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ORIENTATIONS AND OTHER FEATURES OF THE NEOLITHIC 'GIANTS' CHURCHES' OF FINLAND FROM ON-SITE AND LIDAR OBSERVATIONS

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Abstract: The orientations and placement of 52 Neolithic stone enclosures in Finland known as 'Giants' Churches' were analysed. In addition, other characteristic features, such as cairns and standing stones in or near the Giants' Churches, were investigated. The axis and gate orientations of the structures were measured using both on-site and airborne laser scanning (lidar) observations. The results showed lidar observations to be useful in archaeoastronomical analysis as a complementary tool to be used with on-site measurements and observations. The Giants' Churches were found to be orientations towards certain solar and lunar events that could have acted as 'seasonal pointers'. The orientations of the gates of the GCs were found to replicate the axis orientations to a large degree. The majority (over 90%) of the GCs were positioned on the eastern or southeastern sides of the ridges on which they were built, indicating the interest of the builders in the eastern horizon and possibly the rising of celestial bodies. The orientations of large (>35-m long) Giants' Churches and small (≤35-m long) ones were compared. The observed differences in the orientations of these two groups suggested that the structures traditionally known as Giants' Churches may be a heterogeneous group consisting of at least two types of structures represented in this study by the two selected size groups. Many large GCs were found to have been oriented towards the solstices, while the smaller ones did not show this feature. It is possible that the smaller Giants' Churches were oriented towards the Moon, while the larger ones were associated to solar events. The smaller Giants' Churches could be the remains of large houses or otherwise belong to a different tradition of construction.

Keywords: Giants' Churches, Neolithic Finland, astronomical orientations, Neolithic astronomy, ancient calendars

1 INTRODUCTION

The Giants' Churches (Finn. *jätinkirkko*, a name originating in folklore; hereafter denoted also as the GCs) are Middle and Late Neolithic (ca. 3000–1800 BCE; Okkonen, 2003) stone enclosures found mainly in Ostrobothnia, on the northwestern coast of Finland. The monuments traditionally classified as GCs are from ~20–>70 metres long and ~15–>30 m wide, and most of them are rectangular or quadrangular; there are only two clearly oval or round GCs, and two so-called 'open' rectangular GCs, which have only three walls. Some of the GCs have double or even triple walls, i.e. smaller inner enclosures inside them (see Figures 1–3). The walls of most GCs are built out of the natural *rakka* boulder fields, with stones of about the size of a man's head and occasionally larger.

The GCs were originally built on the coast, on the tips and tops of capes, peninsulas or islands. Nowadays, these sites are situated on ridges and drumlins deep in the forest, 10–20 km inland, due to the isostatic land uplift caused by the post-glacial rebound phenomenon. The majority of the GCs have been dated by the land uplift method, where their altitude relative to the present sea level gives the date of their construction once the speed of the isostatic land uplift is known (Okkonen, 2003). This dating method has traditionally been used for dating the shore-bound Ostrobothnian Neolithic dwelling sites of the Comb Ceramic and Asbestos Ceramic Cultures, and its validity has been proven by comparison with radiocarbon dates (see Eronen, 2005; Okkonen, 2003). Also, the dates obtained for the GCs by this method are in accordance with the radiocarbon dates obtained for some GCs (see Okkonen, ibid., and various references therein).

Most of the GCs have 'gates', which are symmetrically-placed openings in the walls. Some of these are framed by larger stones termed 'pier stones'. Larger, even 2-m wide boulders are also found in the walls of some GCs and even inside of them. The largest GCs are often surounded by round stone cairns and some have standing stones, 'menhirs' around them. Some of the GCs are surrounded by the remains of Middle and Late Neolithic dwellings situated lower on the ridges (e.g. Kastelli and Kettukangas of Raahe, and Hiidenlinna of Kalajoki—see Koivunen and Okkonen, 1992; Okkonen, 2003; Okkonen and Ikäheimo, 1993).

The GCs may have included wooden parts, e.g. log walls that have long since decayed. The acidic soil of Finland does not generally preserve organic material; therefore, only burnt remains are usually found in excavations. The excavations of the GC at Honkobackharju in Kruunupyy have revealed possible signs of burnt wooden structures (Schulz, 2008). The double walls encountered in some GCs have led to the hypothesis that some of them may have enclosed a more complex inner structure, perhaps even wooden buildings (Ridderstad, 2014). However, the largest, >60-m GCs would have been impos-

Figure 1: The Giant's Church of Kastelli in Raahe. (photograph: Ismo Luukkonen).

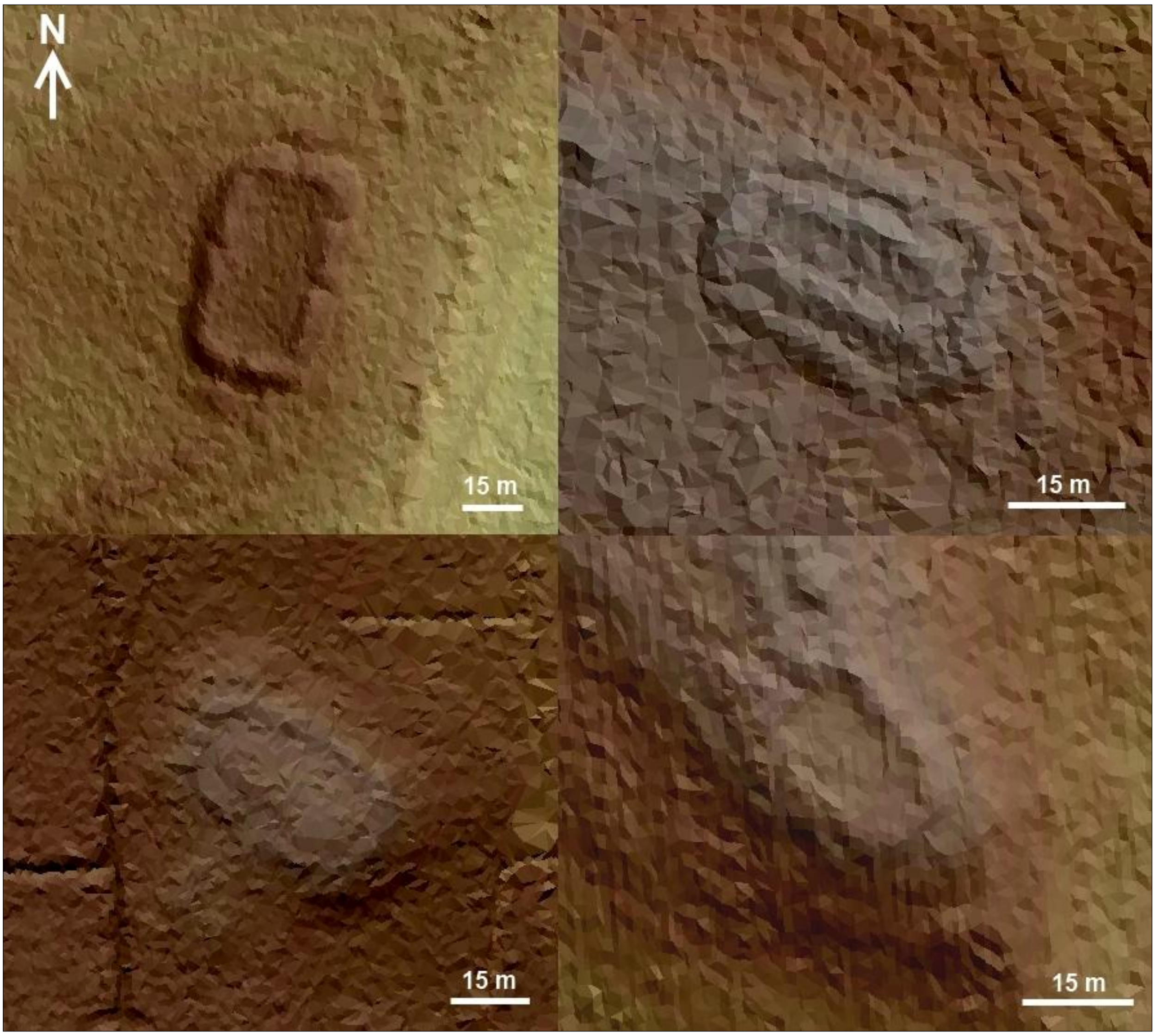

Figure 2: The Giants' Churches of Kastelli of Raahe (top left), Metelinkirkko of Oulu (top right), Rackle of Närpiö (lower left), and Kejsmolandsbacken of Pedersöre (lower right) as seen in the lidar observations. The original lidar data are courtesy of the National Land Survey of Finland (NLS, 2014).

