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Archaeological Dating Using a Data Fusion Approach

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ABSTRACT

A new approach for dating archaeological sites is described. The method is inspired by Hapgood's hypothesis that patterns of glaciation and ice ages can be explained by shifts in the geographic location of the North Pole. We have identified over fifty archaeological sites throughout the world that could have once been aligned to north (i.e., to one of these past poles) when the sites were first established but are now misaligned due to subsequent pole shifts. An algorithm is described that fuses the location and orientation of these sites with Hapgood's original climate-dated pole locations to infer the date of construction of the associated sites. The results suggest that these sites may be far older than is currently thought.

1. INTRODUCTION

Evidence throughout the world indicates that human civilizations have a tendency to align important structures to the cardinal directions - north, south, east, and west. Early Chinese cities were oriented to the cardinal directions [1]. Many ancient sites are aligned to north, sometimes with uncanny precision as the pyramids on the Giza plateau in Egypt [2]. The grid patterns of most modern cities are aligned to the cardinal directions. Aveni [3] states that modern cities tend to be built over the sites of earlier settlements, often preserving the original alignments for convenience of construction and notes that the alignments of churches and of planted fields in certain regions of Mexico follow the directions of alignments that had already been established in pre-Columbian times.

There are however some ancient places that are not aligned to true north such as those in Peru's Sacred Valley, most Mesoamerican temples, and certain sites in Europe, northern Africa, the Middle East, and India. A new approach to archaeological dating is described that assumes when these sites were originally established they were aligned to the cardinal directions (i.e., facing the North Pole) at the time but are now misaligned due to subsequent shifts in the location of the North Pole. Over time as these sites fell into ruin, newer structures were built over or around the original structures while preserving the original site orientation.

Paleomagnetic evidence suggests that Earth's poles are moving [4] and have shifted by a considerable amount in the past [5]. We present experimental results that support Hapgood's hypothesis that climate changes and ice ages could be explained by shifts of the geographic pole [6]. Section 2 summarizes his climate-based pole shift hypothesis. After deriving the spherical geometry relating the geo-location of a hypothetical pole, a site, and its orientation (Section 3), we describe an algorithm for estimating pole locations from site data based on minimizing the difference between the orientation of a site and the direction to the pole from the site (Section 4). In Section 5 we use the algorithm to compute four refined past locations of the North Pole from over fifty sites throughout the world. Section 6 summarizes our findings.

2. POLE SHIFTS AND CLIMATE CHANGE

It is generally assumed climate patterns are driven to a large extent by the amount of solar radiation that reaches the Earth. The amount of radiation depends on a combination of factors including changes in the eccentricity in our orbit around the sun, axial tilt or obliquity, axial and apsidal precession, and orbital inclination. The combination of these effects gives rise to what are called Milanković cycles. Although there is extensive evidence that the variation in solar radiation is an important factor, there are certain problems with the Milanković model related to the timing and magnitude of the cycles and their correlation with climate events. Muller and MacDonald [7] suggested the possibility that an external factor such as extraterrestrial accretion of dust or meteoroids could affect climate. Woelfli et al [8] propose that an encounter with a Mars-sized object 11,500 years ago moved the North Pole from Greenland to its present position.

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Hapgood hypothesized that climate changes and ice ages could be explained by shifts of the geographic pole resulting from displacements of the Earth's crust. Hapgood presented evidence suggesting that during the last ice age the North Pole was located at around 60° N, 83° W, near Hudson Bay in Canada. Citing climate data from a variety of sources, he reasoned that North America, which was then covered by a massive layer of ice and snow, was colder because it had been shifted closer to the pole, while places on the opposite side of the Earth, such as Europe, were warmer because they had been shifted away from the pole and south toward the equator. By examining patterns of climate change, Hapgood estimated that three pole shifts had taken place during the past 100,000 years: 1) from Hudson Bay (60˚N 73˚W) to the current pole, 12,000 to 17,000 years ago, 2) from the Atlantic Ocean between Iceland and Norway (72˚N 10˚E) to Hudson Bay, 50,000 to 55,000 years ago, and 3) from the Yukon (63˚N 135˚W) to between Iceland and Norway 75,000 to 80,000 years ago.

