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Revised calibration of the geomagnetic polarity timescale for the Late Cretaceous and Cenozoic

S. C. Cande
Scripps Institution of Oceanography, La Jolla, California

D. V. Kent
Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York

Abstract. Recently reported radioisotopic dates and magnetic anomaly spacings have made it evident that modification is required for the age calibrations for the geomagnetic polarity timescale of Cande and Kent (1992) at the Cretaceous/Paleogene boundary and in the Pliocene. An adjusted geomagnetic reversal chronology for the Late Cretaceous and Cenozoic is presented that is consistent with astrochronology in the Pleistocene and Pliocene and with a new timescale for the Mesozoic.

The age of 66 Ma for the Cretaceous/Paleogene (K/P) boundary used for calibration in the geomagnetic polarity timescale of *Cande and Kent* [1992] (hereinafter referred to as CK92) was supported by high precision laser fusion Ar/Ar sanidine single crystal dates from nonmarine strata in Montana. However, these age determinations are now considered to be anomalously old due to problems with sample preparation [*Swisher et al.*, 1992, 1993]. A consensus is developing for an age of 65 Ma for the K/P boundary as recorded in marine [*Swisher et al.*, 1992; *Dalrymple et al.*, 1993] and nonmarine [*Swisher et al.*, 1993] sediments, and the 65 Ma age has been adopted, for example, as an anchor point in the Mesozoic timescale of *Gradstein et al.* [1994].

Astrochronologic control for the geomagnetic polarity timescale has been developed by *Shackleton et al.* [1990] and *Hilgen* [1991] for the Pleistocene and Pliocene to the base of the Thvera polarity subchron (subchron C3n.4n) and has been confirmed to about 3.3 Ma using high-precision Ar/Ar dating [*Renne et al.*, 1993]. The astronochronologic estimates for the Brunhes/Matuyama (0.78 Ma) and Matuyama/Gauss (2.60 Ma) boundaries were already used for calibration in CK92; thus the good agreement of CK92 with the astronomical timescale to the older end of chron C2A (Gauss/Gilbert boundary) is not unexpected. An appreciable discrepancy, however, emerges in the early Pliocene where the astronomical timescale gives ages for the constituent polarity intervals of chron C3n (C3n.1n, C3n.2n, C3n.3n, and C3n.4n, or Cochiti, Nunivak, Sidufjall, and Thvera subchrons, respectively) that are systematically 150 to 180 kyr older than the interpolated ages in CK92. *Wilson* [1993] showed that the astrochronology gives a more consistent seafloor spreading history when applied to his revised spacings of anomalies on several Pacific spreading ridges. This points to the magnetic anomaly spacings for this interval used for interpolation by *Cande and Kent* [1992] as the likely source of the discrepancy and suggests that the available astronochronology provides reliable ages for polarity chrons through the Pliocene (see also *Renne et al.*, 1994).

A revised geomagnetic polarity timescale was generated with 65 Ma rather than 66 Ma for the K/P boundary and an astronomical age of 5.23 Ma [*Hilgen*, 1991] for the older boundary of subchron C3n.4n (the base of the Thvera subchron), rather than 2.60 Ma for the younger boundary of chron C2A (Matuyama/Gauss boundary) used in CK92, for the cubic spline interpolation. Calibration data given in Table 1 are otherwise the same as by *Cande and Kent* [1992]. The ages of Pleistocene and Pliocene polarity intervals, corresponding to subchron C3n.4n and younger subchrons, are then inserted from the astrochronology of *Shackleton et al.* [1990] and *Hilgen* [1991] with a refined astronomical age recently suggested for the Gauss/Matuyama boundary by *Langereis et al.* [1994]. The revised geomagnetic polarity timescale is listed in Tables 2 and 3. These tables supersede Tables 5, 6, and 7, respectively, of *Cande and Kent* [1992].