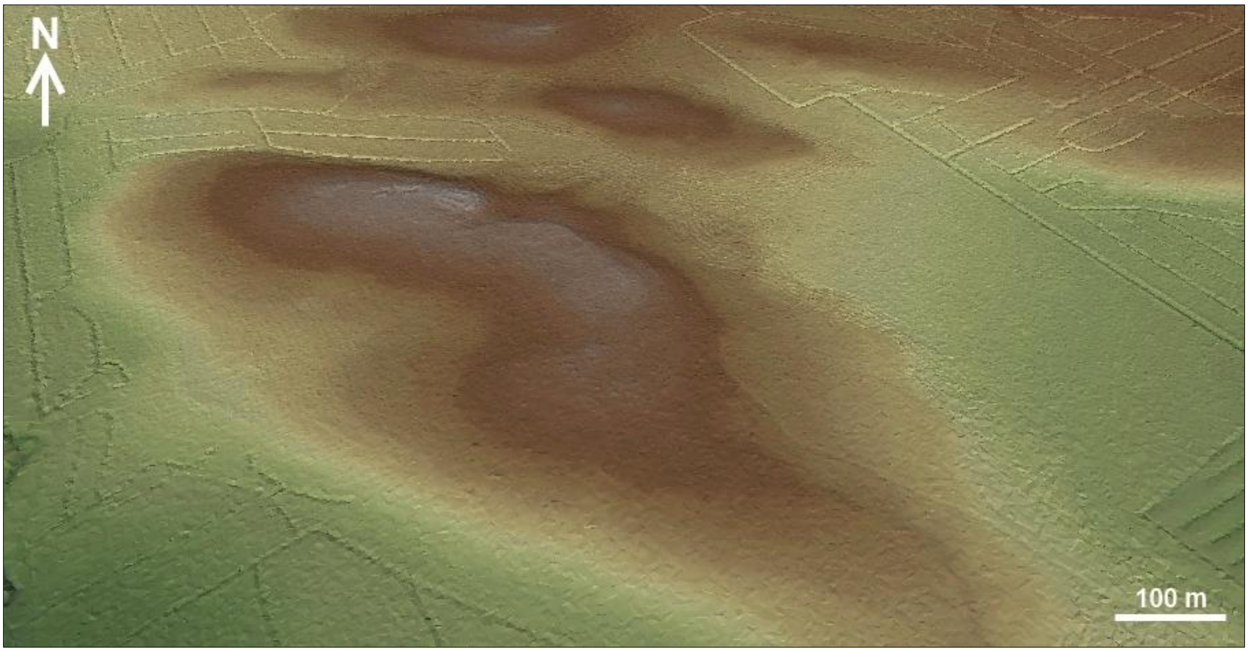

Figure 3: Metelinkirkko of Oulu was built on the top of a small ridge on an island, and to face primarily the eastern and southern directions, as most of the GCs. The original lidar data are the courtesy of the National Land Survey of Finland (NLS, 2014).

sible to cover with a single roof structure using the technology of the period.

The GCs have been associated with the culture that used the Pöljä style asbestos-tempered ceramics found on some GC sites (Forss, 1991; Okkonen, 2003). The builders of the GCs were hunter-gatherers living in marine environments (Okkonen, ibid.). Most of the bones from the Middle and Late Neolithic dwelling sites close to the GCs are from seals. Different kinds of fish and birds, elk, beaver and other game also were important. The average temperature was higher than today, and the living conditions were favourable, even at Ostrobothnia's latitude of between ~63° and 65° North (see Solantie, 2005). Agriculture was known, but at the time it did not contribute significantly to the diet (Alenius, et al., 2013; Cramp, et al., 2014; Vuorela and Hicks, 1996). There is also evidence of extensive foreign trade, possible protection of resources, and increased social complexity (see Costopoulos, et al., 2012; Koivunen, 1996; 2002; Okkonen, 2003; 2009; Vaneeckhout, 2008; 2010; Zvelebil, 2006).

The original function of the GCs is not known. Many different hypotheses have been presented to explain the existence of these kinds of monumental constructions in a hunter-gatherer society. In the various theories presented since the eighteenth century, the GCs have been seen for example as graveyards, temples, hunting enclosures and even as gigantic cold storages for seal meat (see, e.g. Okkonen, 2003, and references therein).

In previous studies of the orientations of the GCs, orientations to both solar and lunar events have been suggested (Okkonen and Ridderstad, 2009; Ridderstad, 2015; Ridderstad and Okkonen, 2015). Especially, the largest GCs seem to have orientations to the sunrises and sunsets of the solstices. Some orientations to the mid-quarter days, as well as to the full moon, risings or settings of the minor lunar standstill and the so-called 'megalithic equinox', have also been proposed.

In this study, the orientations of the axes and gates of the GCs were analysed using both on-site measurements and lidar[1] observations. The 52 GCs selected for the present study form a more complete sample than those of previous studies. The orientations of the smallest and the largest GCs were compared with each other to reveal possible similarities and differences. In addition to the orientations, other data gathered on-site during the fieldwork were examined and combined with the results of the orienttation analysis in order to help to refine the definition of what the GCs are and which purpose(s) they might have served.

2 OBSERVATIONS

The sample of the present study included 52 Neolithic stone structures classified or tentatively classified as GCs in the register of the NBA (2014).[2] However, in this study, some of the smallest constructions traditionally denoted as GCs in the NBA (2014) were left out, based on their apparently erroneous classification—Pentti Risla (pers. comm., 2009) has identified them as Neolithic housepits.

The orientations of the GCs were measured both on-site and from airborne laser scanning (lidar) data provided by the National Land Survey of Finland (NLS, 2014). Only one GC (Rackle

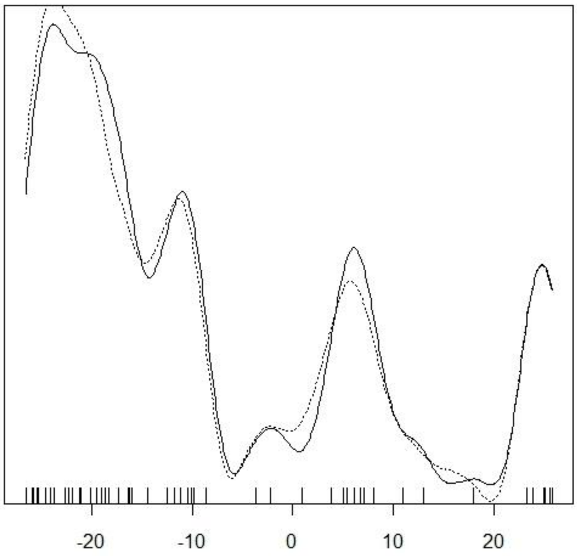

Figure 4: Declination distribution of the axes of the Giants' Churches towards the east. In this figure, north is right.