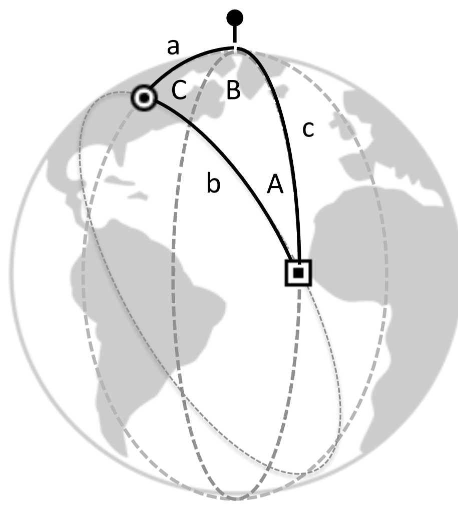


Figure 1 Site A, current pole B, and previous pole C are vertices of a spherical triangle. The angle A is the azimuth of the previous pole at the site. Segments of spherical triangles are great circles.

3. SPHERICAL GEOMETRY

With reference to Figure 1, let A, B, and C to be the locations of a site, the current North Pole, and a hypothesized pole, respectively. If (λ_A, φ_A) and (λ_C, φ_C) are the latitudes and longitudes of the site and hypothesized pole, define the angles

$$\begin{aligned} a &= \frac{\pi}{2} - \lambda_C, \\ c &= \frac{\pi}{2} - \lambda_A \\ B &= \varphi_C - \varphi_A \end{aligned} \tag{1}$$

We wish to solve for the angle A (the azimuth angle of the hypothetical pole from the site) as a function of the locations of A and C on the sphere. Starting with the sine and cosine rules for spherical triangles:

$$\frac{\sin A}{\sin a} = \frac{\sin B}{\sin b} = \frac{\sin C}{\sin c} \tag{2}$$

and

$$\cos b = \cos a \cos c + \sin a \sin c \cos B \tag{3}$$

since $\sin b = \sqrt{1 - \cos^2 b}$,

$$\sin A = \frac{\sin a \sin B}{\sin b} = \frac{\sin a \sin B}{\sqrt{1 - \cos^2 b}} \tag{4}$$

$$A = \sin^{-1}\left[\frac{\sin a \sin B}{\sqrt{1 - (\cos a \cos c + \sin a \sin c \cos B)^2}}\right] \tag{5}$$

4. ALGORITHM FOR DETERMINING POLES FROM ALIGNED SITES

Let $\mathcal{A}$ be a set of N sites that may be aligned to a hypothetical pole, where $\lambda_A(n)$, $\varphi_A(n)$, and $\theta_A(n)$ are the latitude, longitude, and orientation of the n-th site. The orientation of a site can be represented by the principal direction of rectangular structures, a major axis or an axis of symmetry, or extended linear features (Figure 2).

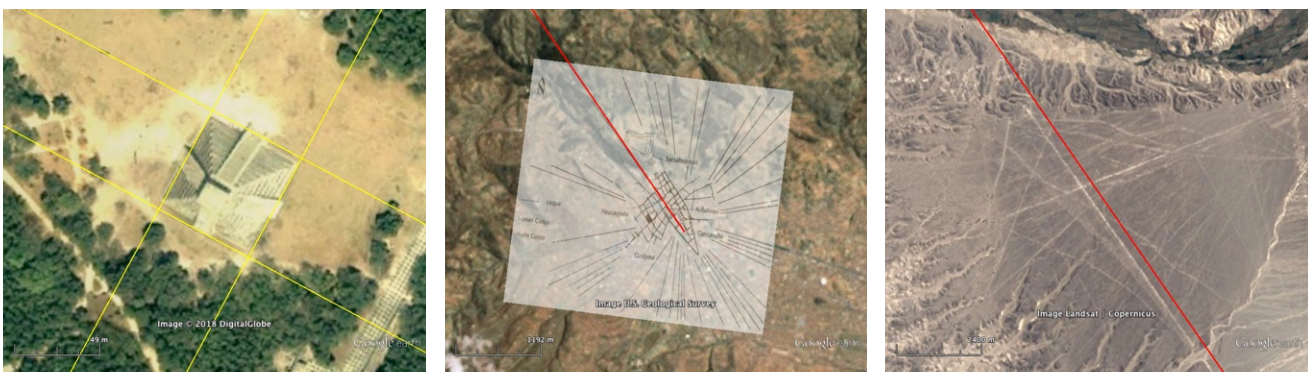


Figure 2 Determining site alignments: from a rectangular object such as the Pyramid of Quetzalcoatl at Chichen Itza (left), the axis of symmetry of the city of Cuzco (center), and one of the Nazca lines (right).

