PROBABILITIES OF DESIGNED ALIGNMENTS AMONG LARGEST PREHISTORIC MOUNDS AND MOST PROMINENT NATURAL FEATURES IN SCANDINAVIA – with a comparison to patterns among train stations, campgrounds, and feed stores

Four different sets of existing geographical features in Scandinavia are compared to randomly distributed points in their abilities to create accurate large-scale three-point alignments. Three of the sets are contemporary while the paper's focus is an unbiased set of the largest mounds in Scandinavia (33), and of the most prominent natural features (14). State of the art software maps both existing and randomly created patterns. Statistically, the numbers of alignments created by three contemporary sets fall generally within the expected median range of random phenomena. Within the prehistoric/natural features, however, comparisons at three accuracies of alignment show that the existing patterns in the all-mounds set are equal or better in the upper two accuracies than 98 of the 100 random sets, each with 33 points. The number of three-point alignments in the combination of mounds and natural features is equal or better than numbers in all 100 of the 47 point random sets (all three accuracies). It is reasoned that some number of three-point alignments among the existing sites (both with and without natural features) were intentionally designed and surveyed, yet the total set undoubtedly *also* includes random patterns. Indications of future research to distinguish designed from random geometry are apparent in: 1) the way the all-mound and combination mound/natural feature sets compare; 2) the numbers of alignments with which each point in the analysis is involved; 3) the overlapping of three-point alignments that indicate alignment patterns up to seven points, one of which is tested against frequency of random occurrence; and 4) the need for overlays of mound dating.

Dennis Doxtater
College of Architecture and Landscape Architecture
University of Arizona
USA

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The author's goal of investigating human experiences in built or natural settings has been to understand the workings, at any scale, of two fundamental psychological means of storing information in the mind: as "objects" and as "maps" (a professionally licensed architect with a degree in socio-cultural anthropology, interdisciplinary doctoral work with a minor in environmental psychology). For a fuller discussion about the practical application of this distinction in design and planning see Doxtater (2008). In brief, humans appear to frame what they “do” in physical settings in distinct categories of experience: wayfinding, task-performance, non-symbolic social territoriality, cultural (extrinsic) expression, and visual/non-visual (intrinsic) aesthetics. Each has its own kinds of objects and maps, specialized, as it were, for particular “affordances” in J.J. Gibson’s terms (1996).

Focusing on the “cultural expression” category of experience in physical settings, it is not surprising that the most extensive organization of integrated objects and maps occurs where socio-cultural groups have occupied settings for long periods of time, i.e. primitive, prehistoric, or traditional places. While the description of these settings, particularly as architecture and site complex, typically garners the most attention for their object characteristics, experiential mapping is essential to develop any fully symbolic or religious meaning of the setting. The key word here capturing the integration of symbolic object, space and experiential practice, is “Ritual”.

This perspective drove the author’s dissertation investigating cultural expression in Middle-Ages farm settings in Norway (Doxtater 1981). Note that this initial work was not large-scale, having little to do with possibilities of prehistoric or Middle-Ages surveying. Thirty years ago, it was clear that existing ideas about vernacular farm architecture in Norway lay mostly in the category of “task-performance”, with copious discourse for example about how farmers notched logs, as a prevalent example of an object focus, while associated mapping might have to do with how an outbuilding might be positioned and oriented on the site to enable throwing out the manure downhill.

A conversation with a former director of the Folk Museum at Bygdøy is exemplary. Arne Berg, an architect by profession, had masterfully sketched bird’s eyes views of many Norwegian farms from the memories of living occupants during the Second World War (Berg 1968). While his associated texts might discuss old paths that people continued to take in the *tun* (farmstead) even after the layout changed over the years, these maps were again mostly task-performance. Wayfinding is not an important issue in a setting so well known as these. Sitting in his museum office one morning, graciously supplied with coffee, I asked him why the topmost log in the gable end of the *stue* (domestic dwelling) was called the “*gauken*” (cuckoo)? His explanation, while actually in the realm of cultural expression, described the simple association of its bird-like shape. This structural detail was only necessary in quite late traditional *stues* that carried a main axial (log) beam from gable to gable; the much longer lived medieval *stue* with its smoke opening in the center of the roof didn't have ridge beams.

If the "gauken" term could be traced back to the classic medieval *stue*, it could have expressed more affectively symbolic, spatial and even ritual possibilities. Cuckoo clocks as dwellings show folk celebrations moving across thresholds formed by the house axis and gable, i.e. from one symbolic domain to another. The old folk conception of two halves of the year comes into play as we learn that the cuckoo expresses the cusp between them. The first cuckoo heard in the spring was the harbinger of this passage. Thus it is quite possible that back in very traditional times, the east-west orientation of the domestic dwelling had ritual associations of transitions between north and south symbolic spheres. Cuckoo clocks are latter day representations of a now largely extinct, heritage of ritual layouts and actual practices on farms.

Even today when visitors learn about the old folk culture at Bygdøy, little is said about the rich symbolism and related ritual practices associated with these settings, vividly described in accounts from the early part of the last century, e.g. Birkeli, Munch, Stigum, and Sundt among others.   As for the author's reading of these first hand sources, it was clear that Middle-Ages farms in Norway maintained a highly formalized symbolic layout and ritual usage, probably consistent with patterns from their recent Viking past. One piece of this work focuses on the re-orientation of farm *stues* that began after the Reformation (Doxtater 1990). It argues that, contrary to technical ideas about solar gains in *stues* with windows for the first time, the change from an ancient east-west ridge to new north-south orientation finally recognized a fundamentally Christian spatial structure being expressed more fully in remodeled Reformation churches. Socially, the shift was from dwelling, with its fundamentally Norse meanings, as primary setting for passage rites such as marriage, to the church with all of its connections to larger spheres of organization.

This is an incredible cognitive phenomenon, where apparently without any formalized proscription by the Church, farm families became aware that "life-death", "male-female" domains and axes in the dwelling were ninety degrees off the orientation of newly (re) expressed similar meanings in the church. In a sense this starts to track mapping at larger scales. Even though dwellings may have been ten or twenty kilometers from the church, still there was a feeling of integrated or connected spatial meaning. Of course such a change in *stue* orientation might well have strengthened the meaning behind weekly and rites of passage trips to church, perhaps diminishing ritual usage of more ancient natural collective sites. By the early twentieth century, the domestic *stue* had lost virtually all of its "map" or ritual meanings, while retaining only symbolic "object" vestiges of centers, thresholds and the like. This work on *stue* reorientation has been cited by Scandinavian and UK scholars: (Pearson, M. P. 2006; Pearson, M. P., Sharples, N., Symonds, J. 2004; Söderberg, B. 2003; Pearson, M. P., Richards, C. 1999; Crawford, B. E., Smith, B. B. 1999; Steadman, S. R. 1996; Pearson, M. P. 1993). Any "map" understanding of the old farm culture, particularly in the category of cultural expression, was outside conventional thinking when "objects" as buildings and furnishings were imported to urban folk museums in the early 20th century. While task-performance spatial relationships were recognized, any symbolic meaning in site layout building orientation was not (for a related paper see Doxtater 2005).

One final note about cultural space in Scandinavia may be in order. In the author's work on Swedish office architecture (1994), the evaluation of expressive settings and a less symbolic but highly participatory kind of "local" ritual remains on the scale of unit buildings and sites as kinds of quasi-traditional villages. Swedish offices are unique in the world in their ritualized daily oppositions between individual and groups at up to three formalized social and spatial scales. While some architectural and ethnographic literature on the phenomenon does speak to the category of simple social territories, much emphasizes task-performance or communication adjacency of individuals having to work in groups. Yet here again, not unlike the reorientation of the *stue*, the underlying, spatially formal basis of this fundamentally cultural expression remains in the margins of theory, not only within Scandinavia, but within any broader history of architecture (aspects of Space Syntax analyses being the exception: see Hillier & Hanson 1984). A synopsis article can be found in Sweden's professional journal Arkitektur (Doxtater 1992).

Given the above reasons why map aspects of experience in physical settings remain problematic in terms of practice and research, compared to those of the object, one can quickly understand the guttural negative response of many scholars to the idea that large-scale symbolic frameworks on the landscape might have been important to religion and social organization. First of all, while they may connect obviously symbolic objects like burial or memorial mounds, there is little immediately artifactual or object-like about them. The mounds themselves are so minimalist in object characteristics like formal layouts, overt symbolism and orientation, that it seems highly improbable that their builders located them via accurate, symbolic, geometric patterns in the natural landscape. Yet if one could establish some reasonable probability of such a phenomenon, the implications would be huge. It would suggest that the integrated social contract between individual (family) and collective group (see Daun 1991, Stromberg 1991) didn't begin in Middle-Ages farm communities, lasting for hundreds of years and reemerging in recent decades after a relatively brief hegemonic hiatus. Its origins might rather lie in several thousand years of highly formalized, integrative ritual in the larger natural landscape.

Such ideas need to be eventually vetted in context with literature on landscape based religion or religious sites, e.g. Bradley (2000, 2006), Brink (2004), Hastrup (1985), Mulk & Bayliss-Smith (2006, 2007), or Nash (2000). One should also consider work addressing smaller scale Eliadian spatial structures of symbolism and ritual, e.g. Hedeager (2001), Damell (1985), Doxtater (1981), or the mythic analysis of Ross (1999). Also waiting for some eventual consideration are the more purely social, organizational and spatial implications found in Fabech (2006) or Kristiansen (2004). Even examinations of the orientations of graves, dwellings and early churches, e.g. Abrahamsen (1985), Eide (1986), and Randsborg & Nybo (1984), may yield potential relationships to large-scale geometry.

Landscape archaeologists, while not suggesting formal, ritual layouts, are increasingly discussing how people actively used their larger physical settings. Rudebeck (2002) makes comparisons between the cultural significance of walking on roads in the Mediterranean, including Crete, and roads in prehistoric Scandinavia. While roads were less permanent in the North, they still organized grave monuments and other cultural venues into actively used cognitive, symbolic experiences. Johansen, et. al. (2004) describe the ideas of early Danish archaeologists who suggested that important pathways were created in part by the placement of some 80,000 smaller grave mounds during the Early Bronze Age. They use computer mapping to illustrate these possibilities in one region of Denmark. In Sweden's Bjärre peninsula, Jenny Nord suggests how people experienced its dense cultural landscape, including rocks with cup marks, smaller and larger mounds, and viewsheds (2007). Farther north in the Trondheimsfjord region, Sognnes describes the way Bronze Age mounds were intentionally placed to be seen from active waterways (2000).