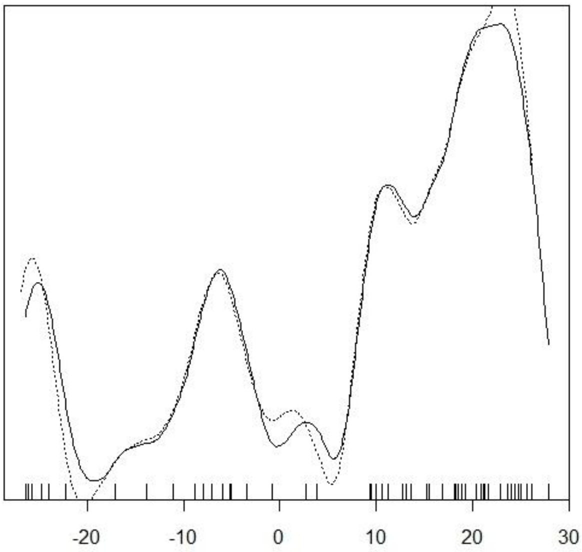

Figure 5: Declination distribution of the axes of the Giants' Churches towards the west.

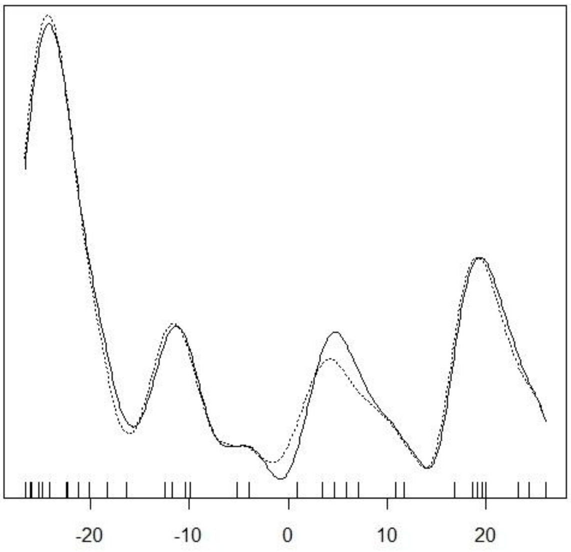

Figure 6: Orientations of the gates of the Giants' Churches to the east.

of Närpiö) was measured from lidar data alone, and one (Hautakangas of Tyrnävä) using both a site map by Sarkkinen (2009) and lidar data.

The on-site observations of this study were carried out in 2008–2014. The orientation measurements were made with a compass. The axis of a GC was calculated using the measured orientations of all walls and the general direction of the long axis, all measured towards both directions. The orientations towards the gates of a GC were measured outwards from the centre of the structure; for the two open-walled structures the centre was defined as the location of the centre of the GC as it would have been had the missing walls been in place to create a fully-rectangular enclosure. Also, many orientations towards prominent cairns and standing stones, as seen from the centres of the GCs, were measured during the project. Many sites were visited more than once, in which case the final result is the average of the measurements made at different dates, corrected for the respective magnetic declination value of each date separately. The average error of the compass measurements was estimated to be ±1.0° in azimuth. If available, the solar position was also used as a reference direction for each orientation measured; in practice, during the six years most of the orientations of the axes and gates were measured relative to the solar position at least once.

The axis orientations of 45 GCs were measured both on-site and from the lidar data. The average absolute difference between the orientations of the GCs measured from the lidar data and the measurements made *in situ* was 1.4°, of the same order as the estimated error of the compass measurements.

In addition to the orientation measurements, other kinds of data were collected during the fieldwork. A map of each GC was drawn, and the surrounding structures, such as cairns, standing stones, nearby dwellings, and the so-called rakka stone pits, which are ca. 0.5–1 m deep conical pits built into the rakka stone fields, were recorded. Also, the colours of the stones of the GCs and cairns, when observable under the thick cover of moss and lichen, were recorded. Finally, the exact locations of the GCs on the ridges upon which they were built were recorded, and then combined with geographical map data to estimate the views from the sites as they existed in the Neolithic.

Since the land uplift caused by the post-glacial rebound has moved the Neolithic shoreline and the related human-made structures 10 to 20 km inland and into deep forest, the original horizon height for the measured structures is in most cases no longer observable. Therefore, the horizon heights were estimated from map data provided by the National Land Survey of Finland (NLS, 2014). Since, for most of the GCs, the exact time of construction is still unknown, it is not known whether they were built on the small outer islands in the open sea or during a later 'archipelago stage', when the islands had grown bigger and were in a more sheltered location closer to the mainland coast. Therefore, two horizon models were used for the calculation of the orientations of the GCs:

(1) a model where the horizon height was estimated from the maps, with no contribution from possible treeline included; and

(2) the same as the model A, but with a 15-m high treeline included wherever the orientation would have been towards a land mass large enough to harbour a substantial tree cover.

It turned out that there were no great differences between the results obtained using the two models (see Figures 4–11). This is due to the fact that the GCs were often built on locations higher than their surroundings and on the tips of islands and capes, where the original nearest treeline would have been quite far away, usually on the other side of an area of open water. The results of the horizon models were also compared with the horizon heights in the present coastal areas and archipelago of southwestern Finland, which supported the validity of the modelled results obtained for the probable horizons visible from the GCs in Neolithic times.

In 2009–2013, partly side by side with the present project, a 'housepit observation project' was carried out. This involved measuring the orientations of Middle and Late Neolithic house remains in Ostrobothnia. Those observations provided important comparative data in the form of the features of the large housepits contemporaneous with the GCs. The results of that project, some of which are referred to in this paper, will be published in full in Ridderstad (2016).

3 RESULTS

The results of the orientation measurements for the 52 GCs are presented in Table 1 and Figures 4–11. In Figures 4 and 5, the declination distributions for the orientations of the axes of the GCs towards the eastern and western horizons are shown for both of the horizon models used (the rug plot is shown for the second model only).

In the eastern direction (Figure 4), at the large scale most of the axes are oriented towards the southeastern and southern segments of the horizon, roughly between the declinations of –10° and –26°. Separate groups of orientations can be observed around the declinations of ca. +6° or +7°; –10° or –11°, and –20°. There seem to be separate clusters at ca. +25° and –25°.

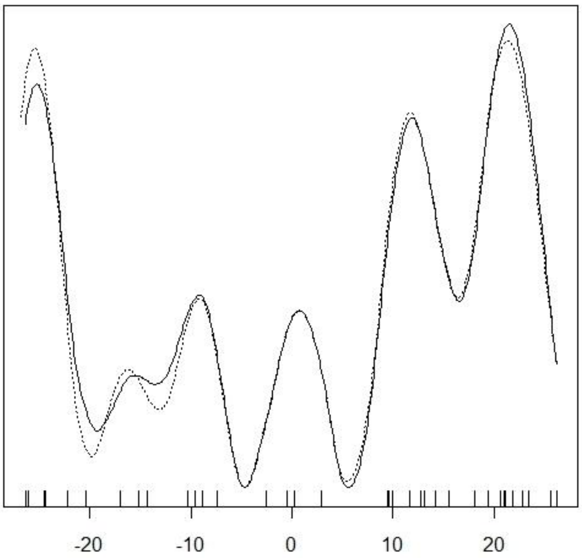

Figure 7: Orientations of the gates of the Giants' Churches to the west.

