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RESEARCH ARTICLE

A New Model to Explain the Alignment of Certain Ancient Sites

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Abstract—In a previous study of more than two hundred ancient sites, the alignments of almost half of the sites could not be explained. These sites are distributed throughout the world and include the majority of Mesoamerican pyramids and temples that are misaligned with respect to true north, megalithic structures at several sites in Peru's Sacred Valley, some pyramids in Lower Egypt, and numerous temples in Upper Egypt. A new model is proposed to account for the alignment of certain unexplained sites based on an application of Charles Hapgood's hypothesis that global patterns of climate change over the past 100,000 years could be the result of displacements of the Earth's crust and corresponding shifts of the geographic poles. It is shown that more than 80% of the unexplained sites reference four locations within 30° of the North Pole that are correlated with Hapgood's hypothesized pole locations. The alignments of these sites are consistent with the hypothesis that if they were built in alignment with one of these former poles they would be misaligned to north as they are now as the result of subsequent geographic pole shifts.

Keywords: ancient sites; pyramid alignment; pole shifts

INTRODUCTION

In a previous study of ancient sites, the alignments of almost half of the sites could not be explained (Carlotto, 2020). These sites, which are distributed throughout the world, include the majority of Mesoamerican pyramids and temples that are misaligned with respect to true north, megalithic structures at several sites in Peru's Sacred Valley, some pyramids in Lower Egypt, and numerous temples in Upper Egypt. From a

review of the archaeological and archaeoastronomical literature, eight basic reasons were identified that typically account for the orientation of an archaeological site: 1) to cardinal directions (i.e. facing north, south, east, and west), 2) to solstice sunrise or sunset directions, 3) to sunrise or sunset directions on days when the sun passes directly overhead, 4) to directions of major and minor lunar standstills, 5) to a planet, 6) to a star or constellation, 7) to magnetic north, and 8) in the direction of a site of religious or spiritual importance. We also considered other explanations such as landscape and topography that have been used in some cases to account for the alignment of certain sites. For example, Shaltout and Belmonte (2005) analyzed the orientation of more than one hundred temples in Upper Egypt and Lower Nubia to discover that they face many different directions. Their principal conclusion is that local topography (the course of the Nile), not astronomy, was the most important factor in aligning the foundations of the temples.

This paper proposes a new model to explain the alignment of certain sites throughout the world based on an application of Charles Hapgood's hypothesis that patterns of climate change over the past 100,000 years could be the result of displacements of the Earth's crust and corresponding shifts of the geographic poles. The next section discusses the origin of the idea of geographic pole shifts, how information about the motion of the geo-magnetic poles over time suggests that large shifts of geographic poles have occurred in the past, and possible relationships between geographic pole shifts and climate change. The following section describes a new model to explain the alignment of sites to previous pole locations based on an application and refinement of Hapgood's original pole shift hypothesis. Results are organized into eight geographic regions. It is shown that more than 80% of the unexplained sites in our previous study (Carlotto, 2020) reference at least one of these previous pole locations.

GEOGRAPHIC POLE SHIFTS AND CLIMATE CHANGE

Early in the 20th century, Alfred Wegener and others theorized that the continents were once a single large landmass that broke up and slowly drifted apart. Wegener's theory of continental drift explained the complementary shape of coastlines—how the west coast of Africa seems to

fit the east coast of the Americas—and the similarity in rock formations and fossils along matching coastlines. This theory, now known as plate tectonics, divides the outer layer of the crust, called the lithosphere, into a number of plates that move independently of one another over a less rigid layer called the asthenosphere (Kious & Tilling, 1996). Holmes (1944) proposed that the Earth's mantle contains convection cells that dissipate interior heat and move the crust at the surface, thus providing a physical mechanism to drive plate motion. Inspired by Wegener's work, Milanković (1932) investigated the movement of the poles that he believed worked together with plate motion so that "the displacement of the pole takes place in such a way that . . . Earth's axis maintains its orientation in space, but the Earth's crust is displaced on its substratum."

The earth's axis of rotation intersects the surface at the north and south geographic poles, which are currently located in the Arctic and Antarctic. The flow of liquid metal in the outer core generates electric currents. The rotation of earth on its axis causes these electric currents to induce a magnetic field. The location of the magnetic poles slowly wanders in a seemingly random manner around the geographic poles. Rocks, sediment, and archaeological artifacts that contain magnetic minerals such as magnetite record the direction and intensity of Earth's magnetic field when they are heated above the Curie temperature. When a paleomagnetic material cools, magnetic information is retained by the mineral grains. By collecting and analyzing samples at different times and in different places, it is possible to estimate the location of the magnetic poles (paleopoles) as a function of time.

Kirschvink et al. (1997) determined from paleomagnetic data collected in Australia and North America that a massive crustal shift occurred between 534 million and 505 million years ago, which caused Australia to rotate a quarter of the way around the globe. This shift occurred around the time of the Cambrian Explosion, when most groups of animals first appear in the fossil record, and is thought to have been a major factor in the evolutionary changes that later took place. Woodworth and Gordon (2018) used paleomagnetic and ocean sediment data to show that Greenland was much closer to the North Pole 12–48 million years ago than it is today. Daradich et al. (2017) estimate a steady shift of Earth's poles by ~8° over the last 40 million

years toward Greenland has brought North America to increasingly higher latitudes and caused its climate to gradually cool over this period of time.

If polar motion affects climate, the converse may also be true. Prior to the year 2000, the North Pole was slowly moving toward Hudson Bay, at which time it changed direction and began to drift toward Greenland. Chen at al. (2013) claim that the change in direction was caused by the accelerated melting of the Greenland Ice Sheet. Adhikari and Ivins (2016) argue that polar motion is influenced by changes in the amount of water held within the continents. Although these factors appear to control the direction of polar motion, they do not appear sufficient to account for its magnitude. Adhikari et al. (2018) have come to the conclusion that mantle convection, which drives plate tectonics, also seems to be a significant factor affecting polar motion.

It is generally assumed that climate patterns are driven to a large extent by the amount of solar radiation reaching 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 (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 Milanković's model as it relates to the timing and magnitude of the cycles and their correlation with climate events. Muller and MacDonald (1997) suggest the possibility that an external factor such as extraterrestrial accretion of dust or meteoroids could affect climate. It has been hypothesized that the Younger Dryas period of rapid cooling in the late Pleistocene, 12,800 to 11,500 years ago, could have had an extraterrestrial cause such as the Taurid meteor swarm (Napier, 2010). Woelfli et al. (2002) propose that an encounter with a Mars-sized object at around this time moved the North Pole from Greenland to its present position.

SHIFTED GEOGRAPHIC POLE SITE ALIGNMENT MODEL

Hapgood (1958) hypothesized that climate changes and ice ages could be explained by large sudden shifts of the geographic pole. He cites extensive evidence suggesting that during the last ice age the North

TABLE 1
Estimated Locations of the North Pole

Name	Latitude	Longitude
Hudson Bay	59.75°	–78.0°
Greenland	79.5°	–63.75°
Norwegian Sea	70.0°	– 0°
Bering Sea	56.25°	–176.75°

Pole was located at around 60° N, 83° W, near Hudson Bay in Canada. Using climate data from a variety of sources, Hapgood 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, he estimated that three geographic 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.