A direct method of determining the location of a pole or some other reference point on the surface of the Earth is to construct a great circle through each site that is aligned to structures or features at the site. Great circles through sites that are aligned with the pole will intersect at the pole (Figure 3). Define

$$d(i,j,n) = \langle A(i,j,n) - \theta_A(n) \rangle \tag{6}$$

to be the difference (modulo 2π) between the orientation of the n-th site and the direction of a pole at location $\lambda_C(j), \varphi_C(i)$ according to (5). For a single site, the image is that of a great circle. For N sites, taking the minimum difference over all the sites

$$d_{min}(i,j) = \min_{n \in \mathcal{A}} \{d(i,j,n)\} \tag{7}$$

produces an image of great circles (Figure 4a).

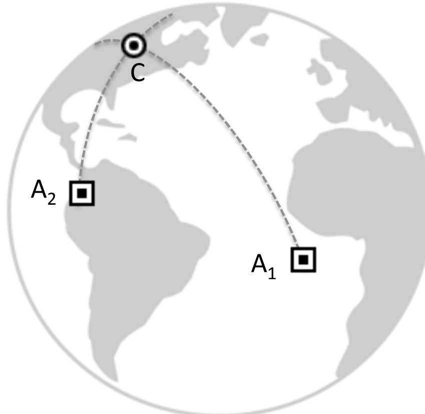


Figure 3 Poles are located at the intersection of great circles.

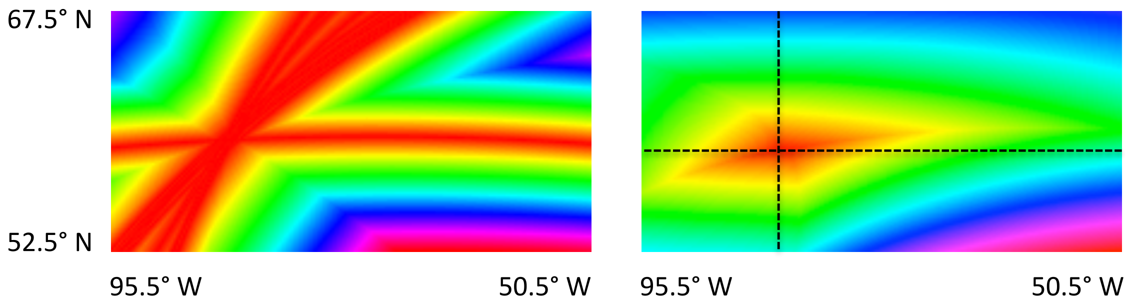


Figure 4 Difference images based on a) the max difference across sites (left) and b) the min difference across sites (right). The smallest differences are colored red and the largest differences are violet.

The pole is determined by finding the intersection of great circles. A simpler method is to assume that a pole exists somewhere within a region $\mathcal{C}$. The maximum difference across all N sites is

$$d_{max}(i,j) = \max_{n \in \mathcal{A}}\{d(i,j,n)\} \tag{8}$$

Finding pole locations can thus be reduced to the simpler problem of finding the location that minimizes (8)

$$(\lambda_C^*, \varphi_C^*) = \underset{(i,j) \in \mathcal{C}}{\operatorname{argmin}}\{d_{max}(i,j)\} \tag{9}$$

.
that is illustrated in Figure 4b for the case of Hapgood's Hudson Bay pole as discussed in the next section.