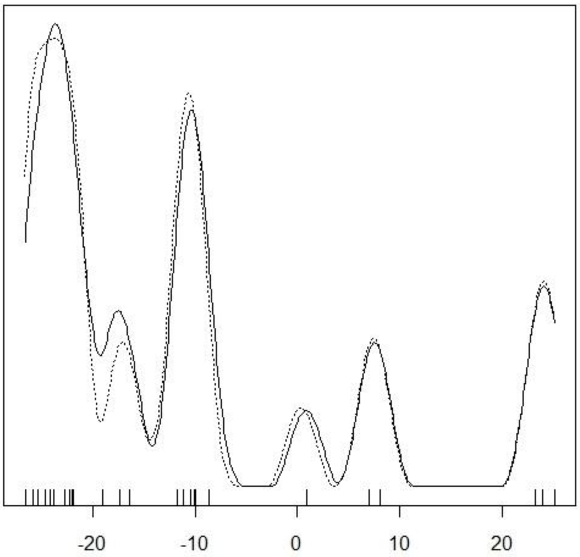

Figure 8. Orientations of the axes of the Giants' Churches >35 m towards the eastern horizon.

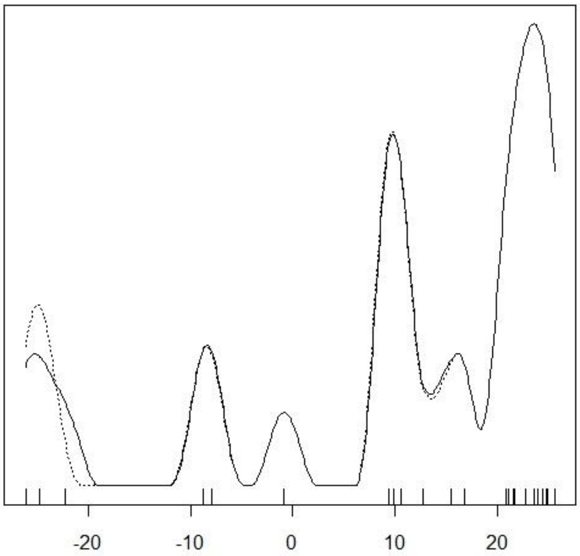

Figure 9: Orientations of the axes of the Giants' Churches >35 m towards the western horizon.

Table 1: Orientations and other features of the Giants' Churches of Finland.*

Name	Location	Latitude	HFSL	Shape	Size	Axis E	Axis W	Gates	Other feat.
		(deg)	(m)		(m)	(az/deg)	(az/deg)	(az/deg)	
Metelinkirkko	Oulu	65.36446228	52.5	Q2	38x29	114.8	294.8	75, 115, 165, 265, 295, 330	C?
Mäntyselkä	Oulu	65.26457281	62.5	Q	25x14	130.6	310.6		C, R
Rajakangas	Oulu	65.23128557	55	Q2	32x26	56.7	236.7	62.7, 271.7	C, M, T, D
Laivakangas NE	Oulu	65.18045354	55	Q	24x16	98.6	278.6	99.3	
Keskimmäisenkangas	Oulu	65.15976517	85	Q2	24x18	74	254		C, R
Luola-aho	Oulu	65.08633155	80	Q	30x20	94.8	274.8		R
Linnasaari	Oulu	65.05705135	55	Q	34x24	140.8	320.8	34.8, 249.8	R
Jättiläissaari	Muhos	64.92881914	82.5	Q	20x16	117.9	297.9	305.4, 327.4	R
Mustosenkangas	Liminka	64.74522394	52.5	Q2	37x23	149.2	329.2	60.3, 150.8, 234.8, 333.3	C
Metelinkangas	Tyrnävä	64.73165332	57.5	Q2	40x22	70	250	248	C
Linnakangas	Tyrnävä	64.71300365	52.5	Q	25x15	139	319	40.2, 144.2, 294.2	C
Kotakangas	Tyrnävä	64.712692	47.5	Q	26x14	150.3	330.3		C, T, R
Käyräkangas 1	Tyrnävä	64.70936823	50	Q2	33x15	75.1	255.1		C
Käyräkangas 2	Tyrnävä	64.70936823	50	Q	29x15	146.7	326.7	147.2, 329.2	C, T
Hautakangas	Tyrnävä	64.69602092	65	Q	47x39	170.1	350.1		D
Linnamaa	Liminka	64.64341865	57.5	Q2	40x28	130.2	310.2	130.2, 310.2	C, T, B, D
Pikku Liekokangas 1	Raahe	64.63746901	57.5	Q	18x13	83.2	263.2	84.2	C, B
Pikku Liekokangas 2	Raahe	64.63746901	57	Q	18x13	79.5	259.5		C
Kastelli	Raahe	64.63149319	57.5	Q	62x36	14.25	194.25	11, 46, 103, 168, 197	C, P, D
Linnankangas	Siikajoki	64.62834011	55	Oval	27x18	6.1	186.1	78.9	
Kiviojankangas	Raahe	64.62364796	52.5	Open Q	40x21	166	346	270	C, B
Pesuankangas	Siikajoki	64.61879234	52.5	Q	34x24	137	317	137, 317	C, M
Pikku Jakenaro	Raahe	64.58563819	78.5	Q	33x16	178.5	358.5	253.8	C
Kettukangas	Raahe	64.58233593	57.5	Q	30x20	48.6	228.6	193.6	C, M, P, D
Pirttivaara	Raahe	64.54814349	60	Q2(m)	44x32	175.2	355.2	179.4	C, R, M, D
Pirttivaara B	Raahe	64.54814349	60	Q	22x15	79.2	259.2		C, R, B, M, D
Pirttihaudankangas	Raahe	64.53984564	60	Q2	58x35	89.3	269.3	89.3	C, R
Miehenneva	Alavieska	64.26534801	52.5	Q2	40x25	111.7	291.7		
Hangaskangas	Kannus	64.0654465	60	Open Q	40x30	133.1	313.1	183	C, M, B
Hiidenlinna	Kalajoki	63.97554087	60	Q	46x29	72.9	252.9	72.9, 163, 182.1, 247, 337.8	C, R, D
Pahikaisharju	Kannus	63.96774947	57	Qm	40x20	116.1	296.1		C, M
Hautakangas	Kokkola	63.82688344	62.5	Q	32x20	2	182	230	B
Kirkkoharju	Kokkola	63.80259228	40	Q3	60x30	158.1	338.1		C, T, B
Pikku Hautakangas	Kokkola	63.77691769	70	Q	28x16	140.3	320.3		C, R
Tressunharju	Kokkola	63.72758928	60	Qm	40x18	146.7	326.7		
Honkobackharju	Kruunupyy	63.71442404	55	Q	25x18	176.8	356.8	177, 357	C
Kåtabacken	Kruunupyy	63.67821342	50	Q3	75x32	113	293	298.3	C, R
Högryggen	Kruunupyy	63.6498702	50	Q2	36x20	174.8	354.8	174.8, 354.8	
Snårbacken	Kruunupyy	63.58221987	65	Q	17x10	123.3	303.3	277.8	C
Hembacken	Pedersöre	63.57276641	42.5	Q	50x20	149.2	329.2	39.7, 277.8, 329.2	C, R, M
Tallbackharju N	Pedersöre	63.54038725	50	**Oval**/T	50x30	148.2	328.2	160.2, 192.7, 231.7	C, T
Tallbackharju N	Pedersöre	63.54038725	50	Oval/**T**	50x30	13	193		
Tallbackharju	Pedersöre	63.53451097	57.5	Q2	25x20	3.7	183.7	183.7	C, R
Svedjebacken	Pedersöre	63.51118357	57.5	Q2	58x34	112.9	292.9	113, 293	C, R, M, T, D
Storbacken 1	Evijärvi	63.47642094	66	Q	35x20	65.2	245.2		
Jäknabacken	Pedersöre	63.47382895	55	Q	65x35	147.7	327.7	148	C, M, P
Kejsmolandsbacken	Pedersöre	63.43456187	55	Q	28x20	138	318	42.9, 319.9	C
Bäckeshällorna N2	Vöyri	63.27022574	40	Q	35x20	121.8	301.8		C
Iso Mahosaari	Lieksa	63.26590478	97.5	Q2	23x18	160.6	340.6		C, R
Korkeamäki	Kauhava	63.25007553	65	Q2	60x30	163.4	343.4		C, T, B
Tavoma 1	Vöyri	63.15699536	62.5	Q	35x20	126.9	306.9	117.6, 301.6	R, M
Höjsalträsk	Vöyri	63.11311806	62.5	Q2	38x20	27.2	207.2	27.2, 207.2	C, R
Rackle	Närpiö	62.67226913	40	Q	50x30	119.2	299.2	14.2, 119.2, 220.2, 299.2	?