Rand Flem-Ath noted that if the North Pole were in Hudson Bay, the major axis of Teotihuacan, an ancient Mesoamerican city 25 miles northeast of modern-day Mexico City, which is currently oriented 15.4° east of north, would be aligned to within a few degrees of due north (Wilson & Flem-Ath, 2000). Motivated by this observation, more than fifty sites not aligned to north were identified that could have once been aligned to one of Hapgood's hypothesized pole locations. An algorithm was developed that used the orientation (azimuth) angle and geographic coordinates of these sites measured in Google Earth to estimate a set of hypothetical "best-fit" pole locations (Carlotto, 2019). Table 1 lists the four hypothetical locations of the North Pole computed by this algorithm. The estimated Hudson Bay pole location is less than 200 miles from Hapgood's original Hudson Bay pole. If the North Pole

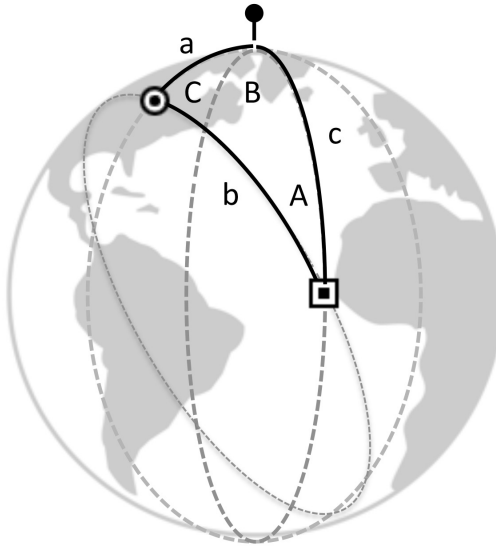


Figure 1. The locations of a site A, North Pole B, and previous pole C are the vertices of a spherical triangle. Segments of spherical triangles are great circles. The angle A is the azimuth of the previous pole location measured at the site.

were at that location, Teotihuacan would be aligned to the cardinal directions. The estimated pole in northern Greenland is 1,250 miles west of Hapgood's original Iceland/Norway pole, and the estimated pole in the Norwegian Sea is about 300 miles south of it. A fourth computed pole location is in the Bering Sea north of the Aleutian Islands, about 1,500 miles from Hapgood's original Yukon pole.

With reference to Figure 1, let A be the location of a site, B the current location of the North Pole, and C the location of the North Pole at the time the site was first established. The angle A is the current alignment of the site with respect to north. A shift in the geographic pole causes both the latitude as well as the orientation of a site to change. If (λ_A, ϕ_A) and (λ_C, ϕ_C) are the latitudes and longitudes of the site and past pole in the current geographic reference frame, the orientation (rotation) angle of the site is

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

where

$$\alpha = \frac{\pi}{2} - \lambda_c$$
$$c = \frac{\pi}{2} - \lambda_A \qquad (2)$$
$$B = \varphi_C - \varphi_A$$

Its latitude prior to the pole shift would have been 90° – λ_C where

$$\lambda_C = \cos^{-1}(\cos a \cos c + \sin a \sin c \cos B) \qquad (3)$$

By comparing the orientation angle of a site measured using Google Earth to Equation 1, it is possible to determine if the site could have once faced north. In addition, by substituting previous pole values from Equation 1 and Equation 3 into the solar and lunar alignment equations (Carlotto, 2020), it is possible to determine if the site was aligned to solstices, zenith passages, or lunar standstills relative to those poles.

RESULTS: SITES ALIGNED TO PREVIOUS POLE LOCATIONS

Tables 2–9 indicate the alignments for more than two hundred ancient sites to the current (Arctic Ocean) pole, and former estimated Hudson Bay, Greenland, the Norwegian Sea, and Bering Sea pole locations. The sites are organized into eight geographic regions. The key to the alignments is as follows:

Cardinal directions, i.e., geographic poles, and equinoxes (E)
Magnetic pole at the time of construction (X)
Zenith passage (Z)
Solstices (S)
Major and minor lunar standstills (M,m)
Stellar alignments (st)
Alignments to "Sacred Directions" (D)

Only six of the eight alignment hypotheses were examined for the shifted poles, as there is insufficient information to evaluate "st", and "D" would not be affected by a crustal displacement.

TABLE 2
Alignments of Sites in Africa

Name	Latitude	Longitude	North	East	Current	Hudson Bay	Greenland	Norway Sea	Bering Sea
Algeria, Jabal Lakhdar	35.063404	1.183731	-5	85				E	
Egypt, Abu Rawash, Pyramid of Djedefre	30.032262	31.074714	0	90	E				
Egypt, Abusir, Pyramid of Neferefre	29.89377	31.201454	0	90	E				
Egypt, Abusir, Pyramid of Neferirkare	29.895093	31.202249	0	90	E				
Egypt, Abusir, Pyramid of Sahure	29.897622	31.203367	0	90	E				
Egypt, Abydon, Temple Ramses II	26.186426	31.91628	44.2	134.2				S	
Egypt, Abydos, Osirion	26.184099	31.918465	36.3	126.3		S			
Egypt, Abydos, Pyramid of Ahmose I	26.175056	31.937822	36	126		S			
Egypt, Abydos, Temple Seti I	26.184968	31.919183	36.3	126.3		S			
Egypt, Cairo, Mosque of Ibn Tulun	30.028691	31.249394	-39	51					
Egypt, Dahshur Pyramid of Senusret III	29.818888	31.22555	0	90	E				
Egypt, Dahshur, Bent Pyramid	29.790449	31.209324	0	90	E				
Egypt, Dahshur, Pyramid of Amenemhat II	29.805807	31.223038	0	90	E				
Egypt, Dahshur, Red Pyramid	29.808882	31.206113	0	90	E				
Egypt, Deir Bahari, Mortuary Temple of Mentuhotep II	25.737375	32.606178	23.2	113.2	S				
Egypt, Deir el Medinah, Temple of Hathor	25.728846	32.602128	-40	50			S		
Egypt, Dendara, Sacred Lake	26.14180698	32.66953166	16.1	106.1					E
Egypt, Dendera, Temple of Hathor	26.141914	32.670205	18.9	108.9	st,m			S	
Egypt, Edfu Temple of Horus	24.976747	32.873087	12.8	102.8				M	
Egypt, Elephantine, Temple of Khnum	24.084492	32.886206	-42	48			M		
Egypt, Giza, Khafre	29.975726	31.1308	0	90	E				
Egypt, Giza, Khufu	29.979067	31.13404	0	90	E				
Egypt, Giza, Menkaure	29.975811	31.131242	0	90	E				
Egypt, Kom Ombo	24.452085	32.928353	43.3	133.3		m		S	
Egypt, Lisht, Pyramid of Amenemhat I	29.574802	31.225304	0	90	E				
Egypt, Lisht, Pyramid of Senusret I	29.56016	31.22113	0	90	E				
Egypt, Luxor West, Temple Ramses III	25.719683	32.600711	-42	48			M		
Egypt, Luxor, Karnak, Temple of Amun Re	25.718484	32.659044	26.6	116.6	S				
Egypt, Meidum Pyramid	29.388368	31.157503	0	90	E				
Egypt, Pyramid of Teti	29.875142	31.221847	-12.5	77.5			E		
Egypt, Saqqara, Mastaba of Shepseskaf	29.838852	31.215273	0	90	E				
Egypt, Saqqara, Pyramid of Djedkare-Isesi	29.850983	31.220924	0	90	E				
Egypt, Saqqara, Pyramid of Djoser	29.87139735	31.21653162	5	95					
Egypt, Saqqara, Pyramid of Khendjer	29.832363	31.224043	0	90	E				
Egypt, Saqqara, Pyramid of Pepi II	29.840246	31.213496	0	90	E				
Egypt, Saqqara, Pyramid of Qakare Ibi	29.84159	31.217712	-10	80			E		
Egypt, Saqqara, Pyramid of Unas	29.868182	31.215012	0	90	E				
Egypt, Saqqara, Pyramid Userkaf	29.873332	31.219334	0	90	E				
Egypt, Shunet El Zebib	26.18951	31.908055	-41.7	48.3				m	
Egypt, Siwa Oasis, Amun Temple	29.201375	25.516151							E
Egypt, Temple of Edfu	24.978092	32.873475	3	93					
Egypt, Temple of Esna	25.29344448	32.55612504	-23	67	M				
Egypt, Temple of Hathor, El Kab	25.138586	32.828651	-44	46			M		
Egypt, Temple of Isis at Shenhur	25.86104	32.776808	10	100				M	
Egypt, Temple of Ramses II	25.727588	32.610283	41	131				S	
Egypt, Zawyet El Aryan, Layer Pyramid	29.93282	31.161262	-12	78			E		
Ethiopia, Bete Giyorgis	12.031714	39.04119	5.8	95.8	m				
Ethiopia, Yeha Temple	14.28570335	39.01911389	11.4	101.4				m	
Sudan, Dangeil, Amun Temple	18.131307	33.9598	16.5	106.5			S		E