5. EXPERIMENTAL RESULTS

Four sets of fusion results are presented. We start with sites that lie in the general direction of a pole Hapgood determined to have existed before 12,000-17,000 years ago near 60°N 73°W east of Hudson Bay (Table 1). A search for a pole that is consistent with the site locations and orientations in the table reveals a minimum max difference location at 59.75°N 78°W with a minimum max difference alignment error $d^* = d(\lambda_C^*, \varphi_C^*)$ of 0.23°. Figure 5 shows the color-coded max difference image and the minimum max difference location with meridians to the sites in the table. The ancient city of Teotihuacan in Mexico is one of the sites in Table 1 that is aligned to the Hudson Bay pole.

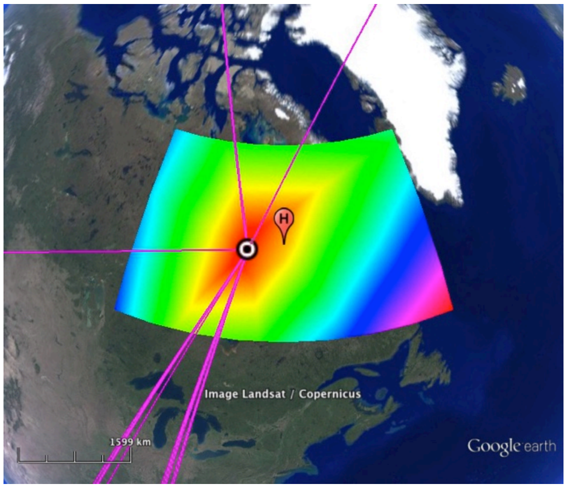
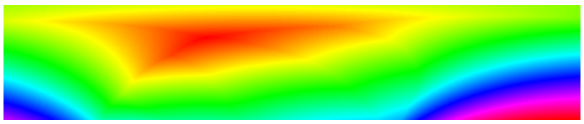


Figure 5 Hudson Bay pole max difference image (left). One meridian with respect to the Hudson Bay pole is aligned with the Pyramid of the Sun at Teotihuacan in Mexico (right). Google Earth.

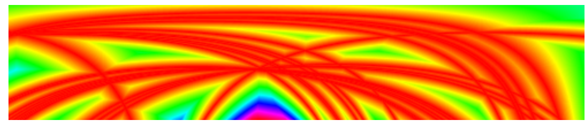
Table 1 Sites aligned to Hudson Bay pole.

Site	Name	Latitude	Longitude	Orientation
1	Xochicalco	18.803889	-99.295917	15.43
2	Altun Ha	17.76395	-88.347061	7.60
3	Tikal	17.222094	-89.623614	8.60
4	Copán	14.84	-89.14	7.65
5	Calakmul	18.105392	-89.810829	8.80
6	Teotihuacan	19.6925	-98.843889	15.60
7	Tula	20.064451	-99.3405	15.47
8	Tiatelolco	19.450994	-99.13751	15.42
9	Tenango	19.108425	-99.597693	15.71
10	Palenque	17.483978	-92.04632	10.10
11	Uxmal	20.359444	-89.771389	9.20
12	El Tajín	20.448058	-97.378242	14.50
13	Ha'amonga 'a Maui Trilithon	-21.136606	-175.048087	32.70
14	Shri Martand Sun Temple	33.745588	75.220286	-13.90
15	Rameshwar Mandir	16.21768	73.462012	-14.00

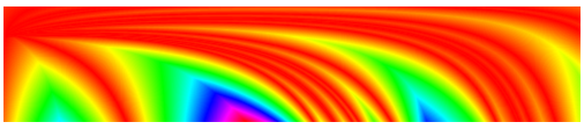
Hapgood hypothesized that an earlier pole existed between Greenland and Europe at 72°N 10°W before 50,000 to 55,000 years ago. We located 27 sites that appeared to be oriented roughly in this direction. As was done previously, starting with Hapgood's pole, we were able to compute a refined location based on the max difference (Figure 6a), however, the difference in orientation angles was quite large, more than 9°. By examining the min difference image, multiple poles were evident (Figure 6b). Splitting the sites into groups revealed the existence of two distinct poles (Figure 6c,d). The first group of sites (Table 2) includes places such as the Parthenon in Athens, Greece that face a pole in northern Greenland (Figure 7) located at 79.5°N 63.75°W. The average alignment error of these sites to the Greenland pole is 0.18°.