Table 1. Revised Age Calibrations for Geomagnetic Polarity Timescale

Polarity Chron	South Atlantic Distance, km	Age, Ma
C3n.4n(o)	84.68	5.23*
C5Bn(y)	290.17	14.8
C6Cn.2r(y)	501.55	23.8
C13r(.14)	759.49	33.7
C21n(.33)	1071.62	46.8
C24r(.66)	1221.20	55.0
C29r(.3)	1364.37	65.0†
C33n(.15)	1575.56	74.5
C34n(y)	1862.32	83.0

Position within polarity chron is given as either decimal fraction from younger end, or (o) for older and (y) for younger end of chron.

* Ages for polarity chron C3n.4n(o) and younger are made equivalent to astronomical timescale of *Shackleton et al.* [1990] and *Hilgen* [1991], with refinement of *Langereis et al.* [1994].

† Revised K/P boundary age, see text. Other age calibration data from *Cande and Kent* [1992].

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Table 2. Revised Normal Polarity Intervals

Normal Polarity Interval, Ma	Polarity Chron
0.000 - 0.780	C1n
0.990 - 1.070	C1r.1n
1.770 - 1.950	C2n
2.140 - 2.150	C2r.1n
2.581 - 3.040	C2An.1n
3.110 - 3.220	C2An.2n
3.330 - 3.580	C2An.3n
4.180 - 4.290	C3n.1n
4.480 - 4.620	C3n.2n
4.800 - 4.890	C3n.3n
4.980 - 5.230	C3n.4n
5.894 - 6.137	C3An.1n
6.269 - 6.567	C3An.2n
6.935 - 7.091	C3Bn
7.135 - 7.170	C3Br.1n
7.341 - 7.375	C3Br.2n
7.432 - 7.562	C4n.1n
7.650 - 8.072	C4n.2n
8.225 - 8.257	C4r.1n
8.699 - 9.025	C4An
9.230 - 9.308	C4Ar.1n
9.580 - 9.642	C4Ar.2n
9.740 - 9.880	C5n.1n
9.920 - 10.949	C5n.2n
11.052 - 11.099	C5r.1n
11.476 - 11.531	C5r.2n
11.935 - 12.078	C5An.1n
12.184 - 12.401	C5An.2n
12.678 - 12.708	C5Ar.1n
12.775 - 12.819	C5Ar.2n
12.991 - 13.139	C5AAn
13.302 - 13.510	C5ABn
13.703 - 14.076	C5ACn
14.178 - 14.612	C5ADn
14.800 - 14.888	C5Bn.1n
15.034 - 15.155	C5Bn.2n
16.014 - 16.293	C5Cn.1n
16.327 - 16.488	C5Cn.2n
16.556 - 16.726	C5Cn.3n
17.277 - 17.615	C5Dn
18.281 - 18.781	C5En
19.048 - 20.131	C6n
20.518 - 20.725	C6An.1n
20.996 - 21.320	C6An.2n
21.768 - 21.859	C6AAn
22.151 - 22.248	C6AAr.1n
22.459 - 22.493	C6AAr.2n
22.588 - 22.750	C6Bn.1n
22.804 - 23.069	C6Bn.2n
23.353 - 23.535	C6Cn.1n
23.677 - 23.800	C6Cn.2n
23.999 - 24.118	C6Cn.3n
24.730 - 24.781	C7n.1n
24.835 - 25.183	C7n.2n
25.496 - 25.648	C7An
25.823 - 25.951	C8n.1n
25.992 - 26.554	C8n.2n
27.027 - 27.972	C9n
28.283 - 28.512	C10n.1n
28.578 - 28.745	C10n.2n
29.401 - 29.662	C11n.1n
29.765 - 30.098	C11n.2n
30.479 - 30.939	C12n
33.058 - 33.545	C13n
34.655 - 34.940	C15n
35.343 - 35.526	C16n.1n
35.685 - 36.341	C16n.2n
36.618 - 37.473	C17n.1n
37.604 - 37.848	C17n.2n
37.920 - 38.113	C17n.3n
38.426 - 39.552	C18n.1n
39.631 - 40.130	C18n.2n
41.257 - 41.521	C19n
42.536 - 43.789	C20n
46.264 - 47.906	C21n
49.037 - 49.714	C22n
50.778 - 50.946	C23n.1n
51.047 - 51.743	C23n.2n
52.364 - 52.663	C24n.1n
52.757 - 52.801	C24n.2n
52.903 - 53.347	C24n.3n
55.904 - 56.391	C25n
57.554 - 57.911	C26n
60.920 - 61.276	C27n
62.499 - 63.634	C28n
63.976 - 64.745	C29n
65.578 - 67.610	C30n
67.735 - 68.737	C31n
71.071 - 71.338	C32n.1n
71.587 - 73.004	C32n.2n
73.291 - 73.374	C32r.1n
73.619 - 79.075	C33n
83.000 -118.000	C34n