Key: From left to right, the data columns show: the names of the GCs; locations; heights above mean sea level (HFSL); latitudes in degrees north; shapes; sizes; the axis orientations of the GCs towards the east in degrees of azimuth; the axis orientations of the GCs towards the west in degrees of azimuth; the gate orientations of the GCs in degrees of azimuth; and other features of the GCs. The shapes of the GCs are: Q = quadrilateral, usually a rectangle; Q2 = Q with double walls; Q3 = triple walls; Qm = Q divided into two, 1/3 and 2/3 sized 'rooms' by an inner wall; Open Q = Q with one wall missing; Oval; and T = triangular. The capital letters in the last column indicate the following features: C = cairn/s; R = rakka pit/s; M = standing stone/s; T = triangular standing stone; B = boulder/s inside the GC; D = dwelling remains around the GC; and P = piles of burnt stone. Notes: (1) Pirttivaara and Pirttivaara B may together form a Qm-type GC, with Pirttivaara B forming an extension of Pirttivaara; (2) the two values for the axis of Tallbackharju N result from the shape of the GC resembling a rounded triangle with one wall longer than the others, which leaves two possible definitions for the direction of the long axis.

Correspondingly, in the western direction the axes point mainly towards the northwestern and northern segments of the sky. Separate orientation peaks can be observed at the declinations of –25°, –6° or –7°, +10°, +19°, +21° and +25°.

The orientations of the gates of the GCs are shown in Figures 6 and 7. The distribution of the gate orientations towards the eastern horizon (Figure 6) has peaks at the declinations of ca. +19°, +5°, –11° and –24°; the latter seems to consist of two separate groups, one around ca. –20° and the other around –25°. Towards the west, the gate orientation distribution peaks at the declinations of +21°, +12° or +13°, 0°, –10° and ca. –25°.

Also the orientations of the smallest and the largest GCs were separately examined. The largest known single-room housepits (i.e. the remains of Neolithic semi-subterranean pithouses) are ca. 32 m long (Ridderstad, 2016). Therefore, the GCs were divided into two groups: those with their long axes >35 metres, and those with their axes ≤35 m in length. The sample size of the former group became 25 and the latter 27 (Pirttivaara B was left out, since it is connected by a cairn formation to Pirttivaara and its orientation may therefore have been affected by the position of the larger enclosure).

In Figures 8 and 9, the axis orientations of the GCs >35 m long are shown. Towards the eastern horizon (Figure 8), the orientation distribution has two tall peaks: one at –10° and another one at ca. –24°. Towards the western direction (Figure 9), the peaks are at +10° and +24°.

The orientations of the GCs with axes ≤35 m long are shown in Figures 10 and 11. The orientation distribution towards the east (Figure 10) has its largest peak around the declination of –20° or –19°. There are also peaks at the declinations of ca. +6° and –26°. Towards the western horizon (Figure 11), the largest peak is centred at ca. +19°. There is another peak at –5° or –6°, and also a cluster of orientations centred at ca. +13°.

In addition to the axis and gate orientations, also other features of the GCs were observed during the study. It turned out that the majority (>90%) of the GCs were positioned on the eastern or southeastern sides of the ridges upon which they were built. The dominant colour of the wall stones and particularly the large pier stones of the GCs was red: ca. 80% of the GCs for which it was possible to reliably determine the colour of the stones, turned out to be mainly red in colour. Most GCs were found to have in or around them additional structures that could be characterised as 'ritualising': cairns (perhaps used for burial or sacrifices—see Okkonen (2001) and standing stones. The orientations towards

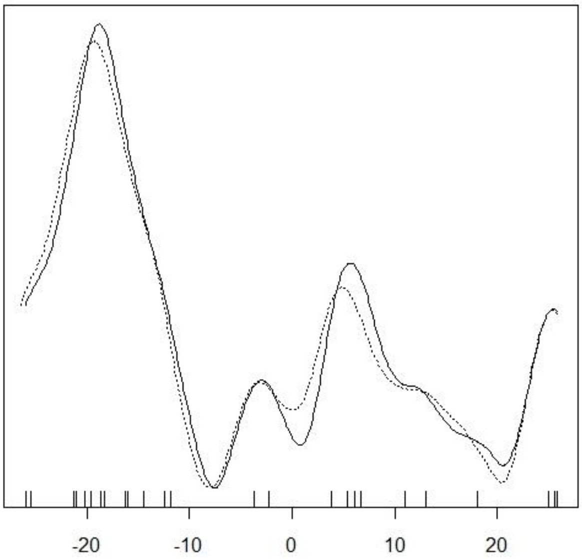

Figure 10: Orientations of the axes of the Giants' Churches ≤35 m towards the eastern horizon.

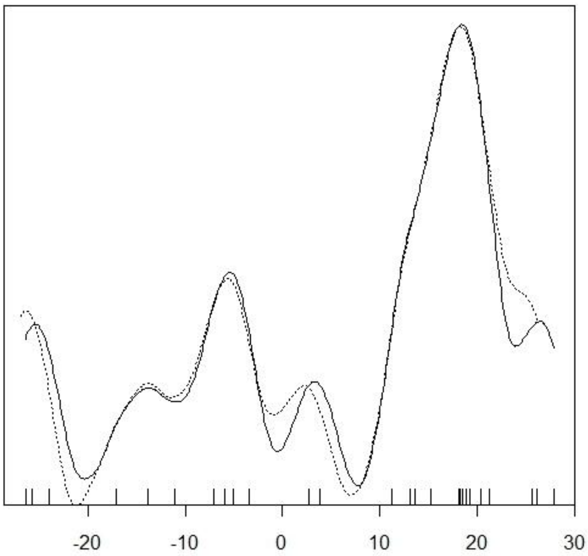

Figure 11: Orientations of the axes of the Giants' Churches ≤35 m towards the western horizon.

many prominent cairns and standing stones were measured during the project (see Section 4, below). The standing stones were ca. 0.5–2 m tall. Some were still in an upright position, while others had fallen next to a pit they had probably been standing in. The largest of the standing stones had anthropomorphic features (denoted with M in Table 1), while another special class of 'menhirs' were the red, triangular stones either protruding out of the easternmost walls of some GCs or at some distance outside of them (denoted with T in Table 1). In addition to these, some GCs had remains of dwellings and large piles of fire-cracked stones in their immediate vicinity (i.e. within a radius of about 100 m); the latter have been connected to the processing of seal blubber oil (see Okkonen, 2003).