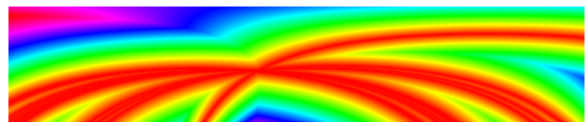
a) Max difference image for all 26 sites



b) Min difference image for all 26 sites



c) Min difference to one subset of sites



d) Min difference to the other sites

Figure 6 Refining Hapgood's Norway Sea pole.

Table 2 Sites aligned to Greenland pole.

Site	Name	Latitude	Longitude	Orientation
1	Tower of Babel	32.536284	44.420803	-11.30
2	The Parthenon	37.971517	23.72659	-13.50
3	Temple of Jupiter	34.006694	36.203826	-12.20
4	Western Wall	31.776657	35.23447	-12.10
5	Layer Pyramid	29.93282	31.161262	-12.00
6	Teti Pyramid	29.875142	31.221847	-12.50
7	Ahu Tahai	-27.140076	-109.427314	8.30
8	Nan Madol	6.844537	158.335795	7.00
9	Cuicuilco	19.301021	-99.183798	7.00
10	Chalcatzingo	18.676715	-98.770783	6.80
11	Tenochtitlan	19.435	-99.131389	7.00
12	Palenque	17.483978	-92.04632	5.40
13	Monte Alban	17.042122	-96.768184	6.45

Figure 7 Greenland pole max difference image (left). Meridian with respect to Greenland pole is aligned with the Parthenon and other features on the Acropolis in Athens, Greece (right). Google Earth.

The second set of sites (Table 3) includes places such as Chichen Itza in Mexico that face a pole in the Norway Sea located at 70°N 0°W, not far from Hapgood's original pole. The average alignment error of these sites to the Norway Sea pole is 0.12°.

Table 3 Sites aligned to Norway Sea pole.

Site	Name	Latitude	Longitude	Orientation
1	Nazca Lines	-14.712825	-75.17485	19.3
2	Chan Chan	-8.103554	-79.07076	19.5
3	Caral	-10.893458	-77.52054	19.5
4	Atlantic Grid	31.276114	-24.052242	12.1
5	Brihadisvara Temple	10.782614	79.131735	-20.02
6	Tazumal	13.98	-89.67	20.56
7	Cholula	19.06	-98.30	20.58
8	Coba	20.49	-87.74	21.14
9	Comalcalco	18.28	-93.20	20.83
10	El Tepozteco	19.00	-99.10	20.66
11	Palenque	17.48	-92.05	20.75
12	Chichen Itza	20.68	-88.57	21.12
13	Acatitlan	19.55	-99.17	20.45
14	Tulum	20.21	-87.43	21.29