E = cardinal directions, i.e. geographic poles and equinoxes. M, m = major and minor lunar standstills. S = solstices. st = stellar alignments. If no alignment is given, the reason is unknown. In some cases, there may be more than one explanation for an alignment.

TABLE 3
Alignments of Sites in Asia

Name	Latitude	Longitude	North	East	Current	Hudson Bay	Greenland	Norway Sea	Bering Sea
Cambodia, Koh Ker	13.78322	104.5374528	-12.5	77.5	Z				
Cambodia,Preah Khan of Kompong Svay	13.40382	104.75421	-28.2	61.8	M				
China, Chongling Mausoleum of Emperor Dezong of Tang	34.70738	108.82853	-4.2	85.8	x				
China, Jinling Mausoleum of Emperor Xianzong of Tang	34.570992	108.265923	-9	81	x				
China, The Lianhu Altar	36.632869	101.746123	15.8	105.8	S				
China, Tomb of Consort Ban	34.379801	108.704492	-11	79					
China, Tomb of Emperor Ai of Han	34.400855	108.764606	0	90	E				
China, Tomb of Emperor Cheng of Han	34.374896	108.698001	-10	80	x				
China, Tomb of Emperor Gaozu of Han	34.434691	108.876647	-14	76					
China, Tomb of Emperor Hui of Han	34.422895	108.841317	-17	73					
China, Tomb of Emperor Jing of Han	34.443823	108.940784	0	90	E				
China, Tomb of Emperor Ping of Han	34.397774	108.712421	0	90	E				
China, Tomb of Emperor Wen of Sui	34.28785	108.02289	-3	87	x				
China, Tomb of Emperor Wu of Han	34.338085	108.569684	-8	82	x				
China, Tomb of Emperor Xuan of Han	34.181063	109.022312	0	90	E				
China, Tomb of Emperor Yuan of Han	34.390303	108.739114	0	90	E				
China, Tomb of Emperor Zhao of Han	34.361753	108.640108	-11	79	x				
China, Tomb of Empress Dou	34.235825	109.118614	22.6	112.6	m				
China, Tomb of Empress Dowager Bo	34.220993	109.096341	21.6	111.6	m				
China, Tomb of Empress Fu	34.402608	108.772545	-4	86	x				
China, Tomb of Empress Li	34.340327	108.562002	-9.5	80.5	x				
China, Tomb of Empress Lü	34.433824	108.881292	-10.2	79.8	S				
China, Tomb of Empress Shangguan	34.363135	108.630538	-8	82	x				
China, Tomb of Empress Wang (a)	34.393242	108.733835	0	90	E				
China, Tomb of Empress Wang (b)	34.446291	108.9475	0	90	E				
China, Tomb of Empress Wang (c)	34.178951	109.028396	0	90	E				
China, Tomb of Empress Xu (a)	34.374648	108.68474	-9.5	80.5	x				
China, Tomb of Empress Xu (b)	34.12734	109.055786	0	90	E				
China, Tomb of Empress Zhang Yan	34.423195	108.836961	-15	75					
China, Tomb of Marquis Zhang Ao	34.427745	108.851209	-15	75					
China, Tomb of Princess Chengyang of Emperor Taizong	34.6156	108.49314	-6	84	x				
China, Tomb of Princess Xincheng of Emperor Taizong	34.62365	108.49888	-21	69					
China, Yarnaz Valley,Yarkhoto	42.952022	89.061138	-40	50	M				
India, Amritsar, Golden Temple	31.619938	74.876511	33.2	123.2	M				E
India, Chidambaram, Chidambaram Nataraja	11.399234	79.693715	-1	89	E				
India, Chitoor, Srikalahasti Temple	13.749686	79.698308	0	90	E				
India, Kanchipura, Ekambareswarar Temple	12.847302	79.699525	18.3	108.3	m				
India, Khadirbet, Dholavira	23.88690735	70.21377639	-5	85					
India, Madhya Pradesh, Sas Bahu Temple	16.018856	75.881959	-4	86			Z		
India, Madhya Pradesh, Tigawa Temple	23.690196	80.066918	-10	80			E		
India, Mahabalipuram, Shore Temple	12.616492	80.199267	13	103	Z	S			
India, Rameshwar Mandir	16.21768	73.462012	-14	76		E			
India, Shri Martand Sun Temple	33.745588	75.220286	-13.9	76.1		E			
India, Sigiriya	7.957173	80.760031	8.3	98.3	Z				S
India, Tamil Nadu					E,S,Z				
India, Thanjavur, Brihadisvara Temple	10.782614	79.131735	-20.5	69.5	st,m				
India, Tiruvannamalai, Annamalaiyar Temple	12.231884	79.06679	11.4	101.4	Z				
India, Udaipur Rajasthan, Sas Bahu Temple	24.735191	73.716283	-16	74		E			
India, Venkateswara Temple	13.68325	79.347195	-7	83			E		
Indonesia, Gunung Padang	-6.994518	107.056383	-20	70				E	
Inner Mongolia, Xanadu	42.356388	116.184304	0	90	E				
Japan, Osaka Castle	34.687298	135.525826	5.7	95.7			E		
Maldives, Thinadhoo	0.530107	72.99717	43	133	D				
Pakistan, Harappa	30.628104	72.863909	0	90	E				
Russia Por-Bazhyn	50.615271	97.384872	9.5	99.5				S	
Thailand Angkor Wat	13.412469	103.866986	0	90	E				
Thailand, Ayutthaya, Wat Phra Mahathat	14.356943	100.567509	-5.3	84.7	x				
Thailand, Kao Klang Nai, Sri Thep	15.465521	101.144681	9.5	99.5			Z		
Thailand, Prasat Hin Phimai	15.22093	102.493861	-22	68				E	
Thailand, Prasat Mueang Tam	14.496089	102.982608	-11	79				Z	
Thailand, Prasat Phanom Rung	14.532044	102.940223	-5.5	84.5	x				
Thailand, Prasat Si Khoraphum	14.944574	103.798352	0	90	E				
Thailand, Wat Phra Sri Rattana Mahathat	14.798673	100.613862	0	90	E				

D = "sacred directions". E = cardinal directions, i.e. geographic poles and equinoxes. M,m = major and minor lunar standstills. S = solstices. st = stellar alignments. X = magnetic pole at the time of construction. Z = zenith passage. If no alignment is given, the reason is unknown. In some cases, there may be more than one explanation for an alignment.