The use of lidar data in the orientation analysis combined with the traditional method of on-site measurements provided some interesting results. The shapes of some GCs could be observed to be more complex than previously thought. The GC of Miehenneva that had been recorded as a J-shaped structure in some reports showed up as a double-walled fully rectangular GC in the lidar observations. Lidar observations also confirmed that the deviating orientation of the western wall of the Metelinkirkko of Oulu and the curved outer walls of Kåtabacken of Kruunupyy were true features of the structures and not observation errors (both structures are located in thick forest that effectively hampered long-sightline on-site observations). On the other hand, most gates and other small structures (cairns, standing stones and remains of small dwellings) surrounding the GCs could not be reliably observed with the presently-available resolution of the lidar data.

4 DISCUSSION

The present study included 52 Giants' Churches, providing a more complete sample than the previous studies (see Okkonen and Ridderstad, 2009; Ridderstad, 2015; Ridderstad and Okkonen, 2015). Also a new, more accurate horizon model was developed. The main purpose of the study was to further investigate the astronomical orientations of the Giants' Churches indicated by the previous studies, as well as to examine other characteristic features of the GCs to help address the question of their classification and, via that, their possible original functions. An additional aim of the study was to utilise a new investigative technique, lidar observations, in an archaeoastronomical orientation analysis of the GCs.

4.1 The Date for Calculating the Celestial Events

Once all GCs that had probably originally been built on the shores of inland lakes were removed from the sample, most of the structures investigated in this study had heights above sea level of between 40 m and 70 m (see the HFSL column in Table 1). The mean and the median values were 56 m and 57 m, respectively. The values of mean height above sea level for the smaller, ≤35-m long GCs and the large, >35-m long, GCs were 57.3 m and 54.7 m respectively.

In the somewhat different sample of GCs of Okkonen (2003), most of the GCs were located between 42 m and 70 m above sea level, with a mean height of 56.7 m. The dating of the sea-shore-bound GCs by Okkonen (2003) to ca. 3000–1800 BCE is thus applicable to the present sample of CGs as well.

The GCs at Kastelli and Kettukangas of Raahe that are 57.5 m above sea level have an average radiocarbon date of ca. 2900 BCE (see Okkonen, 2003 and references therein). Taking into account the effect of the lifetime of the dated material itself, the median height above sea level value of 57 m of the GCs in Northern and Central Ostrobothnia would thus correspond to ca. 2700–2800 BCE. Based on a combination of the height above sea level values and the radio-carbon dates, the year for calculating the celestial events for the GCs of this study was taken to be 2600 BCE.

4.2 Orientations Towards the Sun

The orientations of the GCs presented above in Figures 4–11 corresponded to various astronomical events in 2600 BCE. In Table 1 and Figures 4–11 it can be seen that some GCs have individual orientations towards the sunrises and sunsets of the solstices (declinations ±24°) and the solar mid-quarter days of early May, August, November, and February (declinations ±16°; see Ruggles, 2005). There are few values around the declinations close to 0° corresponding to the equinoxes, suggesting that the equinoxes were not as important as the solstices. Instead, the declination distributions indicate that the times about one month after and before the solstices and the equinoxes, corresponding to the declinations of ca. ±20° and ±10°, may have been especially important. The declinations between –25° and –27°, as well as those between +25° and +27°, are very close to the north-south direction and may thus indicate a deliberate orientation along the cardinal directions.

Most of the axis and gate orientations towards the eastern horizon belong to four main groups of declinations: (+5°, +6° and +7°), (–10°, –11°, –12° and –13°), (–19°, –20° and –21°) and (–24°, –25° and –26°). Towards the west, the signs are reversed, but the same relation holds. If the declinations very close to the north-south line (i.e. –25° and –26°) are left out, the average separations (17.5°, 8.5° and 4.0°) between the central declinations of the groups seem to be close to an exponential distribution. This is interesting, since it can be connected to the observation that the distances between the different groups correspond to roughly equal distances in solar days between the equinoxes and the solstices.

In 2600 BCE, 27 days after the autumnal equinox (AE) the Sun was at a declination of ca. –11°. About 42 days earlier, the Sun had been at a declination of +6°. One synodic month later (i.e. 29 or 30 full days after the Sun had been at the declination of –11°) the Sun reached a declination of –20°. And 30 days after the Sun had been at a declination of –20° it reached a declination of ca. –24° (i.e. it was only a few days away from the winter solstice). Considering that the daily variation in the movement of the Sun during the days around the winter solstice is so small that it cannot be detected by the human eye, the said date could in practise have been taken to be the time when the winter solstice started (for example, in Finnish folklore the days around the winter solstice were called the 'nesting days' of the Sun, i.e. the days when it stayed immobile in its 'nest'; Vilkuna, 1950).

The declinations of –11° and –20° also occurred about 30 days and 59-60 days before the vernal equinox, respectively. Or, counting from the winter solstice, the declinations of –20° and –11° would have occurred ca. 33 and 63 days, respectively, after the winter solstice. In the orientations of the GCs towards the western direction, a similar sequence of solar declinations can be observed with respect to the equinoxes and the summer solstice.

The period of 27 days can be compared to the length of one full synodic month, which is ca. 29.5 days. In a lunisolar calendric system, where a month starts with the appearance of the first crescent of the Moon, the full moon of the first full month starting at the autumn equinox or after it occurs on average ca. 27 days after the autumnal equinox. The difference of ca. 2 days results from the fact that the first crescent is not observable with the naked eye until it is ca. 16 hours old at the minimum, and is not easily visible until it is 2–3 days old.

The orientations towards the sunrises 27, 27+29, and ca. 27+29+30 days after the autumnal equinox thus point towards the existence of a lunisolar calendric system, where the month would started with observations of the first crescent Moon. The declination of +6°, on the other hand, can be connected to a different system of lunisolar markers: the Sun was at this declination 14–15 days, i.e. about half a synodic month before the autumnal equinox and also ca. 15 days after the vernal equinox. The 14-day period could be related to the average day of occurrence of the first crescent or the first full moon after the vernal equinox. The time of the second similar event would then be about one synodic month later, i.e. ca. 44 days after the vernal equinox, closely corresponding to the time of the solar mid-quarter day of early May.

The everyday practical calendar in the Neolithic probably was based on lunar phases, i.e. the synodic months. At least after the introduction of agriculture in early Neolithic Finland one might expect that a lunisolar calendric system that combined the tropical year of ca. 365 days and the synodic month of ca. 29.5 days was developed. A simple annual luni-solar calendar would probably have begun by starting to count the months in relation to a solstice or an equinox. It is well known from historical sources that ancient peoples often started a month by observing the last lunar crescent visible in the east before sunrise, the first lunar crescent in the west after sunset, or the full moon. The time of the full moon could, of course, be important in itself, especially at certain times of the year. The orientations seen in the GCs suggest that both the days of the start of the month at the sighting of the first lunar crescent and the time of the full moon may have been important, or that there may have been several different lunisolar calendric counts at use.