The primary purpose of the present paper, however, does not yet reach out to these ultimately necessary considerations, in some academic field(s) studying sacred geography, about what might have been the actual experiences and cultural purpose of large-scale alignments.

Rather it simply attempts to illustrate that using a little computer technology, one can more thoroughly evaluate the *possibility* that prehistoric cultural expression (maps) occurred at the largest landscape scales in Scandinavia, just as it did in smaller scale subsequent examples described above.

Technical issues of prehistoric surveying

One of the first impediments to doing serious research on large-scale ritual maps is the common task-performance assumption that prehistoric people didn't have the necessary surveying technology. This issue, however, may be one of the least problematic. Perhaps the best earliest evidence of larger scale surveying in Europe comes from the Roman placement of twelve watchtowers along a straight 80 km line over hilly terrain in Germany (Söderman 1989). The greatest deviation of any particular tower from this line along the Neckar River is two meters (deviation of about 0.016° at an average distance between towers of about 7,000m; limit of unaided visual acuity is 0.017°). The question here is not whether the Celts or other Iron Age peoples borrowed this technology from the Romans, but whether such surveying ability existed much earlier in the Mediterranean world, and perhaps made its way north in Bronze or even Neolithic periods. Bronze Age archaeology (e.g. Kristiansen & Larsson 2005) describes considerable cultural transmission that occurred between the Mediterranean and the North. While evidence of this transmission does not include large scale surveying, the positioning of the four most recognized "palaces" in a framework of natural sites on Minoan Crete provides a clear example of this kind of technological ability in the period around 1700 B.C. (Doxtater 2009). Much more is known about the remarkable surveying and related mathematical abilities of the Egyptians (Dilke 1971), culturally associated with the Minoans.

This technology, as remarkable as it may seem, turns out to be quite simple. The actual "instrument" used by the Romans might have been threesomes of "range poles" (Gallo 2004:14) aligned across the landscape. In "prolonging" a line, one of the (exterior) poles is moved to an aligned next position and so on. The accuracy of this method depends on the diameter of the poles and their distance apart. Given poles of 0.10 m in diameter, an accuracy of visual acuity or 0.017° can be achieved when the poles are spaced about 300 m. As a field experiment in large scale Chacoan organization in the American Southwest (900-1250 A.D.), the author built two three meter tall tripods, each with a plumb bob (Doxtater 2002, 2007). Surveying in the field tested backsighting methods with the tripods about six meters apart. It proved possible for a single surveyor to align an interim point between two landscape features 100 km or more apart, at accuracies in the range of visual acuity (0.017°). Prolonging a long line, as defined by Lekson (1999:118) for his 700 km "Chaco Meridian" also in the Puebloan Southwest, is easier than creating one or more new aligned interim points between two preexistent distant landscape points, where the two end points cannot be seen from any one interim point.

What is most interesting about the Roman layout is the accuracy and geometry of the line itself, since neither viewing the waterway nor signaling the two nearest towers would require the towers to be aligned in a single long accurate line. It could have simply been a bit of technological showmanship, with the prolonged line reflecting the general direction of the Neckar River. While the line is several degrees from being a meridian (north-south), it apparently couldn't have been oriented to magnetic north because the Romans didn't have compasses (Gallo 2004:23). If there was some spiritual or symbolic connection of the line to more distant natural or built features, say from a mountain pass in the Alps toward Rome, and some northern landscape feature farther north, then the surveying process could have been different. In this case the watchtowers would have been interim points in a much longer line.

Here this process would have been one of trial and error. Approximate interim points could have been set up on ridges or high points along the full length of the line. It must be possible to view the two adjacent points from each point of the total line. While the technology is still simple backsighting with pairs of tripods at each point or using range poles, multiple iterations of aligning with different threesomes will eventually straighten the line to requisite accuracies. See Lewis (2001:223) for diagram and fuller explanation of this process. Recently, the author sent such a simulation, as part of a larger paper on the Ancestral Pueblo in the US Southwest, to the editor of the *Journal of Surveying Engineering*, Tomàs Solar, an expert in the field with the National Oceanic and Atmospheric Administration (US). The goal was a technical critique of surveying issues. While the article didn't fit the equipment oriented profile of the journal, he did read the paper thoroughly. After e-mail exchanges about technical issues were over, the author still didn't know if the editor believed that the Ancestral Pueblo people could have done this kind of surveying. After a simple e-mail asking this question, the editor simply replied: "why not?"

Considering such possibilities in prehistoric Scandinavia, one logically asks about stretches of open water between land areas. Were winters cold enough, for example, to ice over the Skagerrak Strait between present day Denmark and Norway, thus making connecting surveying possible? Map data on historical conditions from the SMHI (Swedish Meteorology and Hydrology Institute) illustrates that the strait is mostly covered in a typical hard winter. But what was the climate during the Early Bronze Age, beginning about 1,500 B.C.? The Holocene pattern is a major warm-up after the last ice age and then a gradual cooling down, at least until very recently. The climatic summary of the Ystad Project, a major cultural/ecological study over the past 6000 years in Southern Scandinavia (Skåne), provides evidence that in spite of warmer summers, winters were colder (Berglund 1991:439). Thus in the case of the Skaggerak, although precise climatic determinants are difficult for prehistoric periods, it is not at all impossible that ancient surveyors could often count freezing over in hard winters, perhaps even more so than in historically recorded times.

Descriptive accuracy, selection of sites, and probability testing: an example of Danish *Borgs*

The first more scholarly critiques of assertions of designed landscape alignments relied upon computer procedures testing claims about Ley Lines in England, usually under 10 km in length. As detailed thirty years ago by archaeologists Williamson and Bellemy (1983), random arrays of points at similar scales and accuracies produced many coincidental alignments. Other brief studies of random alignments--as much exercises in computer application *per se*--produced similar conclusions, e.g. O'Carroll (1979) and Papadopoulos (2001). For any given number of points (sites) of a given dimension, spread in a defined spatial area, numbers of three, four, five, etc. point random alignments at a defined accuracy can be predicted. Generally these facts are taken to mean that most if not all assertions of intentionally aligned landscape features are probably wrong.

Two things have been missing in these limited critiques of larger symbolic landscape structures. First is the most obvious, i.e. that just because some larger number of random alignments exists among a set of features doesn't rule out intentional patterns among some subset. It just means that using comparisons with random phenomena to prove intentional design is more complicated. While prehistoric builders might have understood a few coincidental alignments, particularly with natural features, and might have intentionally designed additional layouts, they would have had no clue about some much larger number of random patterns. The second and more important ingredient missing in the limited literature on random geometries is application to a particular cultural landscape setting, where the selection and definition of "points" is clear, and the spatial and cultural scale of analysis is well reasoned. The first mainstream publication to test the alignment of built features against random patterns was Swanson's GIS based analysis of signal fire alignments at relatively small scales of several kilometers on Cerro Moctezuma, the apparently sacred peak with a kiva-like feature visible to the west of Paquime in Northern Mexico (2003). Using ten randomly generated sets of points on the mountain, and the Student's *t*-test statistical process, he concluded that the existing pattern of signal locations had a high probability of intentional design. Note the limited number of random sets used and the reliance on statistical methodology to infer probability.

Also more recently, but in the Old World archaeology of Scandinavia, Stahlqvist (2000) enlisted statistical faculty at the University of Uppsala for his novel dissertation seeking to prove that Neolithic peoples used the locations of small burial mounds, at relatively short distances, to create "cardinal crosses" associated with territorial boundaries. By randomly varying points away from existing intersections and along the axes of cardinally (north-south or east-west) related crosses, Stahlqvist, et.al. felt they had distinguished designed from random patterns. The mixed reception of this work by Scandinavian archaeologists appears to be one of the motivations behind Wienberg's (2002) piece on "*Pseudoarkeologi and sacral topographi*". A professor of Middle-Ages Archaeology at Lund, Wienberg wants to know where the limits between legitimate research and popular beliefs, *a la* Von Daniken, lie.

Interestingly enough, Wienberg early in his career admittedly became interested in a possible designed alignments among Danish parish churches. Ultimately he mathematically determined that with 2692 such churches peppered across the limited landscape of Denmark, the probabilities of random alignments are very high (he doesn't say what number of churches can be expected to align, nor at what accuracy). This was proof enough for him, apparently, that because random alignments exist, medieval church builders couldn't have lined up any subset of the whole. Even in Wienberg's largely negative critique of Stahlqvist—where the number of small burial mounds far exceeds that of parish churches--one finds little technical discussion about surveying techniques, geometric accuracies, or even probability analyses. This is generally true about all the examples of sacred geography discussed in Wienberg's overview, and exposes several problematic issues on *both* academic and amateur sides of the larger question.

Before *anyone* can begin to seriously figure out whether prehistoric people surveyed site positions, one must have the ready means to accurately describe geometric relations on the surface of an ellipsoid earth. This is not rocket science, given computers, GPS, professional surveying equipment and a bit of advanced math. The author, for his part, paid over 10K for custom descriptive and analytical software called "Geopatterns" (Doxtater 2007). A new 8K version is in the works.

The second essential issue builds on this descriptive basis, carefully specifying reasonable sets of sites in well-defined areas by which to test existing patterns against random ones. At one extreme is the huge number of sites, like Wienberg's Danish churches or Stahlqvist's mounds (he as well was first interested in landscape patterns of churches), where it seems difficult to select a subset within which designed patterns might be plausible from the perspective of a cognitive, ritually used (or perhaps esoterically known) map. Other examples, like the fifteen round churches on Bornholm, afford a clear set, but no testing against random patterns is ever included in assertions of designed landscape patterns (see Wienberg's discussion of Bornholm "theories").

To clarify the problem a bit, one can quickly take the example of the late prehistoric Danish *borgs* (generic term for prehistoric ring forts), first citing existing amateur assertions about alignments, then looking more closely with Geopatterns. One can use the set of six listed in Wikipedia, including very accurate GPS positions. This is a very small, clearly discrete set. While Wikipedia isn't necessarily the ultimate source, definitions are most often written by experts in their fields. In this case the writer mentions insider knowledge about a possible *borg* in the Oslo Fjord (not included in the set).

Given the six *borg* names and locations, one can find amateur websites where people have drawn Google Earth lines that appear to align Aggersborg, Fyrkat and Trelleborg (W). Placing these positions in Geopatterns, one can quickly determine that the precise line between the centers of the *borgs* at the two ends runs about 1,464 meters from the center of Fyrkat *borg*. The angular error of Fyrkat from this line is 1.613°. Typically no figures of accuracy are given in such web sites. So how accurate is 1.613°? When archaeoastronomers talk about accuracies of alignments between features on the earth and heavenly objects, they tend to use a range up to two full degrees (Anthony Aveni used this number in a presentation at a Society of American Archaology conference in Austin, Texas). The answer to this question in regard to Aggersborg-Fyrkat-Trelleborg may well lie in another geometric *borg* relationship.