TABLE 4
Alignments of Sites in Europe

Name	Latitude	Longitude	North	East	Current	Hudson Bay	Greenland	Norway Sea	Bering Sea
Bosnia, Pyramid of the Sun	43.977259	18.176514	8.4	98.4					E
Greece, Athens, The Parthenon	37.971517	23.72659	-13.5	76.5			E		
Greece, Delphi Amphitheater	38.482477	22.500577	-38.2	51.8	D	E			
Greece, Knossos	35.297863	25.163092	11.8	101.8			m		E
Greece, Mycenae, Lion Gate	37.73075184	22.7564996	-40	50		E			
Greece, Mycenae, Tomb of Agamemnon	37.726725	22.754367	10.5	100.5			m		E
Greece, The Temple of Artemis	37.949611	27.363921	21	111					
Italy, Rome, Circus Maximus	41.885944	12.485215	36.7	126.7	M				
Italy, Rome, Palantine Hill	41.889209	12.487459	36.7	126.7	M				
Italy, Sardinia, Monte d'Accoddi	40.79075445	8.448907568	9.1	99.1				M	Z
Malta, Gozo, Ġgantija Temple	36.04726	14.269015	37	127	M				
Spain, Mosque-Cathedral of Cordoba	37.878906	-4.779387	-30.4	59.6	S				
Spain, Naveta d'Es Tudons	40.00307541	3.891652768	-19.2	70.8	m				
Turkey, Hagia Sophia	41.01314018	28.98318202	34.3	124.3	S				
Turkey, Hattusa	40.01994347	34.61545489	38	128	M	S		m	m
UK, Calanais Standing Stones	58.197566	-6.745127							
UK, Glastonbury Tor	51.144444	-2.698611	-26.5	63.5	m				
UK, Stonehenge	51.178868	-1.826163			S,M,m				

D = “sacred directions”. E = cardinal directions, i.e. geographic poles and equinoxes. M,m = major and minor lunar standstills. S = solstices. If no alignment is given, the reason is unknown. In some cases, there may be more than one explanation for an alignment.

TABLE 5
Alignments of Sites in North America

Name	Latitude	Longitude	North	East	Current	Hudson Bay	Greenland	Norway Sea	Bering Sea
Canada, AB, Badlands Guardian	50.01037	-110.113133			E				
US, California, Blythe Intaglios, B1	33.800585	-114.532055	0	90	E				
US, California,Blythe Intaglios, B3	33.800402	-114.538078	29	119		E			
US, Georgia, Ocmulgee National Monument	32.838868	-83.606114	34	124	M				
US, New Mexico, Chaco Canyon, Pueblo del Arroyo	36.060854	-107.9663	24	114	M				
US, Ohio, Great Serpent Mound	39.02642	-83.431091	27.7	117.7	S				
US. Illinois, Cahokia, Monks Mound	38.660158	-90.062466			S,M				

E = cardinal directions, i.e. geographic poles and equinoxes. M = major lunar standstills. S = solstices. In some cases, there may be more than one explanation for an alignment.

TABLE 6
Alignments of Sites in the Pacific Ocean

Name	Latitude	Longitude	North	East	Current	Hudson Bay	Greenland	Norway Sea	Bering Sea
Chile,Easter Island, Ahu Akivi	-27.115014	-109.395043	-2.7	87.3	E				
Chile,Easter Island, Ahu Nau Nau	-27.074425	-109.322455	-19.6	70.4	m				
Chile,Easter Island, Ahu Tahai	-27.140076	-109.427314	8.3	98.3			E		
Chile,Easter Island, Ahu Tongariki	-27.125774	-109.276933	30	120	S				
Chile,Easter Island, Ahu Vinapu	-27.174098	-109.405737	8.1	98.1			E		
Micronesia, Nan Madol	6.844537	158.335795	-33	57	M		E		
Micronesia, Nan Madol, Temple of Nan Dawas	6.844537	158.335795	7	97	Z		E		
Samoa, Pulemelei Mound	-13.735237	-172.324399	-7.3	82.7					
Tonga, Ha'amonga 'a Maui Trilithon	-21.136606	-175.048087	32.7	122.7		E			

E = cardinal directions, i.e. geographic poles and equinoxes. M,m = major and minor lunar standstills. S = solstices. Z = zenith passage. If no alignment is given, the reason is unknown. In some cases, there may be more than one explanation for an alignment.

TABLE 7
Alignments of Sites in the Middle East

Name	Latitude	Longitude	North	East	Current	Hudson Bay	Greenland	Norway Sea	Bering Sea
Iran, Chogha Zanbil	32.00899687	48.5215934	-43.5	46.5		m	M	m	S
Iraq, Dur-Kurigalzu	33.35367069	44.20216381	-39.6	50.4				S	M
Iraq, Tower of Babel	32.536284	44.420803	-11.3	78.7			E		
Iraq, Ziggurat of Ur	30.962711	46.103126	-33.3	56.7	M				
Jerusalem, Dome of the Rock	31.778087	35.235306	-7.3	82.7	D				
Jerusalem, Western Wall	31.776657	35.23447	-12.1	77.9			E		
Jordan, Petra, Temple of the Winged Lions	30.330297	35.442554	17.5	107.5					E
Jordan, Qasr Il-Abd, Irak Al-Amir	31.912785	35.751941	-15	75				E	
Jordan, Umayyad Mosque in Amman	33.51159288	36.3066567	-6.4	83.6					Z
Lebanon, Baalbek, Temple of Jupiter	34.006694	36.203826	-12.2	77.8			E		
Saudi Arabia, Mecca, Kaaba	21.42251	39.826174	-34.9	55.1	M				
Turkey, Harran	36.865021	39.031565	9.6	99.6			m		
Yemen, Great Mosque of Sana'a	15.353123	44.214876	-25	65	M				

D = "sacred directions." E = cardinal directions, i.e. geographic poles and equinoxes. M,m = major and minor lunar standstills. S = solstices. Z = zenith passage. In some cases, there may be more than one explanation for an alignment.

