform foraminiferal ooze, and no lithologic distinctions are possible.

Broecker and colleagues (*9*) gave 126,000 ± 6000 years ago as the radiometric date for the lower boundary of the X zone in the Caribbean core Vema 12-122. We estimated the age of the upper boundary of the X zone to be 88,000 years ago ± 10 percent on the basis of an average rate of sedimentation for Vema 12-122 of 2.38 ± 0.10 cm per 1000 years (*9*).

The ages of the boundaries of the Blake event are estimated by extrapolation of average rates of sedimentation for the entire X zone in each core. From the data presented in Table 1, it is apparent the dates estimated on the basis of average rates of sedimentation for some of the cores are somewhat variable. Some of this variation can be accounted for by hiatuses and turbidites within sediments of the X zone (Fig. 1). Core RC 11-248 contains a clearly defined turbidite layer at least 20 cm thick in the upper half of the X zone. If one assumes that the pulse of a turbidity current includes some erosion followed by a period of rapid deposition, the sediments in this core do not record continuous deposition. Core RC 11-256 contains an apparent hiatus at the upper boundary of the event. Therefore, a rate of deposition based on the sediments of the X zone in cores RC 11-248 and RC 11-256 is meaningless, because a complete record of the event is not present in either case.

The lower boundary of the X zone in RC 7-4 is in flow-in, and the sedimentation rate for this core is not reliable. The core RC 7-2 was taken from the Blake Outer Ridge in a zone of intermittent nondeposition or mild erosion, or both (*7*) which tends to preclude a dependable sedimentation rate.

In contrast to the cores mentioned above, V 20-174, A 179-4, and RC 10-49 show no lithic evidence of breaks in sedimentation and appear to represent continuous deposition in a relatively stable environment. Since the dates assigned to the boundaries of the X zone are based on radiometric measurements of Caribbean sediments, we consider cores RC 10-49 and A 179-4 the most reliable for estimating the age and duration of the magnetic event. On the basis of the rate of sedimentation within the X zone of these two cores, the boundaries of the Blake event are placed at 108,000 and 114,000 years ago ± 10 percent.

JERRY D. SMITH
JOHN H. FOSTER
*Lamont Geological Observatory, Columbia University, Palisades, New York 10964*

### References and Notes

1. N. Bon Hommet and J. Babkine, *Comptes Rend.* **264**, 93 (1967).
2. A. Cox, *J. Geophys. Res.* **73**, 3247 (1968).
3. J. H. Foster, *Earth Planet. Sci. Lett.* **6**, 463 (1966).
4. N. D. Opdyke, B. Glass, J. D. Hays, J. H. Foster, *Science* **154**, 349 (1966).
5. D. B. Ericson, M. Ewing, G. Wollin, B. C. Heezen, *Geol. Soc. Amer. Bull.* **72**, 193 (1961).
6. A. Cox, R. R. Doell, G. Dalrymple, *Nature* **198**, 1049 (1963).
7. B. C. Heezen, C. D. Hollister, W. F. Ruddiman, *Science* **152**, 502 (1966).
8. F. L. Parker, *Bull. Amer. Paleontol.* **52** (235), 182 (1967).
9. W. S. Broecker, D. L. Thurber, J. Goddard, T. Ku, R. K. Matthews, K. J. Mesolella, *Science* **159**, 297 (1968).
10. Lamont Geological Observatory Contribution No. 1295. Based on material provided by the Lamont Geological Observatory core library. Supported by NSF grant GA 824, NSF 1193 and ONR grant TO-4. J.D.S. held a Duke University traineeship under the Co-operative Research and Training Program in Biological Oceanography. We thank A. Kaneps, who carried out the paleontological analysis of the cores, helped describe the lithological stratigraphy of the cores, and contributed to the preparation of the manuscript; J. D. Hays, B. C. Heezen, and N. D. Opdyke for advice and criticism; and D. R. Horn, M. Delach, W. F. Ruddiman, J. V. Gardner, W. L. Prell, and W. Ryan for their support.