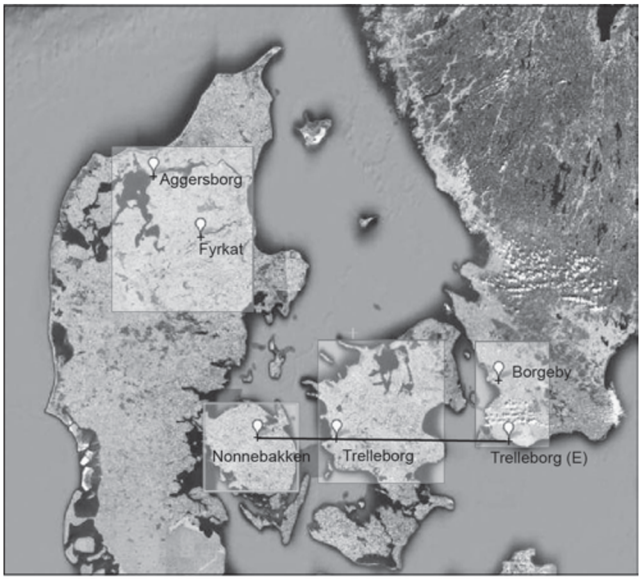


Fig. 1. Locations of six Danish *borgs* and related test areas for comparative random points.

The three southernmost *borgs*, Nonnebakken, Trelleborg (W), and Trelleborg (E) form a far more accurate alignment. The line from the center of Nonnebakken to the center point of Trelleborg(E) in southern Sweden, misses the center of the most popularly known Trelleborg (E) by 28 m, or an error of 0.022°. The diameter of the highly formal ring layout is about 185 m and the distance of the overall line is 174.887 km. Accuracy here is just above that of the line of Roman watch towers, again 0.016° or right at the limit of visual acuity with the naked eye. The three rings in Denmark are positioned much farther apart than the Roman towers. In addition to this alignment of the three southernmost *borgs*, this line is also cardinal (west-east) in orientation. The relationship between Nonnebakken and Trelleborg (W), on Denmark, is more accurate at 89.859° (0.141°), while Trelleborg (W) to Trelleborg (E) is 88.268° (1.714°).

In contrast to cases where very large numbers of sites exist, a clearly limited well defined set of sites allows one to set up reasonable test areas to compare existing geometric patterns with ones generated randomly. The test areas illustrated in figure 1 reflect approximate geographies where the six *borgs* exist. Most of the areas in the test frames are buildable.

One can first test the alignment of Aggersborg-Fyrkat-Trelleborg at the existing accuracy of 1.613°. How often does this pattern occur randomly? Placing similar numbers of random points in each of the four test areas, a three-point alignment at this accuracy occurs five times in ten test sets, or 50% of the time. Just like flipping a coin. When we reduce the accuracy to that of the existing Nonnebakken-Trelleborg (W)-Trelleborg (E), or 0.022°, setting the application to statistically search in groups of 10 sets (6 random points each), one goes through ten groups, or 100 sets, without finding an alignment. Then searching groups of 100 sets, the first alignment is found in the 300-400 set range. Continuing on to 1,000 total sets (again of 6 random points each), the total number of alignments found is five, or 1 in 200 (0.005%).

Using the "search string" capability in the application to combine simple patterns, the cardinal relationship between Nonnebakken and Trelleborg (W), at 0.141°, can be added to the three point alignment, i.e. "A+C(2)", where the parentheses state the overlap or commonality of points between the two patterns. This essentially requires three random points to not only be aligned within 0.022°, but at least two of the points also need to be cardinally related at the accuracy of 0.141°. This pattern can obviously only occur among random points in the three southernmost test areas. Running the application search similarly in groups, the first pattern is found in the 2,000-3,000 range of sets. Then four additional matches occur in the following 98,000 sets (groups of 10,000). The probability here is 1 in 20,000 (0.00005%).

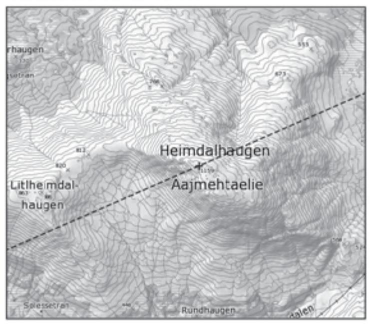
Probabilities in these ranges seem to indicate that precise "professional", compared to "amateur", description and testing might bring the *possibility* of prehistoric surveying in Scandinavia into the realm of serious research.

"Object" description and "map" location of largest mounds and important natural features

The focus of the following exercise is based on a list of 33 largest mounds 49 meters and above in diameter, and 14 most significant natural features. The reader should note that this exercise does *not* attempt to show that *any particular* alignment was designed. Unlike the simple test of the six *borgs*, larger numbers of sites will produce generally similar numbers of randomly

GUDFJELLOYA

HEIMDALHAUGEN



BERTNEM

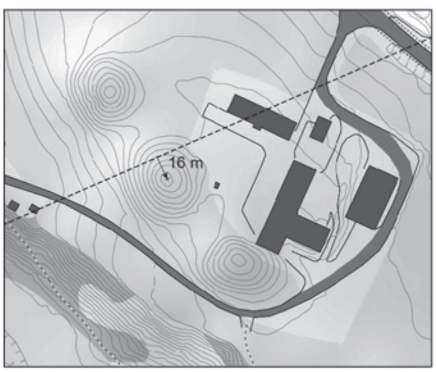


Fig. 2. Two accurate three-point alignments: one involving a large mound site (above) and the other, three natural features (right).

HELAGSFJELLET

generated alignment patterns. The attempt, however, is to illustrate, with simple probabilities, that the number of existing patterns, while mostly in the range of at least random outliers, is nonetheless statistically high. The much more challenging issue of distinguishing between designed and random patterns will be suggested as future research.

The two alignments of figure 2 are shown primarily to be “up-front” about how certain sites and features have influenced first of all the present inquiry into large-scale surveying, and more importantly how they relate to the choice of sites and features used in probability tests. The 0.013° (average of two angular accuracies from each end). 69.705 km alignment between Bertnem-Heimdalshaugen-Gudfjelloya is accurate within the range of the Roman watchtowers and Danish *borgs*. The precise line from the two benchmarks on the tops of Gudfjelloya and Heimdalshaugen misses the high point of Bertnem’s center mound by about 16 m. While technologically prehistoric surveyors might easily have laid out such a line, thus locating the three large mounds, given the number of large mounds and other natural features in Scandinavia, one cannot at present set up a probability test for this small subset.

The second alignment of figure 2 is a totally coincidental geometry between three natural features: Gudfjelloya, Helagsfjellet, and Yding Skovshøj, up until very recently the highest topographic point in Denmark. The line is also very accurate at 0.011°. The writer became aware of both of these alignments while spending considerable time a decade or so ago looking at the locations of Middle-Ages churches in Trondheimsfjord and Storsjön, two communities on either side of the highest mountain in the area, Helagsfjellet, with respective *alting* sites and evidence of reciprocal ritual exchange during late prehistoric times. This study didn’t produce enough testable patterns to warrant further work.

These two alignments existed in the author’s data prior to the present study of the set of largest mounds. The comparison between existing three-point alignments and those created in test areas with equivalent random points will obviously be stated in terms of total numbers for each (at different accuracies). The preexisting knowledge of the two illustrated alignments produces a slight skewing of the results at the magnitude of one alignment. The all natural alignment of Gudfjelloya, Helagsfjellet and Yding Skovshoj, as well as two others, occur in *both* existing patterns and random mound-natural feature relationships as well. They are constants and their inclusion in the test sets does not negatively bias results.

How then were the sites of the two existing sets chosen? The list of thirteen natural features, including the four illustrated above, are taken to be a logical set of most evidently significant regional points in Scandinavia. Some have archaeological sites associated with them, many do not. This is not however, a determinant of inclusion. Rather, it is the natural character of the feature in its respective region:

1. **Gudfjelløya:** Perhaps one of the most intrinsically and culturally interesting natural sites in Scandinavia, Gudfjelløya (God-Mountain-Island). The Sami offering site lies at the boundary between agricultural cultures to the south, and hunting and gathering ones to the north (Skevik 2005:249). The following is a condensation of description and sources about Gudfjelløya from Manker (1957:274-277). The first recorded source for "*Tunnsjøguden*" is from 1723 (Johan Randulf) as part of an explanation of a carved god figure as the "*Tonsie Gud*". The cult site is said by several sources to be well known among the Sami, and used for a long time. Linder (1854) speaks of lore about the offer place on a protruding island (812 m high and about 3,000 m in diameter) with a rock cleft in which the remains of reindeer and other sacrifices are found. The Sami left their reindeer alive and tethered near the ravine in the rocks for the gods to eat. The ravine on the top of the island is described by Helland (1909) as possibly penetrating down to the level of the lake. The lake is remarkable in itself; it is so deep that it doesn't freeze over in the winter (L. Johansson 1946). The well-known Sami site does not belong to the more private sacrifice place "*tjekku*", but was used collectively "*sjielavaja*". From the Ostersunds-Posten (1953) comes the description of a flat rock wedged in the cleft, on which offerings are left at solstice times (*solverv*). Manker's own investigation of the island describes the "*sprickan*" or crevasse as running in an east-west direction about 20 m at a width of from 20-50 cm. The depth could not be determined, but the sound of dropped stones reverberated for some time. He concludes that Gudfjelløya gives the highest convincing impression (of a natural sacred place) with its pronounced elevation and its "459 m" rock face down into the lake.

2. **Helagsfjellet:** At 1797m, the highest and most prominent peak between Trondheimsfjord in Norway and Storsjön immediately east in Sweden, areas with

prehistoric ritual relationships. Visible from higher points in both areas, the peak contains the unique glacier in the central area between most southerly and northerly mountains of the Scandinavian spine. In Swedish, *"Hel"* is defined as "whole", "entire" or "complete", and *"lag"*, as a "law", "social group" or "team". Even though one can find no recorded folklore history associated with the peak, its name can connote some coming together of a group, perhaps even ritual. Understandable in this vein, perhaps, is the name of its southern flank "Predikstolen", or "pulpit".