TABLE 8
Alignments of Sites in South America

Name	Latitude	Longitude	North	East	Current	Hudson Bay	Greenland	Norway Sea	Bering Sea
Bolivia, Chincana Labyrinth	-15.990127	-69.202952	44	134	D			S	
Bolivia, Puma Punku	-16.56172	-68.680046	2	92			E		
Bolivia, Quenuani	-16.259407	-69.17127	-20	70	S		S		
Bolivia, Tiwanaku	-16.554933	-68.673487	2	92			E		
Peru, Caral-Supe	-10.893458	-77.52054	19.5	109.5	S				
Peru, Caral-Supe, Huanca Pyramid	-10.893458	-77.52054	19.5	109.5				E	
Peru, Chan Chan	-8.103554	-79.07076	19.5	109.5	m			E	
Peru, Chavin	-9.594527	-77.177002	14.7	104.7	D				
Peru, Cuzco	-13.518587	-71.975952							E
Peru, Huanuco Pampa	-9.875388	-76.816395	0	90	E				
Peru, Huayna Picchu, Temple of the Moon	-13.151931	-72.546507			M				
Peru, La Centinela	-13.45007514	-76.17223285	5.6	95.6				Z	
Peru, Machu Picchu, Temple of the Three Windows	-13.163592	-72.545414	-34.7	55.3					E
Peru, Machu Picchu, Terraces	-13.164219	-72.544831	-25	65		S			
Peru, Marcahuasi, Face	-11.77567	-76.581853	43	133	D			S	
Peru, Nazca Lines	-14.712825	-75.17485	19.3	109.3	D			E	E
Peru, Ollantaytambo, Temple of the Sun	-13.257536	-72.267129	-35	55					E
Peru, Sacsahuaman	-13.50933	-71.980916			D				
Peru, Sechin Bajo	-9.4648088	-78.26525923	-25.5	64.5	S				
Peru, Warawtampu	-10.46549	-76.536647	-24.2	65.8	D				
Peru. Chotuna	-6.720363	-79.952796	0	90	E				

D = "sacred directions." E = cardinal directions, i.e. geographic poles and equinoxes. M,m = major and minor lunar standstills. S = solstices. Z = zenith passage. In some cases, there may be more than one explanation for an alignment.

Of the 95 unexplained sites identified in our initial study, the shifted pole model is able to explain all but 17 of the alignments. 62 sites face one of the previous pole locations, 21 to solstices, and 21 to lunar standstills that reference previous pole locations. In some cases a site had more than one alignment; e.g., Knossos appears to be both

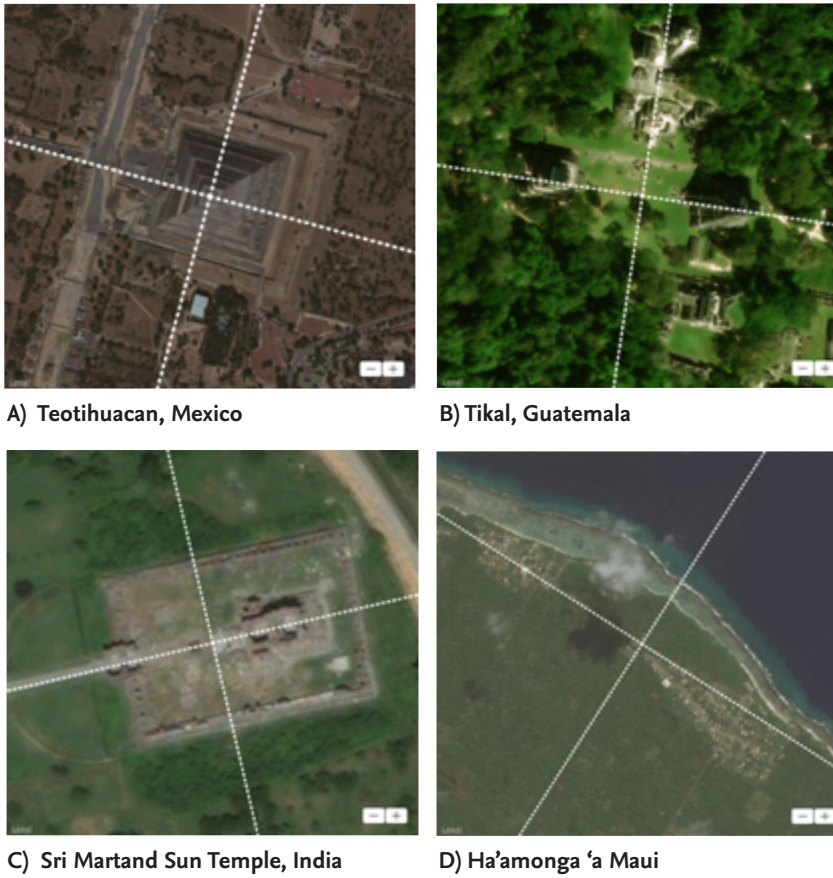
TABLE 9
Alignments of Sites in Mesoamerica

Name	Latitude	Longitude	North	East	Current	Hudson Bay	Greenland	Norway Sea	Bering Sea
Belize, Altun Ha, Sun God Pyramid	17.76395	-88.347061	7.6	97.6		E			
Belize, Xunantunich	17.088922	-89.141631	-10.3	79.7	D				
El Salvador, Tazumal	13.979547	-89.674131	18	108	m				
Guatemala, Mixco Viejo	14.871668	-90.664167	12.5	102.5	D	E			
Guatemala, Tikal	17.222094	-89.623614	8.6	98.6		E			
Guatemala, Yaxchilan	16.899655	-90.967093	30.4	120.4	D				
Honduras, Copan, Step Pyramids	14.84	-89.14			Z				
Mexico, Acatitlan	19.55	-99.17	20.3	110.3	Z			E	
Mexico, Alta Vista	23.478544	-103.945607				S,M,m			
Mexico, Bonampak	16.704	-91.065	38	128			M		
Mexico, Calakmul	18.105392	-89.810829	8.8	98.8		E			
Mexico, Calixtlahuaca	19.335038	-99.69757	-30	60	M				
Mexico, Chalcatzingo	18.676715	-98.770783	6.8	96.8			E		
Mexico, Chichen Itza	20.68	-88.57	21	111	M,Z			E	
Mexico, Chimalacatlan, C1	18.446236	-99.105878	-34.7	55.3	M				E
Mexico, Chimalacatlan, C2	18.444804	-99.104331	28.7	118.7	m				S
Mexico, Cholula	19.0583048	-98.30190553	25	115	S				
Mexico, Coba, Grand Pyramid	20.492974	-87.724195	-39	51		M			
Mexico, Comalcalco	18.27819958	-93.20032665	24	114	S				
Mexico, Cuauhtinchan Archeological Site, Cuauhcalli	18.9535	-99.502888	15.4	105.4	m				
Mexico, Cuicuilco	19.301021	-99.183798							
Mexico, El Cerrito Archaological Zone	20.551376	-100.444027	7.4	97.4			E		
Mexico, El Tajin, Pyramid of the Niches	20.448058	-97.378242	14.5	104.5		E			
Mexico, El Tajin, Southern Ballcourt	20.448058	-97.378242	0	90	E				
Mexico, El Tajin, Tajin Chico	20.448058	-97.378242	40	130					
Mexico, El Tepozteco	19.00078611	-99.1015579	26	116	m				
Mexico, La Venta	18.103191	-94.040946	-12.2	77.8	D				
Mexico, Mayapan	20.629823	-89.46059							
Mexico, Mitla	16.92704923	-96.35934812	12	102		E			
Mexico, Monte Alban	17.042122	-96.768184	6.45	96.45			E		
Mexico, Monte Alban, Building J	17.042122	-96.768184	-43	47	st				
Mexico, Palenque, North Group	17.483978	-92.04632	10.1	100.1		E			
Mexico, Palenque, Temple of the Inscriptions	17.48	-92.05	20.6	110.6				E	
Mexico, Tenango	19.108425	-99.597693	14	104		E			
Mexico, Tenochtitlan	19.435	-99.131389	7	97			E		
Mexico, Teotihuacan	19.6925	-98.843889	15.6	105.6	st	E			
Mexico, Tiatelolco	19.450994	-99.13751	8.5	98.5					
Mexico, Tula	20.064451	-99.3405	15.47	105.47	m				
Mexico, Tulum	20.21	-87.43	22.3	112.3				E	
Mexico, Uxmal, Palace of the Governors	20.359444	-89.771389	30	120	S				
Mexico, Uxmal, Pyramid of the Magician	20.359444	-89.771389	9.2	99.2		E			
Mexico, Uxmal, Templo Mayor	20.359444	-89.771389	19.6	109.6	Z			E	
Mexico, Xochicalco, Grand Pyramid	18.803889	-99.295917	0	90	E				
Mexico, Xochicalco, Temple of Quetzalcoatl	18.803889	-99.295917	15.4	105.4		E			