The 'seasonal calendric' orientations seen in the GCs can be compared to the medieval Nordic calendars, where the year was divided into four equal parts by four key dates: the Heart of Winter in the middle of January, the Summer Nights in mid-April, the Midsummer in mid-July, and the Winter Nights in mid-October. Originally, these days had corresponded to the times of the full moon, but became fixed in the Julian Calendar introduced after the arrival of Christianity. The four-divided year had been at use already in the Iron Age, and it has been suggested that it may be even older, having been established in hunter-gatherer times (Vilkuna, 1950). The Heart of Winter, for example, originally was the time of the full moon of the coldest month of the year, which would have been the first or second month, or the first full month after the winter solstice. In fact, it can be shown that the Heart of Winter and the Midsummer correspond to the times of the thermal minima and maxima of the year in Finland, and the Summer and Winter Nights approximately coincide with the permanent rise and decrease of the daily averaged temperatures above and below zero in the spring and in the autumn, respectively (ibid.). The equinoxes, on the other hand, do not coincide with any key dividing points of the annual temperature at the latitudes of Finland. This would have been the situation also in late Neolithic Ostrobothnia, even though the climate was slightly warmer than today. There, as in the Iron Age and historical times, the present month of April would have signified the start of spring time. The sunrise around the declination of +10° or +11° could thus have signified the start of the spring and summer period of the year. Correspondingly, the declination of –10° or –11° could be related to the start of the winter period, in a way similar to the calendric system of the Nordic Iron Age. In the same seasonal calendar, the sunrise at the declination of +20° would have corresponded to the annual thermal maximum in mid-July, and the declination of –20° at the time of the annual thermal minimum in mid-January. Together, the orientations of the GCs to the sunrises of specific days determined by the lunar phases in a lunisolar calendar could be viewed as a kind of permanent system of seasonal markers, eternalised in the most prominent stone monuments of the culture.

4.3 Orientations to the Moon

The declination of ±5° corresponds to a well-known lunar event: the so-called 'megalithic equinox' or the spring (or autumn) full moon, which is defined as the first full moon rising at a more southerly (northerly) declination than the Sun around the vernal (autumnal) equinox (see da Silva, 2004). Perhaps even the whole cluster of orientations of the GCs centred at ca. ±6° could correspond to that event, with the position of the highest peak slightly shifted.

The orientations to the declinations of ±19° correspond to the northernmost and southernmost full moons of the lunar minimum standstill every 18.61 years. On the other hand, the maximum and minimum declinations of the Moon at the time of the maximum lunar standstill are, at the latitudes of Ostrobothnia, well beyond the range of the declinations crossing the zero horizon line. Therefore, at those times, the Moon either does not rise or does not set at all, and orientations towards the rising or setting Moon are not possible. However, since the full moon is always opposite to the Sun, during the midwinter and the midsummer in the intermediate years of the 18.61-year cycle there still would often have been a situation where the full moon would have been seen at one end of a GC and the Sun at the other. The axis orientations of many GCs with gates at both ends could even be seen as well suited for this kind of 'double-orientation' towards a setting/rising Sun and a rising/setting full moon.

Recently, it has been suggested by Clausen et al. (2011) and Clausen 2014; 2015) that both the orientations of Scandinavian passage graves and West Iberian megalithic tombs could be explained by a combined distribution of orientations to the moon-rises of the spring full moon, the next full moon after the spring full moon (the 'sowing moon'), the southernmost full moon, the autumn full moon, and the full moon preceding the autumn full moon (the 'harvest moon'). The sowing moon would have happened from April to May and the harvest moon from August to September. The full moon would thus have acted as a seasonal marker in a way similar to what was suggested above for the Sun in the case of the GCs.

A possible lunar seasonal marker system for the GCs could have consisted of the spring (or autumn) full moon (the ±6° cluster) and the full moon at its annual extreme positions in midsummer and midwinter (the orientations peaking at ca. ±19°, but reaching to the north-south line near the maximum lunar standstill). This model, however, leaves the ±10° declination peak unexplained.

4.4 Orientations to Stars

Stellar orientations for the GCs were also considered, as it is well known that the heliacal and acronychal risings and settings of stars have been used as seasonal markers in ancient cultures. However, since there are so many bright stars that change declination relatively quickly with the precession of the equinoxes, any ancient monument has to be dated with an accuracy of a few hundred years to reliably suggest an orientation to a star. Currently, not enough radiocarbon dates exist for the GCs to suggest possible stellar orientations. Hopefully, the situation will change in the future.

4.5 Placement of the Giants' Churches

The fact that >90% of the GCs were positioned on the eastern or southeastern sides of the ridges upon which they were built, regardless of the direction of the ridge itself, may indicate that the eastern and southeastern directions were significant to the builders. This in turn may indicate that rising events were more significant than settings and/or that the winter Sun or the summer Moon may have been the intended targets of observation.

Bradley (2001) has suggested that the longhouses of the Central European Linear Pottery Culture (ca. 5500–4500 BCE) were oriented towards the ancestral lands of the builders. In comparison, it is perhaps significant that the eastern and southeastern directions also agree with the directions of the great river routes leading inland to the presumed ancestral lands of the Pöljä Ceramics Culture and other Middle and Late Neolithic Asbestos Ceramic Cultures in Finland and Karelia. The possibility that the GCs were oriented towards the ancestral lands of the builders does not contradict the existence of their astronomical orientations, but could be seen as a complementary feature: celestial events at specific, important times of the year would have also pointed towards the direction of the ancestral homeland.

4.6 Gate Orientations and Other Features

Not all GCs have visible gates at all and in some cases, the gates of the outer walls of a double-walled GC are not in the same places as those in the inner walls. In most GCs that have gates, these are found at the middle of the short-end walls of the structure, i.e. close to the axial direction. Therefore, the gate orientations resemble the orientations of the axes of the GCs; this relation was also found to be true for the gates of the >35-m and the ≤35-m GCs separately. However, the gate orientations towards the east are not concentrated so strongly on the south-east side of the horizon as the axis orientations of the GCs; the situation is similar towards the western horizon. Moreover, there are some peaks in the gate orientation distribution that are not seen in the axis orientations, and the locations of some peaks seem to be in slightly different positions relative to the axis orientation distributions.

Many orientations towards some of the most prominent cairns and standing stones, especially those positioned close to the axial direction in and around the GCs, were also measured. Most of the results of the orientation measurements towards the cairns from the centres of the GCs have been presented in a separate study (Ridderstad, 2013). The results also provided evidence in favour of further examination of the orientations towards the standing stones. At some sites, e.g. at Kotakangas and Korkeamäki (see Table 1) the orientation measured on-site from the centre of a GC towards the standing stone at the 'tip' of the GC could be connected to a solsticial event, while the axis orientation measured using the walls alone for each of these GCs was a few degrees off the direction of the standing stone. Most of those 'axial' stones were triangular and red in colour.

The slight differences between the axis orientations and the orientations towards the gates, cairns or standing stones close to the axial direction raises the question of which of these orientations were most important for the builders of the GCs. Moreover, in many cases, where a gate orientation of a GC was close to a certain event, but not quite towards it as seen from the exact centre of the structure, the event would have been visible through the gate if one moved just a few steps away: every gate of a middle-sized GC already has a window of visibility of more than 1° in azimuth, and a deviation of just 0.5 m in the location of the centre of the structure would make the 'observation window' at least 2° wide.

The possibilities provided by these kinds of wider observational windows call for new interpretations in the archaeoastronomical analyses of the orientations of ancient structures (see Silva, 2014). Instead of concentrating on just one line of sight and a single orientation, a wider 'sky-scape' analysis should be performed for each monument. In the case of the GCs, that kind of approach would preferably include not only the analysis of the celestial events observable via the full window of visibility of each gate, but also the analysis of all celestial events and prominent horizon features close to the axial direction, as well as the orientations towards prominent cairns and standing stones.

The suggested skyscape analysis could provide new opportunities also for the detection of stellar orientations that are now hampered by the lack of precise enough dates for the GCs. For example, in 3000–1800 BCE the rising positions of the Orion asterism grazed the south-easten horizon in Ostrobothnia. Orientations to its stars could have corresponded to some of the orientations of the GCs and possibly provided viable seasonal marker events for centuries if viewed through a wide enough physical window of visibility.