3. **Heimdalshaugen:** 1160 m peak prominent to the Namsen valley. From an encyclopedia of Norwegian Late Iron-Age/Viking geography, one finds a full two pages dedicated to this mountain in Harran, Nord-Trøndelag. Eighteenth century geographers such as Schøning describe the peak as the highest in northern Scandinavia. It is also called "*Trondhjems bukk*" by seamen who use its usually white top as a navigational point from as far away as 120 kilometers. Important are the mythic or sacred meanings of "Heimdal". The philologist K.B. Wiklund's study of Lapp and Scandinavian sacred places clearly identifies Heimdalshaugen as an ancient place associated with the Norse god Heimdal (Melentinskij 1973:48, Turville-Petre 1964:149, Dumezil 1973:130).

4. **Yding Skovhøj**: Until 2005 listed as the highest point in Denmark. Today, technically Møllehøj is highest at 170.86 m elevation. Long standing measurement of Yding Skovhøj at 173 meters, included the height of a small prehistoric mound. Without the mound, the point measures 0.09 cm. lower, 170.77 m, than Møllehøj. The two points are about 2.693 km from each other. The mound at Yding Skovhøj is not included in the largest mound set.

5. **Ejer Bavnehøj:** This natural point is included as kind of alter ego to Yding Skovhøj. It is technically the third highest point in Denmark, located only 123 meters from Møllehøj, recently established as the Danish high point. The adjacent Ejer Bavnehøj has substantial definition as perhaps the recognized high point in historical periods: "At its summit is a 13 m tall tower, built in 1924, commemorating the reunion of the south of Jutland with the rest of Denmark after the First World War. Historically Ejer Bavnehøj was mostly known as a site for a beacon where signal-fires were lit in order to warn the military and

local population if the enemy were on the way. "Ejer" means "owner". The second part of the name, "Bavnehøj", can literally be translated into "bavne" meaning "beacon" and "høj" from the Old Norse word *haugr* meaning hill" (Wikipedia). This point, like that of Yding SkovHøj, also forms a naturally coincidental alignment with Helagsfjellet and Gudfjelloya, but with the less accurate deviation of 0.074°.

6. **Galdhøpiggen:** At 2,469 m, the highest mountain in Scandinavia.

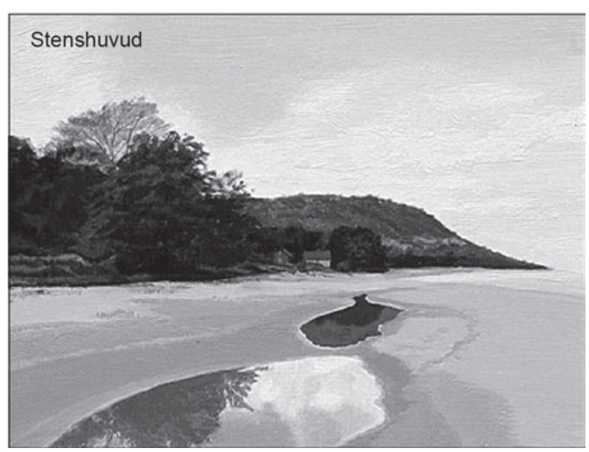
7. **Kebnekaise:** At 2,104 m, the highest mountain in Sweden. This peak is listed in web sites as the most topographically prominent in Sweden.

8. **Straumen:** The narrow inlet in Trondheimsfjord with its coincidental aligned relationship to Galdhøpiggen-Kebnekaise. As seen in figure 3, the narrow, winding inlet to Borgenfjorden has two larger prehistoric mounds, one on each side, each 35 m in diameter according to the Norwegian archaeological database Askeladdan. The center of the passage is accurately aligned to within 0.058° angular deviation from the precise line between Galdhøpiggen and Kebnekaise. This three-point alignment is the third wholly coincidental natural pattern, and, like the other two, its inclusion in the following set comparisons adds one alignment to *both* the existing and random. The two Straumen mounds are not included in the set used in the present exercise.

9. **Snohetta:** At 2,286 m, the highest mountain in Norway outside of Jotunheimen where along with Galdhøpiggan, twenty or so of the highest mountains in Norway lie. Historically, prior to precise elevation measurement, Snøhetta was considered to be the highest mountain in Norway (Wikipedia). It is the name of a world class architectural firm in Norway [very interesting work in this architect's opinion, frequently attempting to express relations between natural and architectural components].

10. **Hoverberg:** Most unique natural feature in Storsjön, associated with large medieval church community of Berg. Its grotto is the largest rock cave in Scandinavia and was home of a giant according to local folklore.

Fig. 3. Locations of fourteen most prominent natural sites used in the exercise; coincidental three-point alignment between Galdhopiggen-Straumen-Kebnekaise.



11. **Taberg:** Down in the flatland of southern Sweden, one finds two comparatively modest, but nonetheless most unique natural high places. The web site description of Taberg Nature Reserve: "The silhouette of the rounded mountain of Taberg with its double peaks can be seen from far and wide. The peaks of the mountain rise 343 and 341 m above sea level. The immediate surroundings of Taberg are legally protected for their importance to the landscape picture". The immediate area has seen considerable prehistoric iron extraction.

12. **Stenshuvud:** The second, also prominent large natural feature, a mound-shaped massif on the edge of the Baltic in the Southeastern area of Scandinavia is a Swedish National Park. Archaeologically well known, it is surrounded by extensive Bronze Age remains, the most noteworthy being the large tomb cairn at Kivik with its impressive stone tablet carvings. This will be one of the mounds included in the present exercise. One of the two prehistoric *fornborgs* (rock wall enclosures) in Southern Sweden is found on top of Stenshuvud.

13. **Tomtabacken:** Topographically the highest point in southern Sweden (Småland 377m). The "hill" is not visually or intrinsically striking compared to Taberg, 30.557 km to the west, but as the highest point in the region it sports an observation tower on its summit.

14. **Himmelbjerg:** Perhaps the most intrinsically recognized natural point in Denmark (147m). Himmelbjerg, as "sky or heavenly mountain" was regarded until the middle of the 19th century as the highest point in the country. A historical, commemorative tower sits on the high point of the larger recreational site visited by thousands every year. Data bases list no significant archaeological sites in the immediate vicinity.

The above list is as logical and obvious a set of most unique natural points—precise bench marks are used for all—in Scandinavia. It must be clear to the reader that these points, with the partial exception of the two involved in the Bertnem alignment, were not chosen because of any preexisting knowledge about the way they align with the set of largest mounds. All of these natural points, except for Tomtabacken, have alignment relationships with other points in the existing largest mound and natural features sets. But this would be true of *any* set of natural features. How difficult would it be to *a priori*, as it were, find some group of fourteen features to create the statistically unique existing pattern discovered in the exercise? Without having worked with comparative design/random analyses, the reader may have difficulty answering this question. From the author's experience in this regard, "cooking the books" in this case would require an extremely long, extensive, trial and error search through multitudes of sets with thirteen features each. Simply put, it would be difficult to assemble even one additional set to match the present list.

The set of largest mounds needs, of course, to be equally logical and unbiased. The ideal method here would be to find a ranked list of mounds in some recognized archaeological journal or data base. Taking only those largest in diameter would then provide the cleanest set. This, however, is not possible because of the way mound sizes are stored in the archaeological data bases in Denmark, Sweden and Norway (at least during resident work in 2007-8). Facing this initial problem, and knowing that the greatest number of largest mounds are (were) in Denmark, contact was made with IT people at the Danish Kulturarvsstyrelsen (Culture Heritage Authority). For the reasonable price of four bottles of Chardonnay, a list was generated of all mounds over 40 meters in diameter. From this list the decision was made for a cutoff of 49 meters, producing 16 sites in Denmark:

1. **Hohøj (72m)**
2. **Buskehøj (70m)**
3. **Holger Danskes Høj (65m)**
4. **Jelling: Dronning Thyras Høj (65m) and Kong Gorms Høj (65m)**
5. **Plathøj (61m)**
6. **Tårup (60m)**
7. **Rævhøj (55m)**
8. **Bavnen (55m)**
9. **Togholm (52m)**
10. **Galgehøj (50m)**
11. **Gildhøj (50m)**
12. **Troldhøj (50m)**
13. **Bredhøj (49m)**

14. Ringstedhøj (49m)

15. Hjortsballehøj (pair at 49 & 45m)

16. Hashøj and Galgebakken (pair, both 40.8m).

In Sweden and Norway it was not possible to obtain such a neat list prepared by impartial others. The 10 mounds in Norway and 7 in Sweden were discovered by conventional literature searching. There may well be others that should be on the list, but again all sites were chosen prior to doing geometric analyses of the total data set (natural plus built) and additions would not bias the results in any negative way as long as they weren't included because of their alignments with sites already in the set. In Norway:

17. Raknehaug (77m)

18. Jellhaugen (60?)

19. Herlaugshaugen (60?)

20. Borre (50m?)

21. Halvdan Svartes Haug or Haraldshaugen (60m)

22. Alstadhaug (50m)

23. Orland (50m)

24. Buhaugen (50m)

25. Kjerkehaugen (50?)

26. Bertnem (3 @ 30-50m),

In Sweden:

1. **Uppsala (3 @ 70m)**
2. **Kivik (70m)**
3. **Anundshög (60m)**
4. **Nordians Hög (50m)**
5. **Uggarda Räir (50m, Gotland)**
6. **Högom (mound group),**
7. **Steglarp/Mellan Grevie (mound group).**