D = “sacred directions.” E = cardinal directions, i.e. geographic poles and equinoxes. M,m = major and minor lunar standstills. S = solstices. st = stellar alignments. Z = zenith passage. If no alignment is given, the reason is unknown. In some cases, there may be more than one explanation for an alignment.

cardinally aligned to the Bering Sea pole and aligned to minor lunar standstills relative to the Greenland pole.

Figure 2 shows 4 of the 18 sites found that face the Hudson Bay pole. All of Teotihuacan is aligned to the Hudson Bay pole, as are structures in Tikal’s North Acropolis. The Sri Martand Sun Temple in India does not currently face the sun, but if it were originally built when the North Pole was in Hudson Bay it would have been aligned as many sun temples are to the cardinal directions at that time. An extended area



A) Teotihuacan, Mexico

B) Tikal, Guatemala

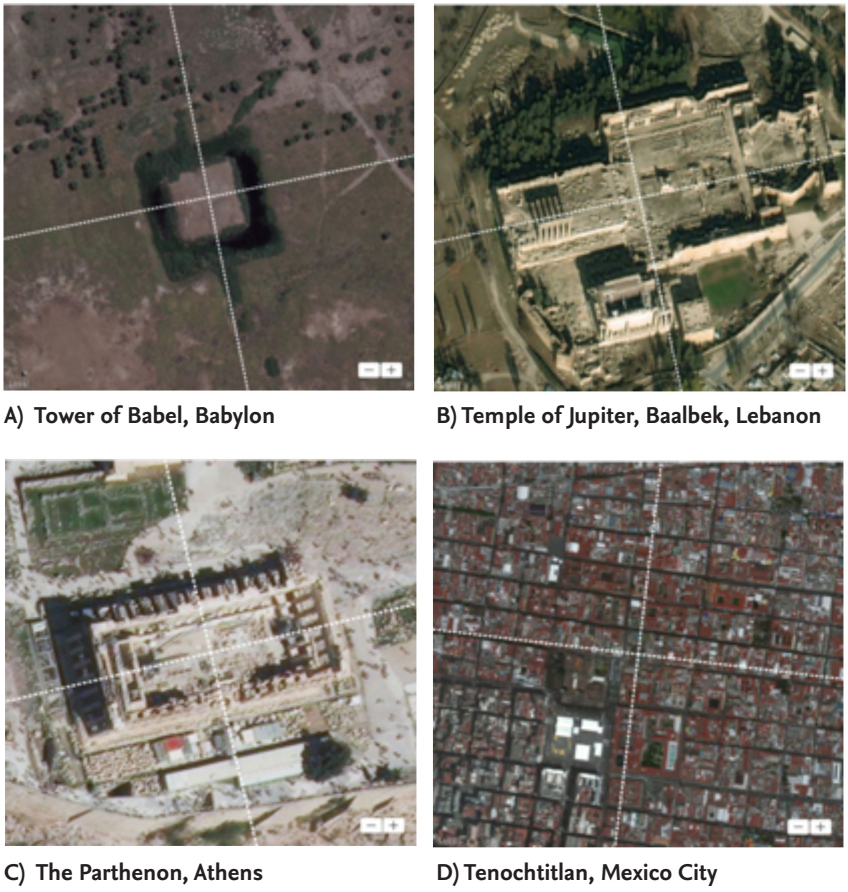
C) Sri Martand Sun Temple, India

D) Ha'amonga 'a Maui

Figure 2. Examples of sites aligned to the Hudson Bay pole. Photo credit: Apple Maps.

on the island of Tonga surrounding the Ha'amonga 'a Maui Trilithon also is oriented in the direction of the Hudson Bay pole.

Twenty sites were found that face the Greenland pole. Four of the sites are shown in Figure 3. The Temple of Jupiter at Baalbek was built by the Romans over an earlier pre-Roman structure (Lohmann, 2010). Similarly, the Parthenon atop the Acropolis in Athens was built over an earlier Parthenon (Beard, 2010). Hannah (2013) reviews Dinsmoor's analysis of the Parthenon and concludes that on August 31, 488 BCE, Athena's "birthday," the sun would have risen north of east along the main axis of the temple. But how do we know when Athena, a goddess,



A) Tower of Babel, Babylon

B) Temple of Jupiter, Baalbek, Lebanon

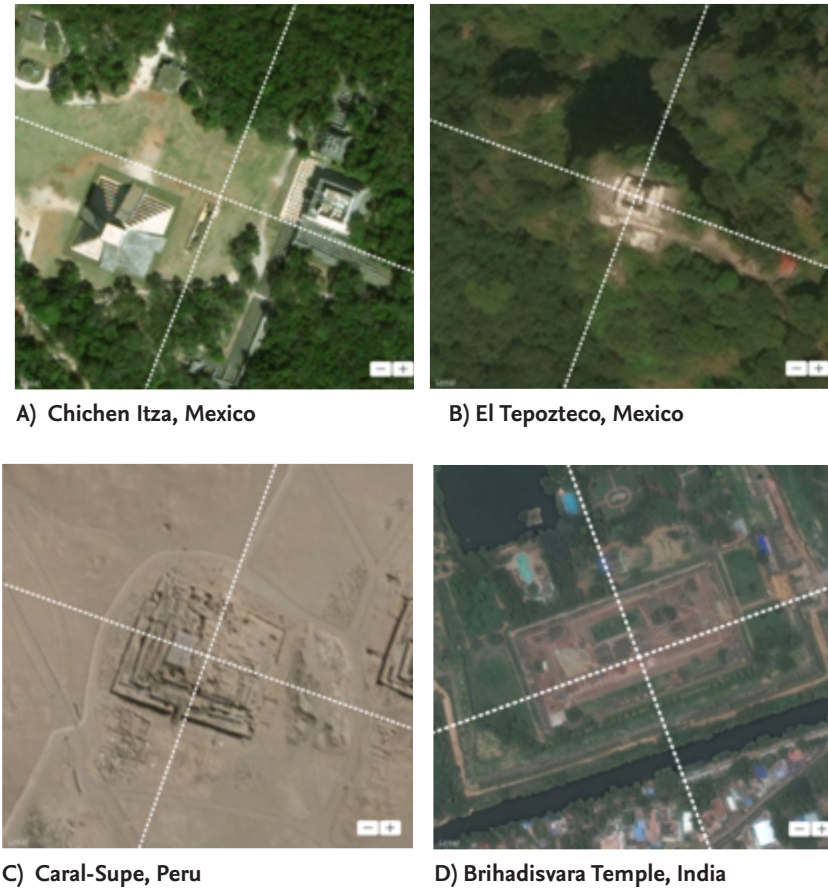
C) The Parthenon, Athens

D) Tenochtitlan, Mexico City

Figure 3. Examples of sites aligned to the Greenland pole. Photo credit: Apple Maps.

the daughter of Zeus, was born? Was the Parthenon aligned with the sunrise on Athena's birthday, or was the date of Athena's birthday established based on the preexisting orientation of the Parthenon? And was this orientation, along with other structures on the Acropolis, originally directed toward an ancient pole in Greenland?