30 August 1968; revised 15 October 1968

## Megalithic Plan Underlying Canterbury Cathedral

Abstract. *Woodhenge and the Trinity chapel, Canterbury, are strikingly similar in outline. One is megalithic, the other Norman Christian over Saxon Christian. An analysis of the geometry shows that both are based on Pythagorean triangles: Woodhenge with sides, 6, 17.5, and 18.5, and Canterbury with sides 12, 72, and 73 in megalithic yards. The structurally more recent eastern end of Canterbury Cathedral may have been built over and around an older megalithic site. The longitudinal axes of the composite cathedral differ by 2°, and these, if aligned on Betelgeuse, would indicate buried megalithic structures dating from 2300, 1900, and 1500 B.C.*

The visitor to Canterbury Cathedral who is fortunate enough to fall in with the retired clergyman, serving as volunteer guide, whose hobby and pride are the history, clerical and architectural, of the great edifice, will have his attention drawn to the misalignment, approximately 2°, between nave and choir. He will see a further deviation of 2° to the south between the choir and the Trinity chapel (Fig. 1). The chapel is apse-shaped with "horseshoe" rather than parallel sides. At the far end, a small circular chapel, the principal apse of the cathedral, named the Corona, or Becket's Crown, lies on the axis of the Trinity chapel. St. Andrew's chapel on the north and St. Anselm's on the south are symmetrically spaced with respect to the Trinity chapel but not with respect to the choir.

Woodhenge is a megalithic monument 3 km from Stonehenge. It is assumed to be of the same age as the early Stonehenge phase of construction (1800 B.C.). It consists of 160 postholes arranged in six concentric symmetrical figures, and is surrounded by ditch and outer bank (*1*). Thom (*2*) made a precise survey of the site (Fig. 2c) and finds that (i) the arcs at the large (major) end have a common center $\alpha$; (ii) the arcs at the small (minor) end have a common center $\beta$; (iii) the distance between the centers $\alpha\beta$ is 6 megalithic yards of 2.72 feet or 0.829 m; (iv) each minor radius is 1 megalithic yard smaller than the major radius; (v) the arcs connecting major and minor ends have a common center at $\gamma$.

Figure 2c shows the triangle $\alpha\beta\gamma$ on one side of the axis only. Circular arcs from $\alpha$ and $\beta$ differing in radius by 1 megalithic yard are connected by an arc from $\gamma$ to form the oval. Arcs from a corresponding point on the other side of the axis (not shown) would complete the oval. The point $\gamma$ must be 1 megalithic yard farther from $\beta$ than from $\alpha$ in order to connect the two ends. If the triangle is a right triangle, the hypotenuse will exceed one side by one unit.

The marvel of Woodhenge is that the triangle $\alpha\beta\gamma$ has the proportions 12, 35, and 37. This makes a perfect Pythagorean triangle, that is, a right triangle having integral sides so that the sum of the square of the two sides equals the square of the hypotenuse, $12^2 + 35^2 = 37^2$. If laid out in megalithic yards, the major and minor radii would differ by 2 megalithic yards. If, how-

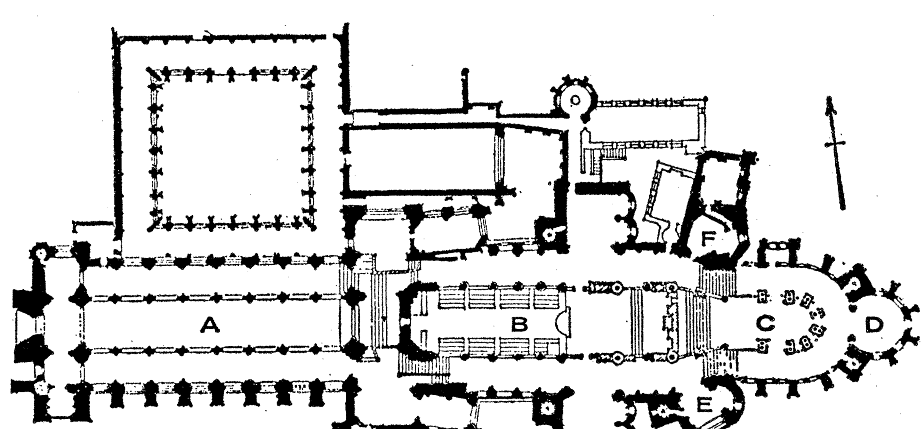


Fig. 1. Canterbury Cathedral. (*A*) Nave; (*B*) choir; (*C*) Trinity chapel; (*D*) Corona; (*E*) St. Anselm's chapel; (*F*) St. Andrew's chapel. [Original drawing from H. Batsford and C. Fry, *Cathedrals of England* (Batsford, London, 1960), p. 43]