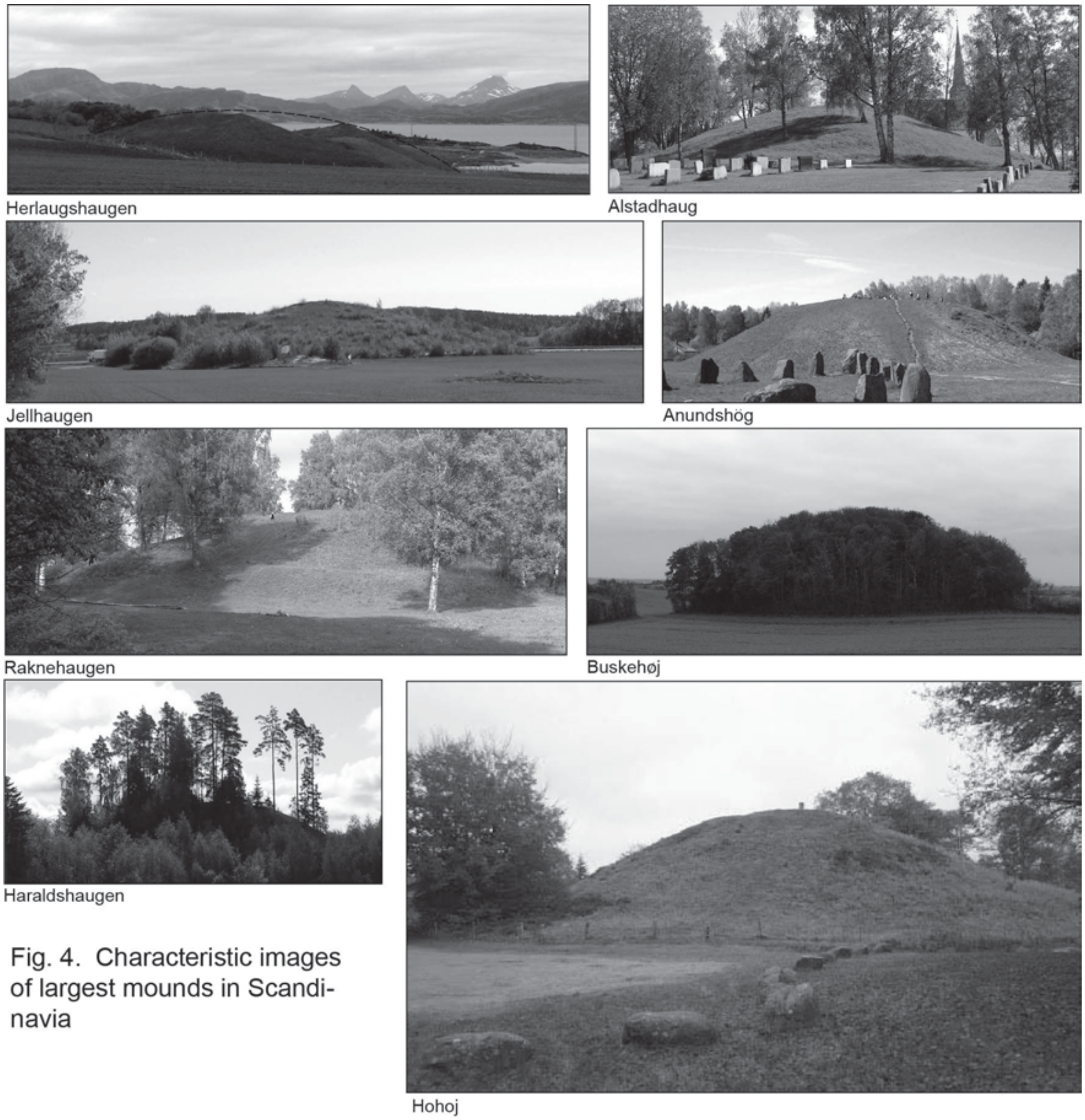


Fig. 4. Characteristic images of largest mounds in Scandinavia

Several of these sites contain a group of mounds and some judgment was necessary about overall size compared to the singular great mounds. Examples of multiple mound sites, beyond pairs, are Borre, Bertnem, Uppsala, Högom and Steglarp/Mellan Grevie. Images of some mounds are shown in figure 4.

As evidenced both from the provided Danish list, and from reading archaeological reports, where they existed, about mounds in Norway and Sweden, it would probably be difficult for any archaeologist to clearly pin down construction dates for the thirty-three different mound sites. Certainly it would be foolhardy for the present interdisciplinary researcher to attempt to do so. While some appear to be neatly categorized, e.g. the very late Jelling or the Bronze Age

Kivik, and several are thought to have been built during the Migration Period, many have not been thoroughly investigated.

Three sets of contemporary features and a baseline of random points

One of the issues frequently raised about comparisons of large–scale geometric patterns between existing and random points in the landscape is the possibility that topography has created statistically unusual relationships. One might imagine a smaller valley, whose disposition is relatively straight. Alignments between sites in this setting might well be thusly influenced. Even in this case, however, if one can adapt the test areas to the valley layout, then a particular set of sites at a specific accuracy of alignments can be tested against random patterns. At the much larger scales of the following exercise--the *average* length of alignments among the prehistoric sites is 810.435 km--geometric influences of topography do not seem to be a likely creator of accurate alignments. In Denmark and Southern Sweden the question is largely moot, anyway, given the very flat character of the land. But even at shorter distances up in the mountainous north, like the Bertnem-Heimdalshaugen-Gudfjelloya line, alignments cross cut valleys, each defined by organic, irregular topographies.

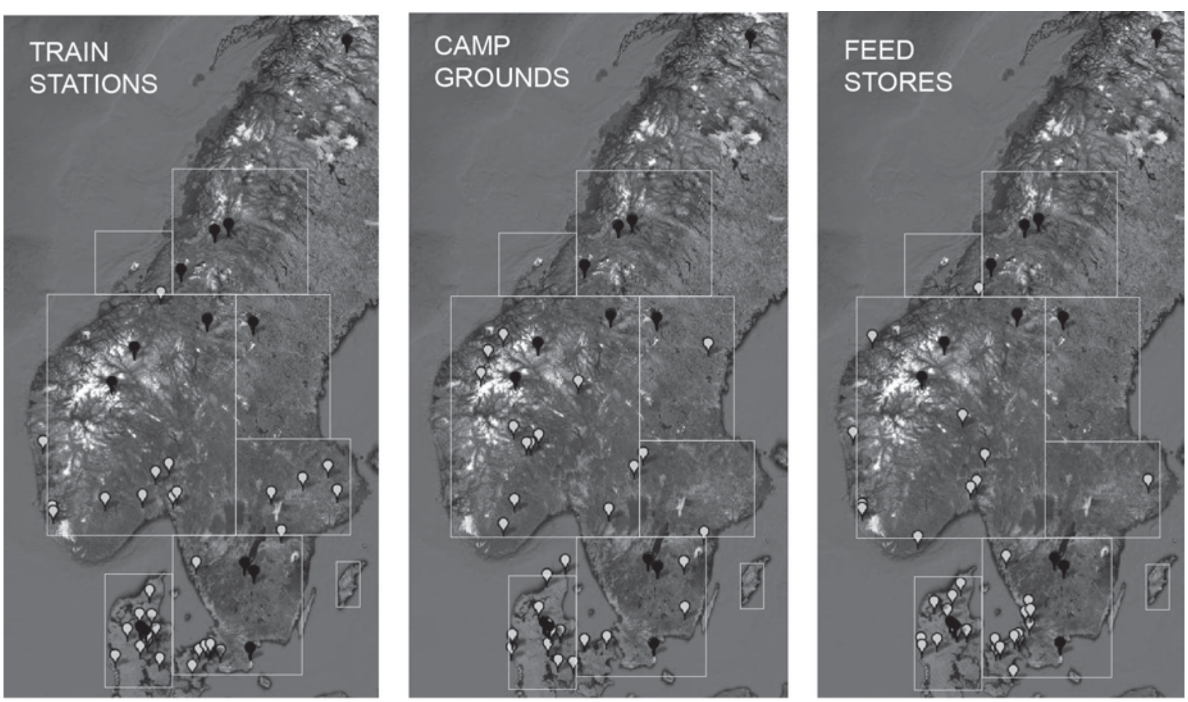


Fig. 5. Locations of three sets of 33 contemporary features each; black markers indicate 14 natural features included in calculation of three point alignments. Outlines of test areas used to generate baseline of 100 sets of random points.

To put a more recognizable face on the assertion that at these scales topography is unlikely to have caused any greater propensity to align, one can look at the number of alignments that contemporary feature sets create. If there is a topographical influence, then the locations of large cities, popular campgrounds, and feed stores might be just as likely to generate higher numbers of random alignments as do largest mounds/natural features. Using the numbers of prehistoric mound sites as a comparative base (33) an equal number of latitude/longitude points of central Train Stations in the largest cities in Denmark, Norway and Sweden were entered in the application (ranked by city size). Similarly, from the website Campingo, the first corresponding number of Campgrounds in each country created a second set to test for alignments. The third, to capture some sort of agricultural geography, was comprised of advertised Feed Stores. No neat list was available here, so the requisite number in each country was added as they were found in the web search. Once in the application, numbers of three-point alignments at or below 0.15°, 0.09° and 0.03° can be quickly determined for each of the three sets (both in the context of the 14 natural features and without).

The baseline of 100 sets of 33 random points to be seen in the following graphs was created from test areas outlined in figure 5. These areas first of all attempt to capture the geographical shape of Scandinavia, independent from variations in topography as discussed above. Because of software limitations to rectangles, this approximation leaves out some land areas and includes some that are water. The numbers of sites of the four cultural sets in each of the test areas are not exactly the same, but a generally reasonable overlap occurs. The random baseline is created by the numbers of prehistoric mounds in each test area, substituting equal numbers of random points in 100 different sets. Because of the time involved in setting up 100 different sets, 33 random points each, the prehistoric baseline is used also to compare with the three contemporary sets.

Testing the existing sets of 1) large mounds, 2) large mounds with natural features

The null hypothesis has two parts: 1) that the diverse large scale natural topography of Scandinavia is essentially random, including some set of most prominent features, and 2) that the placement of largest mound sites in this landscape might possibly be influenced by small scale random topographies, but any larger scale geometric relation between mounds is also random. The test areas of figure 6 are a rough but logical means of emulating of the null hypothesis.