Chichen Itza and El Tepozteco in Mexico, Caral Supe in Peru, and the Brihadisvara Temple in India are 4 of the 12 sites found that face the Norwegian Sea pole (Figure 4). Southwest of the Temple of Quetzalcoatl



A) Chichen Itza, Mexico

B) El Tepozteco, Mexico

C) Caral-Supe, Peru

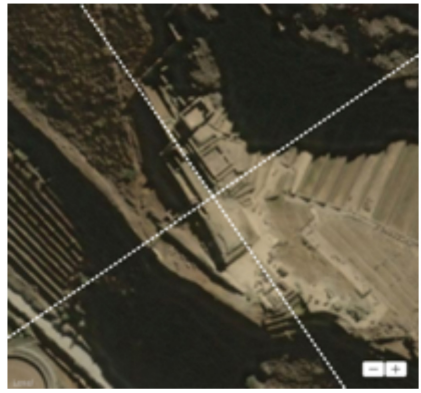
D) Brihadisvara Temple, India

Figure 4. Examples of sites aligned to the Norwegian Sea pole. Photo credit: Apple Maps.

at Chichen Itza, the Caracol is a dome-shaped structure thought to have been an observatory aligned to celestial events, including the summer and winter solstice sunrises and sunsets and the setting of the planet Venus. If this were its intended purpose, why are the Caracol, as well as the Temple of Quetzalcoatl and numerous other structures at Chichen Itza, all oriented in a decidedly non-solar direction, approximately 21.5° east of north, in the direction of the Norway pole?

Figure 5 shows 4 of the 12 sites that have been found to be

A) Nazca line, Peru



B) Temple of the Sun, Ollantaytambo, Peru

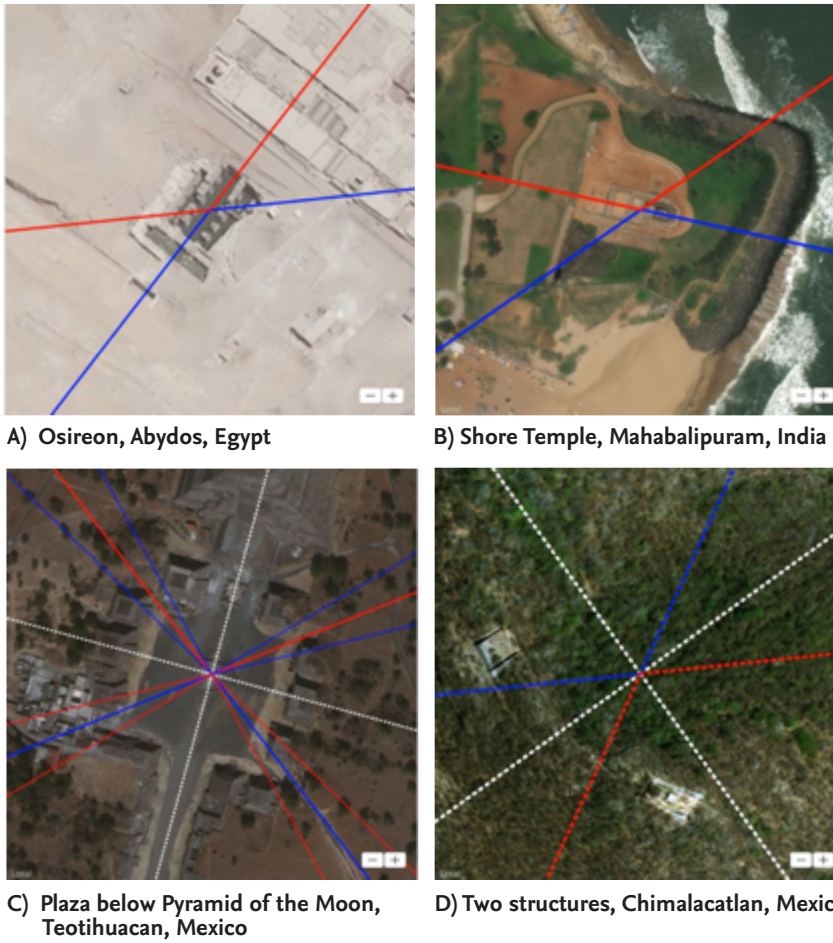
C) Knossos, Crete

D) Temple of the Winged Lions, Petra, Jordan

Figure 5. Examples of sites aligned to the Bering Sea pole. Photo credit: Apple Maps.

aligned to the Bering Sea pole. One of the major Nazca lines is in the direction of the pole (another is in line with the Norwegian Sea pole). The Temple of the Sun at Ollantaytambo in Peru and the Temple of the Three Windows at Machu Picchu are aligned to the Bering Sea pole as are Knossos in Crete and the Temple of the Winged Lions in Petra, Jordan. The direction of the Bering Sea pole is also closely aligned with a pattern of lines called ceques emanating out from the City of Cuzco.

In addition to sites aligned to the cardinal directions, the shifted pole alignment model accounts for 42 previously unexplained sites that could once have been aligned to solstices and to lunar standstills. Four



A) Osireon, Abydos, Egypt

B) Shore Temple, Mahabalipuram, India

C) Plaza below Pyramid of the Moon, Teotihuacan, Mexico

D) Two structures, Chimalacatlan, Mexico

Figure 6. Examples of other sites that reference previous pole locations. Pairs of solid lines are the summer and winter solstice alignments. Dotted lines are lunar standstill directions. **A)** is aligned to the summer solstice sunrise/winter solstice sunset relative to the Hudson Bay pole. **B)** is aligned to the winter solstice sunrise/summer solstice sunset relative to the Hudson Bay pole. **C)** shows solar and lunar alignments relative to the Hudson Bay pole. **D)** is aligned to cardinal directions and major lunar standstills relative to the Bering Sea pole. Photo credit: Apple Maps.

of the sites are shown Figure 6. The Osireon in Abydos is thought to have been an integral part of Seti I's funerary temple yet it was originally built at a considerably lower level than the foundations of the temple (Petrie & Murray, 1903). It is not currently aligned in any direction

of astronomical significance. According to our proposed model, the Osireon would be aligned to solstices if the North Pole were in Hudson Bay. This is also the case for the Shore Temple in Mahabalipuram, India. At Teotihuacan, the Pyramid of the Moon, the Pyramid of the Sun, the Temple of Quetzalcoatl, and the Avenue of the Dead all are aligned in the direction of the Hudson Bay pole. Numerous other structures in the plaza south of the Pyramid of the Moon that do not now reference any obvious astronomical events would have been aligned to solstices and lunar standstills at that time. Structures at Chimalacatlan in Mexico (Vigato, 2015) also appear to reference the Bering Sea pole.