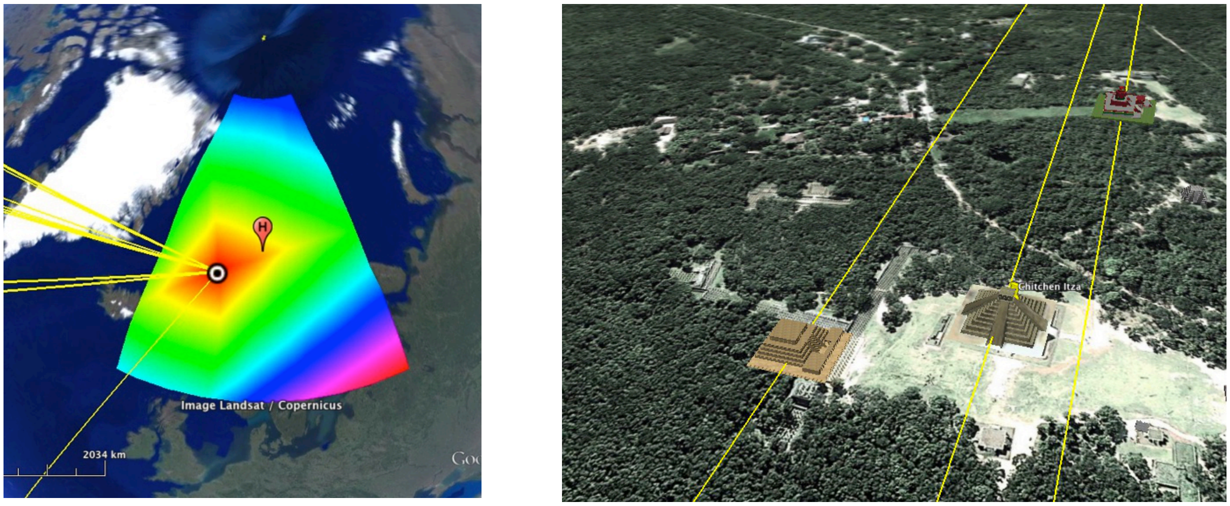
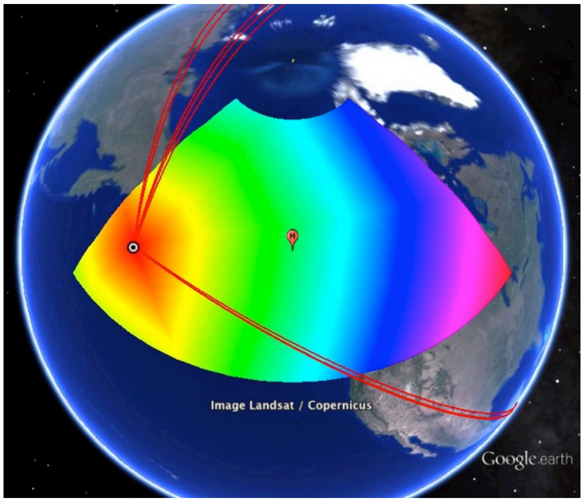


Figure 8 Norway Sea pole max difference image (left). Meridian with respect to Norway Sea pole is aligned with the Pyramid of Quetzalcoatl and other features at Chichen Itza (right). Google Earth.

Hapgood made one more climate-based prediction that an ancient pole once existed somewhere in Alaska near 63°N 135°W perhaps as far back as 75,000 to 80,000 years ago. Using the sites in Table 4 that face this general direction we estimated a refined pole location in the Bering Sea north of the Aleutian Islands at 56.25°N 176.75°W (Figure 9). The average alignment error of these sites to the Bering Sea pole is 0.24°.

Table 4 Sites aligned to Bering Sea pole.

Site	Name	Latitude	Longitude	Orientation
1	Temple of the Sun	-13.257536	-72.267129	-35.00
2	Temple of the Three Windows	-13.163592	-72.545414	-34.70
3	Chincana Labyrinth	-15.990127	-69.202952	-35.00
4	Nazca Lines	-14.712825	-75.17485	-34.70
5	Tomb of Agamemnon	37.726725	22.754367	10.50
6	Knossos	35.297863	25.163092	11.80
7	Temple of the Winged Lions	30.330297	35.442554	17.50
8	Amun Temple (Siwa)	29.201375	25.516151	12.00
9	Amun Temple (Dangeil)	18.131307	33.9598	16.50
10	Golden Temple	31.619938	74.876511	33.20



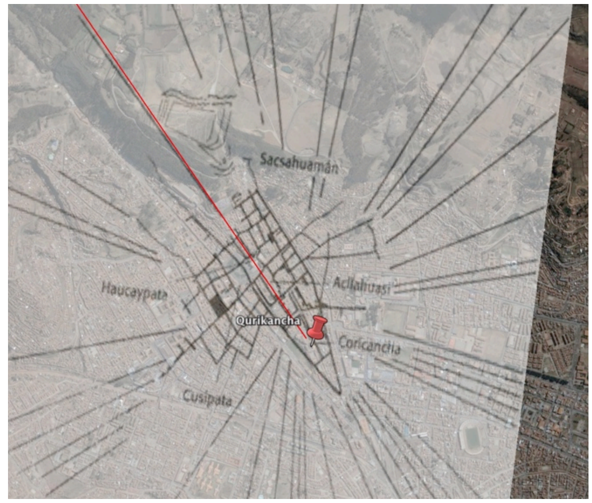


Figure 9 Bering Sea pole max difference image (left). Meridian with respect to Bering Sea pole is aligned with the City of Cuzco (right) as well as numerous sites in Peru's Sacred Valley. Google Earth.