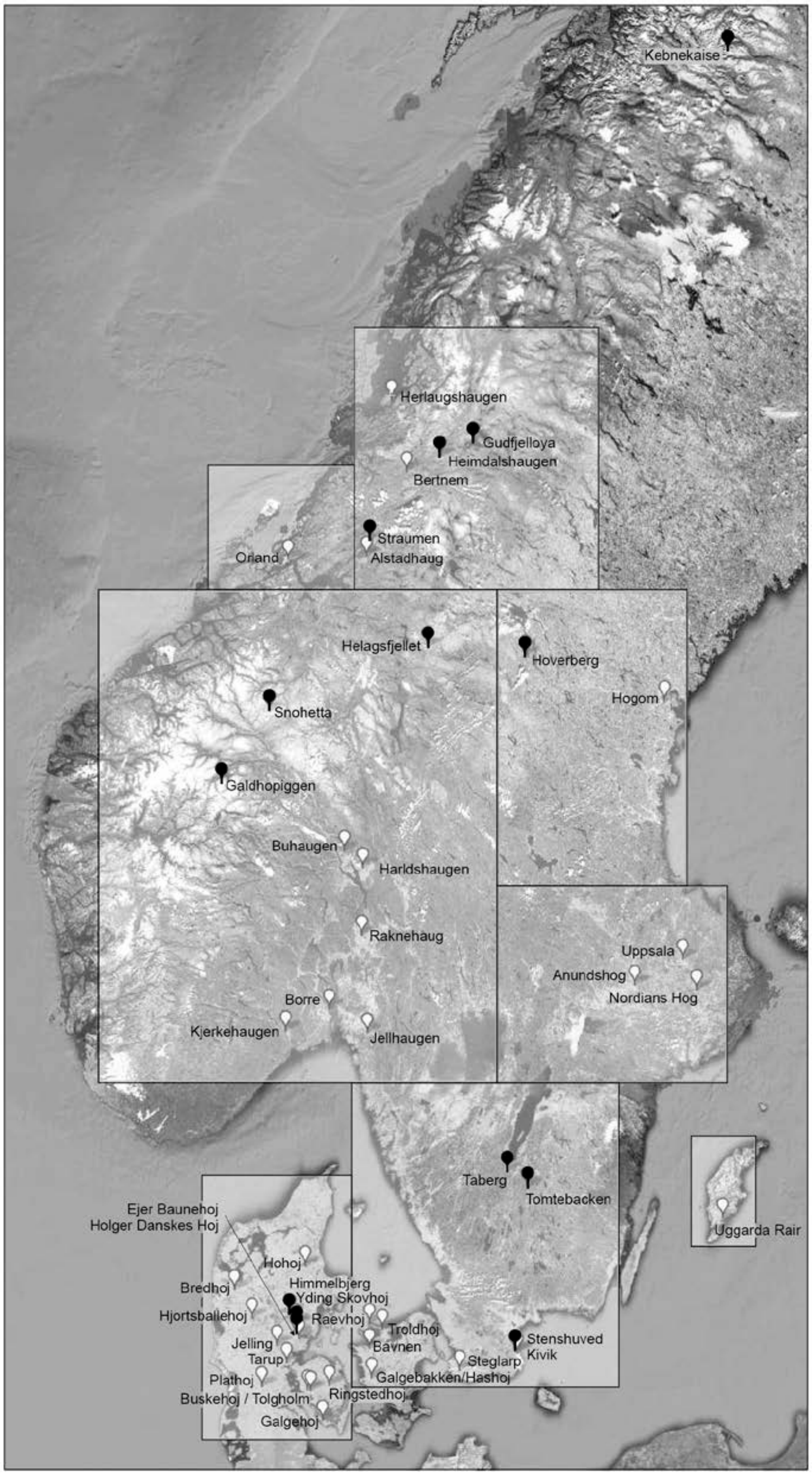


Fig. 6. Locations of 33 largest mounds and 14 most prominent natural features in Scandinavia; test areas used to position equal numbers of random points in 100 sets to compare numbers of three-point alignments.

Equivalent numbers of random points placed in these test areas should create numbers of three-point alignments similar to the existing.

It is prudent to first compare existing largest mounds alignments with those created by sets of random points without including the fourteen natural features. The selection of sites for this test is less subject to some of the inevitable questions about site inclusion of the natural feature set (even though every attempt has been made to make this group as unbiased as possible). If prehistoric societies in Scandinavia were doing large-scale surveying, these practices wouldn't necessarily have been restricted to linkages with natural features. The comparison between "built only" and "nature linked" sets should also be interesting in itself.

In the *borgs* example, a feature of Geopatterns allowed one to ask the computer to automatically create and search high numbers of equivalent random sets at one particular accuracy, without listing data from each random set. In the following situation where sets of 33 random points need to be searched at different accuracies, again, one must manually add requisite numbers of random points to each of the test areas, creating one file with listed locations of the points. This file is then searched at different accuracies in the program's "site analysis" in the same way that relationships among real sites are determined. For present purposes 100 different random files (each with 33 total points in respective test areas) are manually set up and each tested at three accuracies: 0.03° (closest to visual acuity and the Roman watchtower example),

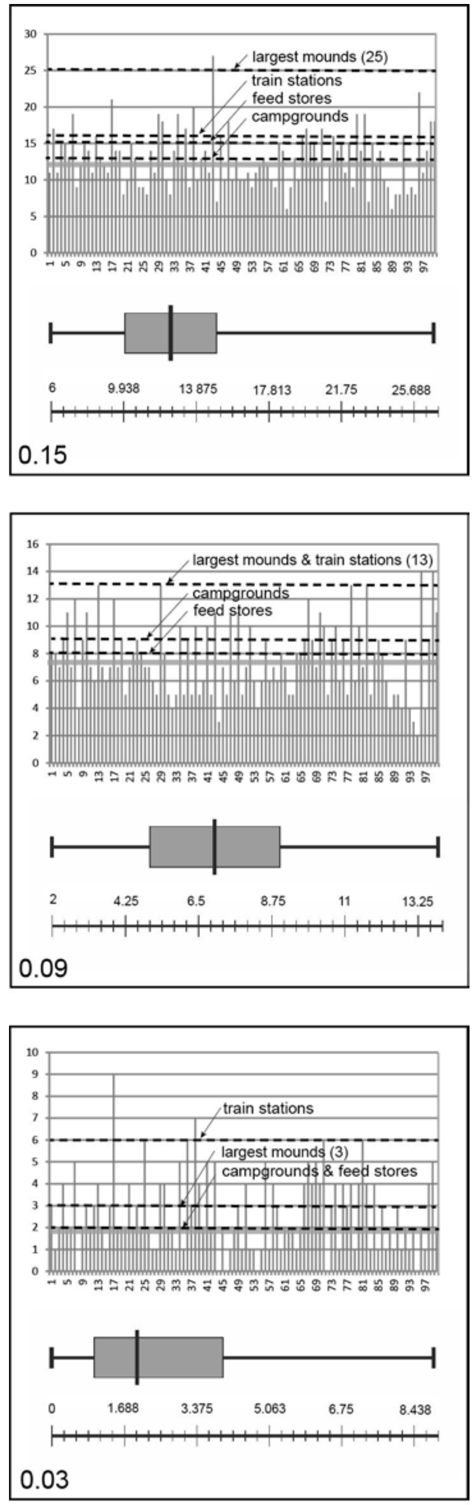


Fig. 7. Column chart and box-and whisker graph comparing numbers of three-point alignments in 100 sets of 33 random points each with four sets of cultural features.

0.09°, and least accurate at 0.15°. Figure 7 shows the comparison of 100 random sets at three accuracies to patterns among 33 existing largest mounds. At 0.03°, existing prehistoric patterns fall squarely within the random probability range as defined by the box-and-whisker graph, at or beyond 62% of the random. But at 0.09° the existing rises well beyond the probability range at or beyond 98% of the random; and at 0.15° the existing does even better at or beyond 99% of the random.

The behavior of the nine scores for the three cultural feature sets (at each of the three accuracies) predictably falls close to the box-and-whisker medians, with two exceptions of the train stations at 0.09° and 0.03°. At first glance, it would appear large-scale spatial transportation connections between train hubs, compared to the lack of any functional relationships among Campgrounds and Feed Stores, are helping to create alignments, even though presumably not specifically designed to do so. Of the six alignments of Train Stations at 0.03°, two seem to suggest this possibility; the pair is actually a foursome: Oslo-Sarpsborg-Göteborg-Malmö. Another line appears to connect at Sarpsborg (Stavanger-Skien-Sarpsborg), but this alignment crosses the Oslo Fjord. The other three cross the open water of Skagerrak Strait. The fact that the actual train stations of Oslo, Sarpsborg, Göteborg and Malmö are very accurately but unintentionally aligned with this precision, may be a case where the geographical coast line may well have influenced the likelihood of such an alignment.

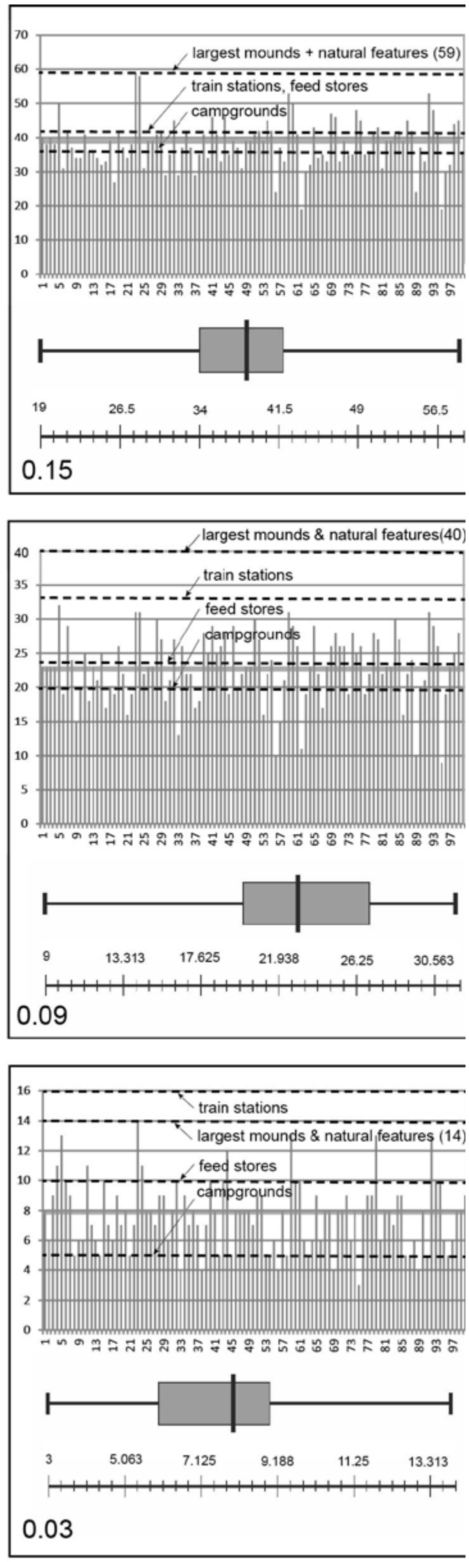


Fig. 8. Column chart and box-and-whisker graph comparing numbers of three-point alignments in100 sets of 33 random points (together with 14 natural features) with four sets of cultural features.

One can now add the 14 natural features shown in previous figures as constantly present in a new list of 100 sets with 33 random points distributed in their respective test areas, searching again at the three levels of accuracy. Figure 8 reveals an even stronger distancing of existing alignments from the random, both including natural features. At 0.03° the existing is at or above 100% of the random, with one equaling the existing. At 0.09° the existing moves totally away from any random set, the highest of which has 32 alignments compared to the existing's 40. At 0.15° the existing recedes a bit but is still at or above 100% of the random, with two equaling the existing.