Figure 7 plots the distribution of site alignments within the eight geographic regions versus pole location. Although the sample size is somewhat limited, certain patterns are evident. There are far more sites in Africa and Asia that are currently aligned to the cardinal directions than to any other direction at any other time. Over time, the number of sites appears to have increased in Mesoamerica and decreased in South America. Most of the sites in these regions were aligned to the cardinal directions. On the other hand, most sites in Europe and the Middle East were aligned to the moon. Where sites exist from the time of the Bering Sea pole to the present in six of the eight regions, there are no sites in the Pacific before the Greenland pole or in North America before the Hudson Bay pole.

DISCUSSION

Aveni (1980) 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 planted fields in certain regions of Mexico follow the directions of alignments that had already been established in pre-Columbian times. Our hypothesis is that, over time, as certain sites fell into ruin, they were rebuilt and expanded, and new structures were added above and/or around them consistent with the original site plan. What remains today thus indicates the original alignment of the site. In sites that contain both cardinally aligned and non-aligned structures there might not be obvious differences between the two if the older non-aligned structures were rebuilt or built over at the same time new cardinally aligned structures were added. Perhaps deeper excavations at these

Figure 7. Distributions of alignments within all eight geographic regions. Each graph plots the number of equinox (E), solstice (S), and lunar standstill (M) alignments relative to the current geographic pole (C), and the four hypothesized prior pole locations in Hudson Bay (HB), Greenland (G), the Norwegian Sea (NS), and the Bering Sea (BS).

sites would provide further evidence of the antiquity of the non-aligned structures.

The proposed shifted geographic pole alignment model explains

many archeoastronomical enigmas including the distributions of temple and pyramid alignments in Mesoamerica and previously unexplained alignments of certain megalithic structures at Baalbek, Abydos, Machu Picchu, Ollantaytambo, and in other places. In analyzing the alignment of archaeological sites in Mexico, Aveni and Hartung conclude that an eastern skew was a standard architectural practice over a wide area in Mexico (Aveni, 2001). By accounting for the alignment of all but four of the Mesoamerican sites examined, the shifted pole model explains the reason for the skew.

The geographic pole shift hypothesis also provides a plausible explanation for the apparent lack of astronomical alignments of temples in Upper Egypt (Shaltout & Belmonte, 2005) that is in stark contrast to the precise alignment of numerous pyramids in Lower Egypt to the cardinal directions. As shown in Figure 8, there are more structures in Lower Egypt that are aligned to the current geographic pole than in Upper Egypt. Conversely there are more structures in Upper Egypt that are aligned to previous geographic pole locations than in Lower Egypt. A geographic pole shift from Hudson Bay to the Arctic would have rotated this part of the world approximately 30° (Figure 9) and displaced a considerable amount of water likely inundating low-lying areas along the Mediterranean Sea including Lower Egypt. A sudden shift of the crust would likely have triggered numerous earthquakes along fault lines. The temples in Upper Egypt lie in the Nile River valley far from large open bodies of water and several hundred miles west of the nearest tectonic plate. Perhaps by virtue of their more protected location, structures aligned to previous poles in Upper Egypt survived the crustal displacement and are therefore more numerous than those in Lower Egypt that were likely destroyed at the time.

That a model capable of explaining the alignment of so many archaeological sites that cannot otherwise be explained is itself predicted on Hapgood's unproven hypothesis, is problematic. It is possible that one day Hapgood's hypothesis may be verified by new discoveries in the earth sciences much like Wegner's theory of continental drift was. Although the idea that pole shifts were caused by an asymmetrical buildup of polar ice was rejected at the time, Hapgood's collaborator, J. H. Campbell, developed a model that showed how materials rising out of / sinking into the lithosphere create imbalances in the mass distribution of the crust such that an area of increasing mass has the effect of

A) Alignments to current geographic pole **B) Alignments to previous geographic poles**

Figure 8. Comparison of the number of sites in Lower Egypt (top of each map) and Upper Egypt (bottom of each map) aligned to the current geographic pole A) and previous hypothesized pole locations B).
A) There are 4 sites aligned to the current geographic pole in Upper Egypt and 20 sites in Lower Egypt.
B) There are 3 sites aligned to previous geographic poles in Lower Egypt and 13 sites in Upper Egypt. Photo credit: Google Maps.

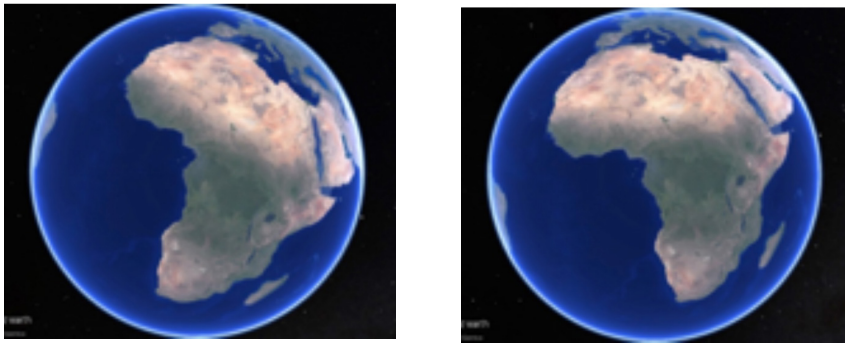


Figure 9. If the North Pole were in Hudson Bay (left), Europe and Africa would be rotated approximately 30° clockwise relative to their current position (right). Photo credit: Google Earth.

rotating the crust toward the equator and an area of decreasing mass has the opposite effect of rotating the crust toward the pole (Hapgood, 1958). The Tharsis formation on Mars is an example of how a large mass imbalance is thought to have shifted the Martian poles 20° approximately 3.5 billion years ago (Bouley et al., 2016). Kirschvink et al. (1997) hypothesized that the movement of continental landmasses about a half billion years ago shifted Earth's North Pole by 90°.

As noted earlier, Chen at al. (2013) showed that small changes in the weight distribution of the crust caused by climate change induce small changes in the movement of the geographic pole. The current sizes of the Antarctic and Greenland ice sheets are approximately 1.3 x 10^{19} kg and 2.7 x 10^{18} kg, respectively, which are two or more orders of magnitude smaller than Tharsis (10^{21} kg). Twenty thousand years ago the Greenland Ice Sheet is estimated to have been almost ten times larger (Blue Marble, 2017) and could have been much thicker. When the mass of the Greenland Ice Sheet was comparable to that of Tharsis, large changes in it could have resulted in large changes in the movement of the Earth's geographic pole.

In his dismissal of theories of ancient civilizations, Brass (2002) states that there is no paleomagnetic evidence for Earth crustal displacements having occurred. As noted earlier, Kirschvink et al. (1997) concluded from paleomagnetic data collected in Australia and North America that a massive crustal shift did occur between 534 million and 505 million years ago. Paleomagnetic dating methods are intended to measure geological processes that occur over timescales of millions of years. Although it is beyond the scope of the present article to elaborate on this point, the absence of paleomagnetic evidence of Hapgood pole shifts may not be evidence of absence but could be due to the inability of paleomagnetic dating methods to temporally resolve and thus detect climate-induced events occurring over timescales that are two or more orders of magnitude faster than tectonic processes.

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