6. DISCUSSION

The average alignment error of the sites in Tables 1-4 to their corresponding pole locations is less than 0.2°. Appendix A estimates random alignment probabilities in the range from one in 10^{-12} to one in 10^{-21}. Archaeologists have been unable to determine why many of these sites are aligned as they are. Our hypothesis that they were originally aligned to previous locations of the North Pole provides a simple and compelling explanation of their layout and proposes a new vastly more ancient dating that challenges conventional theories.

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APPENDIX A - ALIGNMENT PROBABILITY MODEL

Assuming a site can face any direction, the probability that a site is aligned to within δ degrees of a pole is δ/π. The probability that N independent sites are aligned to a pole is $(\delta/\pi)^N$. Figure 10 plots a family of curves. The alignment errors for sites aligned to the Hudson Bay, Greenland, Norway Sea, and Bering Sea poles are 0.23°, 0.18°, 0.12°, and 0.24°. The probabilities that 15, 13, 14, and 10 sites are aligned to these poles are on the order of 10^{-19}, 10^{-17}, 10^{-21}, and 10^{-12}, respectively. The probability that so many sites are aligned to these poles is exceedingly small.

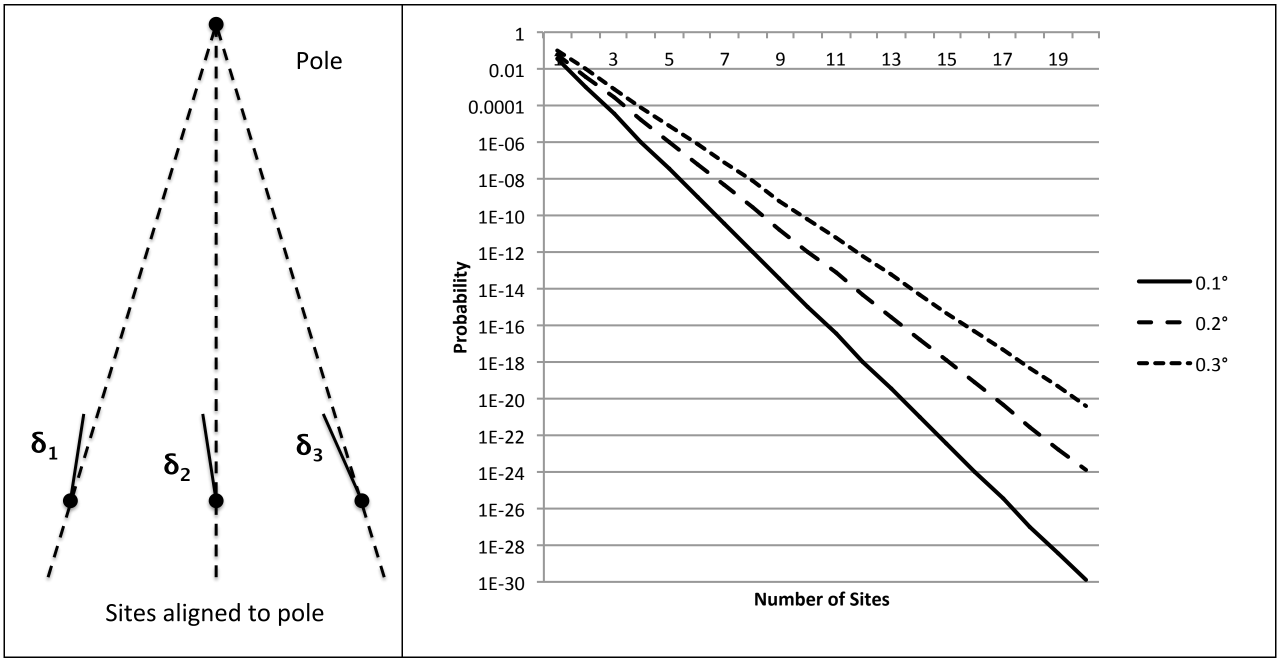

Figure 10 Site alignment probability analysis