With the 14 natural features added, again the same two Train Station numbers of alignments (at 0.09° and 0.03°) deviate more from the box-and-whisker medians than do Campgrounds and Feed Stores. The dramatic jump from six to sixteen alignments at 0.03° means that ten have been created by involving most significant natural features. Obviously these ten and at least four which have no natural features are most completely random phenomena without influence of topography, i.e. 14 of 16. Thus at least one set of contemporary cultural features can be found whose randomness in creating alignments at least competes partially with the prehistoric mounds. Even though Train Stations pretty much randomly create competitive alignment numbers at 0.09° and 0.03° levels, compared to Campgrounds and Feed Stores, at the most inclusive level of 0.15° the prehistoric set of features clearly distances itself from all others.

Implications of the data / future research directions

To get a sense of the prehistoric comparison when natural features were included, which created most distance from the random, the 100 sets were tested along a finer gradient of accuracies ranging from 0.03° to 0.15° (again 100 manually created files each). Figure 9 plots the way both the existing and five random set variants behave as they accrue alignments at increasingly higher inaccuracies. In random phenomena, at least, each range is independent of each other in that previous alignments do not influence successive ones. In the graph, all lines, including the existing, accrue according to varying numbers of alignments added at each increment. Most interesting, perhaps, is the way the existing balloons above the three highest random sets (determined from the 0.15° level). Yet it is too early in this kind of work to read this range from about the 0.06° to 0.105° level as reflecting some sort of evidence of designed landscape layouts. The corresponding dip in the three highest random lines at this range might well be simply a random occurrence.

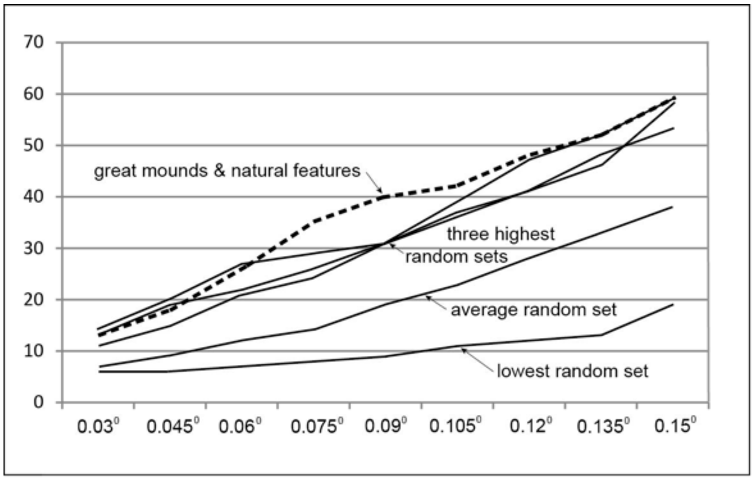


Fig. 9. Comparison of five cumulative random profiles with existing combination of largest mounds and most prominent natural features (from 0.15° level).

Based on present numbers, one cannot say for certain that numbers of alignments among largest prehistoric mounds were intentionally designed. But assuming that technically these societies had the abilities to do so, then the possibility seems to deserve further attention. Interesting research issues should develop as the means of distinguishing designed from random layouts. Future directions might include the following:

1. Accuracies and the role of natural features: Two things appear to point toward the symbolic, cultural importance of linking largest mounds to natural features. First, of course, is the fact that when one adds the 14 features to an already interesting comparison between existing sites and random points, the comparison becomes even more pronounced. But second, when one looks more closely at the list of 59 existing alignments in figure 10 (from the 0.15 level), a markedly greater number of alignments at greater accuracies rely upon participation of natural features. Among the most accurate 30 alignments, 21 involve natural features and 9 large mounds only. Conversely looking at the least accurate 29, only 12 work with natural features and 17 with mounds only. In this illustration, the cusp between these two "groups" is taken at the mid accuracy level of 0.066°. Would a fuller cultural account of the symbolic importance of natural features begin to provide evidence, not only of this content in relation to the building of largest mounds, but in the search for the range of accuracies that prehistoric surveyors might have tended to work within?

	ACCURACY °	LENGTH km	
1.	0.001	1008.724	gudefjeldon - taberg – kivik
2.	0.005	555.391	holger danskes hoj - hohoj - harldshaugen
3.	0.011	992.391	yding skovhoj - helagsfjellet - gudefjeldon
4.	0.012	268.328	togholm – galgebakken/hashoj - stenshuved
5.	0.013	69.705	bertnem - heimdalshaugen - gudefjeldon
6.	0.013	262.366	galgehoj - steglarp - kivik
7.	0.016	918.87	hohoj - helagsfjellet – gudefjeldon
8.	0.018	894.408	holger danskes hoj - ejer bavnehoj – straumen
9.	0.019	1511.305	galgehoj - hoverberg – kebnekaise
10.	0.027	961.285	himmelbjerg - harldshaugen – heimdalshaugen
11.	0.029	794.721	snohetta - raknehaug – stenshuved
12.	0.029	485.639	hohoj - borre – buhaugen
13.	0.029	708.523	galgehoj - taberg – uppsala
14.	0.030	940.897	himmelbjerg - borre – bertnem
15.	0.039	1464.794	ringstedhoj - hoverberg – kebnekaise
16.	0.040	794.365	snohetta - jellhaugen – steglarp
17.	0.040	141.865	himmelbjerg - holger danskes hoj – galgehoj
18.	0.041	1057.218	herlaugshaugen - helagsfjellet – kivik
19.	0.048	639.403	borre - buhaugen – herlaugshaugen
20.	0.050	1432.143	jelling - jellhaugen – kebnekaise
21.	0.053	992.549	yding skovhoj - hohoj – gudefjeldon
22.	0.056	784.359	yding skovhoj - hohoj – helagsfjellet
23.	0.059	848.278	galdhopiggen - straumen - kebnekaise
24.	0.059	160.063	bredhoj - jelling – togholm
25.	0.060	791.990	snohetta - raknehaug - kivik
26.	0.060	139.959	galgehoj - bavnen – troldhoj
27.	0.063	974.081	ejer bavnehoj - hohoj – heimdalshaugen
28.	0.064	945.881	hohoj - borre - herlaugshaugen
29.	0.065	795.296	himmelbjerg - hohoj – hoverberg
30.	0.066	945.881	hohoj - buhaugen – herlaugshaugen
31.	0.068	469.585	raknehaug - jellhaugen – troldhoj
32.	0.072	1042.221	tarup - helagsfjellet - gudefjeldon
33.	0.072	947.226	buskejoj - buhaugen – alstadhaug
34.	0.073	538.588	alstadhaug - helagsfjellet – anundshog
35.	0.074	993.937	ejer bavnehoj - helagsfjellet – gudefjeldon
36.	0.075	967.631	troldhoj - helagsfjellet – heimdalshaugen
37.	0.079	878.082	holger danskes hoj - ejer bavnehoj – alstadhaug
38.	0.080	1044.061	ringstedhoj - jellhaugen – heimdalshaugen
39.	0.081	674.332	togholm - raevhoj - nordians hog
40.	0.088	948.216	togholm - buhaugen – alstadhaug
41.	0.091	1057.564	plathoj - borre – heimdalshaugen
42.	0.093	539.967	bavnen - troldhoj – anundshog
43.	0.108	577.379	gildhoj - borre – buhaugen
44.	0.111	1005.334	holger danskes hoj - helagsfjellet – gudefjeldon
45.	0.111	814.499	jelling - raknehaug – helagsfjellet
46.	0.112	860.512	alstadhaug , jellhaugen , raevhoj
47.	0.113	941.588	orland - hohoj – buskejoj
48.	0.118	1059.527	herlaugshaugen - helagsfjellet – stenshuved
49.	0.122	1037.618	gildhoj - buhaugen – herlaugshaugen
50.	0.123	1071.713	galgehoj - raknehaug – bertnem
51.	0.129	963.509	buskejoj - buhaugen – straumen
52.	0.131	1380.348	bredhoj - borre - kebnekaise
53.	0.136	161.469	plathoj - jelling - hohoj
54.	0.140	650.214	galgehoj - troldhoj – anundshog
55.	0.142	1037.618	gildhoj - borre – herlaugshaugen
56.	0.146	625.674	buhaugen - raevhoj – galgebakken/hashoj
57.	0.147	493.668	raknehaug - raevhoj – bavnen
58.	0.148	1102.515	plathoj - straumen - herlaugshaugen
59.	0.148	650.214	galgehoj - bavnen - anundshog

Fig. 10. Accuracies and lengths of 59 existing three-point alignments at or under the accuracy of 0.15°; shaded alignments indicate the absence of natural features in the pattern.

Of course there are logically both designed and random patterns among the total 59. These comparisons would have to be much further tested to see if this weighting of accuracies in relation to the use of natural features is itself simply random. Similarly in regard to the ballooning of the existing in the graph of figure 8, how can one better interpret this phenomenon in the range from about 0.06° to 0.105° (higher than the split associated with use of natural features) in comparison with the way random accumulative lines behave?

2. Most involved sites: If anything in the consideration of the probable mix of designed and random sites points to intention in the large-scale cultural landscape, it may well be the simple number of alignments in which any particular site is involved, see figure 11. While nothing in the present work attempts say which particular alignment might be designed, logically if Hohøj's involvement exceeds all sites both built and natural, taken across the four accuracies, then this Danish site probably has at least some designed alignments associated with it. It is tempting to speak symbolically about its position as northernmost of largest Danish mounds, its role as largest in Denmark, and its alignment on the naturally coincidental line from Gudfjelloya-Helagsfjellet to both Yding Skovhøj or Ejer Bavnehøj. Yet these kinds of interpretations cannot be central to the limited goals and length of the present paper. After Hohøj, the multiple mound site of Borre on Oslo Fjord is the second most involved built site, with Galgehøj, the southernmost large mound site in Denmark next in showing some greater likelihood of associated designed alignments.

Of the natural features, Helagsfjellet and Gudfjelløya are clearly the most involved. The reader will immediately ask to what extent is this due to including these sites because understood alignments from the author's earlier work. These produced only three alignments, however, (Bertnem-Heimdalshaugen-Gudfjelløya, Gudfjelløya- Helagsfjellet-Yding Skovhøj, and Gudfjelløya-Helagsfjellet-Ejer Bavnehøj), which when subtracted from the total of 11 at the 0.15° level still leaves 8, two more than then next most involved natural feature of Heimdalshaugen.