Table 3. Revised Cryptochrons Identified in Polarity Chrons C1 to C13 and C24 to C28

Interval, Ma	Cryptochron
0.493 - 0.504	C1n-1
1.201 - 1.211	*C1r.2r-1n
2.420 - 2.441	C2r.2r-1
8.635 - 8.651	C4r.2r-1
10.197 - 10.205	C5n.2n-1
10.446 - 10.470	C5n.2n-2
10.710 - 10.726	C5n.2n-3
17.825 - 17.853	C5Dr-1
24.475 - 24.486	C6r-1
25.338 - 25.354	C7r-1
26.347 - 26.359	C8n.2n-1
27.389 - 27.407	C9n-1
27.616 - 27.634	C9n-2
28.118 - 28.130	C9r-1
29.023 - 29.037	C10r-1
29.186 - 29.193	C10r-2
30.278 - 30.292	C11r-1
31.224 - 31.243	C12r-1
31.473 - 31.482	C12r-2
31.844 - 31.863	C12r-3
32.018 - 32.027	C12r-4
32.187 - 32.197	C12r-5
32.446 - 32.465	C12r-6
32.602 - 32.612	C12r-7
32.772 - 32.782	C12r-8
33.266 - 33.283	C13n-1

Table 3. (continued)

Interval, Ma	Cryptochron
33.677 - 33.694	C13r-1
33.877 - 33.885	C13r-2
34.168 - 34.184	C13r-3
34.414 - 34.430	C13r-4
53.550 - 53.558	C24r-1
53.686 - 53.694	C24r-2
53.892 - 53.901	C24r-3
54.031 - 54.040	C24r-4
54.223 - 54.232	C24r-5
54.524 - 54.533	C24r-6
54.757 - 54.766	C24r-7
54.956 - 54.965	C24r-8
55.066 - 55.075	C24r-9
55.286 - 55.296	C24r-10
55.565 - 55.574	C24r-11
56.675 - 56.690	C25r-1
56.833 - 56.849	C25r-2
56.976 - 56.984	C25r-3
57.216 - 57.224	C25r-4
57.361 - 57.377	C25r-5
58.413 - 58.431	C26r-1
58.973 - 58.992	C26r-2
59.179 - 59.189	C26r-3
59.367 - 59.376	C26r-4
59.760 - 59.779	C26r-5
60.098 - 60.107	C26r-6
60.360 - 60.369	C26r-7
63.784 - 63.810	C28r-1

* *Shackleton et al.* [1990] give an age of 1.19 Ma for the Cobb Mt. subchron.

There will undoubtedly be further refinements to the geomagnetic polarity timescale as the results of high-precision radiometric and astronomical dating methods become more widely available in a magnetostratigraphic context. There is already good agreement between the geomagnetic polarity timescale and new radiometric dates at around chron C5 [*Baksi et al.*, 1993; *Baksi*, 1993], chrons C10r and C13r [*McIntosh et al.*, 1992], and chron C33r [*Hicks et al.*, 1995].

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S. C. Cande, Scripps Institution of Oceanography, MC 0215, La Jolla, CA 92091. (e-mail: cande@gauss.ucsd.edu)

D. V. Kent, Lamont-Doherty Earth Observatory, Palisades, NY 10964. (e-mail: dvk@ldgo.columbia.edu)

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