4.7 Orientations of the Small vs. the Large Giants' Churches

The initial sample included 52 large stone enclosures classified as Giants' Churches. It is possible however, that some small and middle-sized GCs might in fact be remains of unusually large Neolithic houses (see Mökkönen, 2011; Okkonen and Ridderstad, 2009; Ridderstad, 2015). Since currently no unambiguous definition of a Giant's Church exists and all of those structures fit the general characteristics (size, appearance, positioning in the landscape, etc.) of a 'traditional' GC, it was decided to keep these structures in the present sample and to try to bring out the mutual differences in the sample by comparing the GCs of different sizes. To accomplish this, the GCs were divided into two groups: those with their long axes >35 metres, and those with axes ≤35 m. The division was based on the fact that all of the suspected house remains are ≤35 m long, and, on the other hand, the length of the largest known Neolithic single-room semi-subterranean pithouse remains in Finland is ca. 32 m (Ridderstad, 2016).

It turned out that the largest GCs were oriented differently from the smaller, ≤35 m ones. For the largest GCs, orientations towards the solsticial declinations of ±24° and 'the ±10° peak', i.e. the sunrises and sunsets about one month before and after the equinoxes, are prominent (see Figures 8 and 9), while the orientations of the smaller GCs are concentrated in the declination groups around ca. ±6° and ±20° corresponding to the sunrises and sunsets about half a month before and after the equinoxes and one month before and after the solstices, or to seasonal lunar events (the autumn) full moon/spring full moon and the midsummer and mid-winter full moons). While some orientations of both the large and the small GCs can be connected to the sunrises and sunsets of the mid-quarter days, the smaller GCs have practically no orientations to the solstices. Neither have the smaller GCs orientations to the sunrises or sunsets about one month after the equinoxes (the ±10° peak), which are so prominent for the largest GCs.

While the orientations of the larger GCs to the declinations from ca. ±24° to ±26° could in principle be connected to the full moon near the solstices, an easily attributable lunar explanation for the ±10° peak has not been found. The orienttations of the smallest GCs, on the other hand, well suit a possible 'lunar seasonal pointer' calendric system: the orientations close to the declinations of ca. ±6° and centred at ±19° or ±20° could indicate the full moons near the equinoxes (the spring full moon and the autumn full moon) and the midsummer and midwinter full moons (of the minor lunar standstill). It is possible that the smallest GCs were oriented to the Moon, while the largest GCs were oriented to the Sun. Based on the height above sea level values, the group of the smaller GCs and thus the tradition of lunar orientations could be slightly older than the tradition of solar orientations, represented by the large GCs.

The younger age of the tradition of the solar orientations seen in the largest GCs could be related to the prominent role the Sun held in Bronze Age religion (for the Bronze Age solar cults see, e.g. Kristiansen and Larsson, 2005). The cultural practices in the late Neolithic Ostrobothnia could also have been affected by the arrival of the Corded Ware Culture that is known to have oriented its graves to the Sun (see Nordqvist and Häkälä, 2014; Schmidt-Kaler and Schlosser, 1984; Tranberg, 2001). However, there is some evidence of the ritual importance of the Sun already in the early Neolithic and possibly even late Mesolithic Finland: many circular stone disks have been found that are decorated with rayed patterns and apparent solar or stellar images; they were perhaps used as the headpieces of wooden staffs or hung from ropes (see Edgren, 1977, especially the Figures 7, 8, 10, and 16). To further address the question, the orientations of both Mesolithic graves and early Bronze Age monuments should be examined and compared with the orientations of Neolithic structures.

The smaller GCs could be remains of large houses or otherwise belong to a different tradition of construction. They could, for example, have been used for 'profane' activities, while the larger GCs may have been intended for ritual use. It is possible, though, that the largest GCs once enclosed one or more small buildings or even a whole former dwelling site, which then would have been ritualized by adding burial cairns, etc. (Ridderstad, 2015). The remains of the possible dwellings or perhaps mortuary houses would show up as the inner double or triple walls observed in many GCs. Unfortunately, none of the largest GCs has yet been excavated to the extent that the possible remains of buildings would have been exposed.

4.8 Lidar as an Archaeoastronomical Tool

The present study also demonstrated the usefulness of lidar observations as a tool in archaeoastronomical analysis. While they cannot replace the on-site measurements and observations, especially the shapes of very large structures can be effectively studied using lidar observations. Even though the current resolution of the lidar data did not enable the detection of the smallest details of the GCs, the axis orientation of a GC could generally be measured from the lidar images with an accuracy comparable to the compass measurements. Moreover, the shape of the local surrounding terrain also can be effectively viewed using lidar data, enabling efficient estimations of the views from a site and the inter-visibility of the surrounding sites and monuments. The latter property is especially important for sites located in boreal forests, where the use of lidar can overcome the blocking effects of the surrounding vegetation.

5 CONCLUSIONS

In this study, the orientations and placement of 52 Giants' Churches (GCs)—Neolithic stone enclosures located in Ostrobothnia and eastern Finland—were analysed. In addition, other characteristic features, such as cairns and standing stones, inside or in the immediate vicinity of the GCs, were investigated. The main aim of the study was to provide more information to help address questions of the defining characteristics, classification and original functions of the GCs. Also, the usefulness of lidar observations as a tool in archaeoastronomical analysis was examined. This study led to the following conclusions:

(1) The orientations of the GCs were found to be towards certain solar and lunar events that may have acted as 'seasonal pointers', i.e. lunisolar or lunar calendric markers related to changing seasons. Orientations to stars could also have acted as seasonal pointers, but the existence of stellar orientations for the GCs could not be validated at this stage of the research.

(2) The majority (>90%) of the GCs were positioned on the eastern or southeastern sides of the ridges upon which they were built, indicating that rising events may have been more significant than settings and/or that the winter Sun or the summer Moon may have been the intended targets of observation.

(3) The orientations of the gates of the GCs were found to resemble the axis orientations, which can be explained by the fact that the gates were usually located in the middle of the two end walls of a GC. However, often there were slight differences between the axis and the gate orientations of a GC.

(4) The observed small differences in the axis and gate orientations of the GCs, as well as the orientations towards standing stones located close to the axial direction of a GC on some sites suggest that, in the future, the orientations of each structure and its surroundings should be individually investigated further to determine whether the orientations towards the gates and/or prominent cairns or standings stones had been more important for the builders than the axial directions of the GCs. It is especially suggested that the reinvestigation should include a 'skyscape' analysis, where the full windows of visibility towards the horizon via the gates from the central parts of a structure should be taken into account.

(5) The large (>35-m long) GCs were oriented differently from the smaller (≤35 m) GCs. Many large GCs were oriented towards the solstices, while the smaller ones did not show this feature. The smaller GCs may have been oriented towards the Moon, while the larger ones were oriented to solar events.

(6) The differences in the orientations of the large and the small GCs suggest that the structures traditionally known as 'Giants' Churches' may be a heterogeneous group consisting of at least two types of structures, represented in this study by the GCs ≤35-m long and the ones >35-m long. The smaller ones may be remains of very large houses, or otherwise belong to a different tradition of construction.

(7) If the small GCs are indeed remains of houses, their orientations might be related to the orientations of the Middle and Late Neo-lithic housepits of Ostrobothnia. The differ-ences observed in the orientations of the largest and the smallest GCs thus provide another interesting direction for research.

(8) Lidar observations were shown to be useful in archaeoastronomical analysis as a complementary tool to be used with on-site measurements and observations, especially in the case of large and irregularly-shaped structures that are difficult to comprehensively observe at ground level.

6 NOTES

1. As the acronym suggests, Lidar (Light Imaging Detection and Ranging) is a remote sensing technique which uses a laser to measure the distance to a target. The measurements can then be used to create a 3-D model of the target (cf. radar).
2. The 'NBA' is the National Board of Antiquities of Finland.

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