0.03	gudefjeldon	4	**0.09**	hohoj	9	**0.105**	hohoj	9	**0.15**	helagsfjellet	11
	hohoj	3		helagsfjellet	8		helagsfjellet	8		hohoj	11
	galgehoj	3		gudefjeldon	7		gudefjeldon	7		buhaugen	9
	heimdalshaugen	2		heimdalshaugen	5		heimdalshaugen	6		gudefjeldon	8
	helagsfjellet	2		buhaugen	5		borre	5		borre	8
	bertnem	2		galgehoj	5		buhaugen	5		herlaugshaugen	8
	borre	2		alstadhaug	4		galgehoj	5		galgehoj	8
	kivik	2		borre	4		alstadhaug	4		heimdalshaugen	6
	holger danskes hoj	2		kebnekaise	4		kebnekaise	4		raknehaug	6
	harldshaugen	2		kivik	4		kivik	4		alstadhaug	5
	himmelbjerg	2		herlaugshaugen	4		herlaugshaugen	4		kebnekaise	5
	stenshuvud	2		ejer baunehoj	4		ejer baunehoj	4		holger danskes hoj	5
	taberg	2		holger danskes hoj	4		holger danskes hoj	4		jellhaugen	5
	snohetta	1		jellhaugen	4		jellhaugen	4		troldhoj	5
	uppsala	1		togholm	4		togholm	4		jelling	4
	yding skovhoj	1		himmelbjerg	4		troldhoj	4		straumen	4
	hoverberg	1		snohetta	3		himmelbjerg	4		anundshog	4
	raknehaug	1		yding skovhoj	3		snohetta	3		kivik	4
	straumen	1		hoverberg	3		yding skovhoj	3		ejer baunehoj	4
	kebnekaise	1		raknehaug	3		hoverberg	3		raevhoj	4
	steglarp	1		troldhoj	3		raknehaug	3		togholm	4
	ejer baunehoj	1		jelling	2		jelling	2		himmelbjerg	4
	buhaugen	1		bertnem	2		bertnem	2		bavnen	4
	togholm	1		straumen	2		straumen	2		snohetta	3
	galge/brak	1		steglarp	2		anundshog	2		yding skovhoj	3
	jelling	0		harldshaugen	2		steglarp	2		bertnem	3
	galdhopiggen	0		ringstedhoj	2		harldshaugen	2		hoverberg	3
	alstadhaug	0		stenshuvud	2		ringstedhoj	2		gildhoj	3
	nordians hog	0		taberg	2		bavnen	2		plathoj	3
	orland	0		uppsala	1		stenshuvud	2		buskejoj	3
	anundshog	0		galdhopiggen	1		taberg	2		stenshuvud	3
	herlaugshaugen	0		nordians hog	1		uppsala	1		steglarp	2
	hogom	0		anundshog	1		galdhopiggen	1		bredhoj	2
	tarup	0		tarup	1		nordians hog	1		harldshaugen	2
	gildhoj	0		bredhoj	1		tarup	1		ringstedhoj	2
	hjortsballehoj	0		buskejoj	1		bredhoj	1		galgebakken/Hashoj	2
	bredhoj	0		raevhoj	1		plathoj	1		taberg	2
	plathoj	0		galgebakken/Hashoj	1		buskejoj	1		uppsala	1
	kjerkehaugen	0		bavnen	1		raevhoj	1		galdhopiggen	1
	jellhaugen	0		orland	0		galgebakken/Hashoj	1		nordians hog	1
	uggarda rair	0		hogom	0		orland	0		orland	1
	buskejoj	0		gildhoj	0		hogom	0		tarup	1
	raevhoj	0		hjortsballehoj	0		gildhoj	0		hogom	0
	troldhoj	0		plathoj	0		hjortsballehoj	0		hjortsballehoj	0
	ringstedhoj	0		kjerkehaugen	0		kjerkehaugen	0		kjerkehaugen	0
	bavnen	0		uggarda rair	0		uggarda rair	0		uggarda rair	0
	tomtebacken	0		tomtebacken	0		tomtebacken	0		tomtebacken	0

Fig. 11. Numbers of alignments with which each of 47 existing points are involved, at four accuracies.

3. Overlapping three-point alignments: As clearly demonstrated in the mentioned computer critiques of landscape alignments, more than three points can align with each other randomly, depending on how one interprets their mathematical relationships. As listed in figure 12, six groups of overlapping three-point alignments occur at the 0.15 level among the existing natural feature/largest mound combined set. This does not mean all of the sites listed in one group align with all of the other sites of the group. Only those three-point alignments listed under each group heading occur. In the "Gudfjelloya-Helagsfjellet" list, for example, the five Danish points, two natural and three mounds, do not form any three-point alignment among them. Thus any possible designed alignment in this group would have probably started with Gudfjelløya-Helagsfjellet and *prolonged* the line south to points in Denmark (again, a less technically difficult process). Aside from Hohøj, the alignments of the other two sites, Holger Danskes Høj and Tarup might well indicate greater possibility of randomness, or perhaps of an inaccurate extension of some initial line to Hohøj south at a later time period without resurveying the long line (apparently not using either the Ejer Bavnehøj or Yding Skovhøj high points). This doesn't explain, however, why Holger Danskes Høj and Tarup wouldn't have been aligned with Hohøj.

The second seven site group listed in figure 12, "Gildhøj-Herlaugshaugen" is a much better internally aligned group. Here five mound sites create seven three-point alignments—at or under an accuracy of 0.142°. Furthermore, because there are no natural features in the five mound group, a good opportunity appears to test the probability of the existing "Gildhøj-Herlaugshaugen" against random sets (the present Geopatterns application was not designed to test sets against a constant background, in this case the 14 natural features). This all-mound list of overlapping alignments also promises a greater separation with the random because of the reduced number of total points, i.e. five mounds form an alignment group within the 33, rather than 47 with natural features included.

The search string A+A(2)+A(2)+A(3)+A(3)+A(3)+A(3), where again the parentheses indicate the overlap of points between additive three-point alignments, captures the seven existing alignments listed in figure 12. Knowing that the application can recognize the pattern, one can then find the frequency that seven overlapping three-point alignments occur in the test areas of figure five (placing 33 points distributed appropriately in each test area for each set). Looking at groups of 100 sets in each run, ten runs (1000) create three random overlapped groups equal to the existing (0.003). This shows that internally good five-point alignments do occur randomly, but quite infrequently.

ACCURACY ° LENGTH km

(7) tarup – holger danskes hoj – ejer bavnehoj – yding skovhoj – hohoj – helagsfjellet - gudfjelloya

1.	0.011	992.391	yding skovhoj - helagsfjellet - gudefjeldon
2.	0.016	918.87	hohoj - helagsfjellet – gudefjeldon
3.	0.053	992.549	yding skovhoj - hohoj – gudefjeldon
4.	0.056	784.359	yding skovhoj - hohoj – helagsfjellet
5.	0.072	1042.221	tarup - helagsfjellet - gudefjeldon
6.	0.074	993.937	ejer bavnehoj - helagsfjellet – gudefjeldon
7.	0.111	1005.334	holger danskes hoj - helagsfjellet – gudefjeldon

(7) gildhoj – hohoj – borre – buhaugen - herlaugshaugen

1.	0.029	485.639	hohoj - borre – buhaugen
2.	0.048	639.403	borre - buhaugen – herlaugshaugen
3.	0.064	945.881	hohoj - borre - herlaugshaugen
4.	0.066	945.881	hohoj - buhaugen – herlaugshaugen
5.	0.108	577.379	gildhoj - borre – buhaugen
6.	0.122	1037.618	gildhoj - buhaugen – herlaugshaugen
7.	0.142	1037.618	gildhoj - borre – herlaugshaugen

(4) galgehoj – troldhoj – bavnen – anundshog

1.	0.060	139.959	galgehoj - bavnen – troldhoj
2.	0.093	539.967	bavnen - troldhoj – anundshog
3.	0.140	650.214	galgehoj - troldhoj – anundshog
4.	0.148	650.214	galgehoj - bavnen – anundshog

(3) buskehoj – togholm – buhaugen – alstadhaug – straumen

1.	0.072	947.226	buskejoj - buhaugen – alstadhaug
2.	0.088	948.216	togholm - buhaugen – alstadhaug
3.	0.129	963.509	buskejoj - buhaugen – straumen

(2) galgehoj – ringstedhoj – hoverberg – kebnekaise

1.	0.019	1511.305	galgehoj - hoverberg – kebnekaise
2.	0.039	1464.794	ringstedhoj - hoverberg – kebnekaise

(2) holger danskes hoj – ejer bavnehoj – alstadhaug – straumen

1.	0.018	894.408	holger danskes hoj - ejer bavnehoj – straumen
2.	0.079	878.082	holger danskes hoj - ejer bavnehoj – alstadhaug

Fig. 12. Overlapping three-point alignments among combination of existing 33 largest mounds and 14 most prominent natural features.

Apart from these numbers, two of the high involvement mound sites, Hohøj and Borre, are on this line which doesn't terminate (moving from the south) at a prominent natural feature but at Herlaugshaugen, the most northerly of the largest mound set. The fact that some number of random alignments are mixed in with probable designed patterns in the overall set of 59

(0.15°), may be somewhat less problematic in the "Gildhøj-Herlaugshaugen" group. One might argue that given the high involvement of two of the mound sites, and the very low probability of overall alignment randomness, mound builders would have been well aware of the line and thus less inclined to locate their particular structure on it for other than symbolically and organizationally related reasons.

4. Dating: Seasoned Scandinavian archaeologists, a group to which the present author doesn't attempt to claim membership, might be more willing to suggest strategies of layering mound dates over alignment data. Does the possible pattern associated with Gudfjelloya-Helagsfjellet associate better with older, Bronze Age society, than the possible nature-less construct perhaps more focused on Viking Borre (even though it integrates Hohøj)? The 0.06° alignment of Scandinavia's largest mound, Raknehaug, with what was long thought to be Norway's highest mountain, Snøhetta, and one of the most important sites in the SE, Kivik seems immediately interesting. But the two mounds in question are from the Migration period and Bronze Age respectively. The possibility that a particular location was ritually important, as suggested by large-scale analysis, before a large mound was built on it could influence the need for and methodology of dating these sites.

Eventually discourse about symbolic locations of at least the largest of Scandinavian mounds could add an essential large scale "map" component to increasingly interesting ritual interpretations of these sites--which nonetheless tend to focus on "object" characteristics--though being well as symbolic (e.g. Svanberg 2005, Goldhan 1999 & 2005). But here is the most interesting of theoretical possibilities. In earliest times the natural landscape and its most unique features may well have been most sacred, particularly in contrast to the most elaborated architectural setting, whether dwelling or ship. Built form then, might have been culturally constrained in its scale and relationship to natural places. It is not illogical to suggest that the earliest designed, formalized collective sacred geometry occurred among mounds and across the natural landscape, rather than in temple-like buildings, of which there were curiously few in Scandinavia.

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