Landscapes of the ‘Coast of Death’: dolmen topographies of NW Iberia

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We ought (to) approach the project of building an **Archaeology of Perception**.

Criado-Boado, F; and Villoch-Vázquez, V. (2000: 188-216).

Abstract

This paper investigates the landscapes of Neolithic communities found within Costa da Morte (Coast of Death), Galicia. Its goal is to uncover whether or not the megalithic monuments of a particular and coherent area of the south-eastern side of the Atlantic Façade are situated in relation to complex locational variables. In particular, in this paper we explore *the entirety of their surrounding horizon*. For the very first time, we were able to demonstrate that very specific natural landscapes surrounding the dolmens of this region in Iberia were likely selectively drawn upon, expanding our understanding of the Neolithic of this area and the peoples’ relationship with their natural world.

Keywords: Megaliths, Iberia, GIS, Landscapes

Introduction

Studies that systematically analyse the entire topographic horizons or landscape patterns surrounding all monuments of a certain class within or across regions to determine the architectural and social systems they might share remain uncommon (e.g. Cummings and Whittle’s 2004 work on Wales, Fraser’s 1988 work on the chambered cairns on Eday and Orkney), and it is very rare for such projects to include an astronomical perspective (Higginbottom et al 2015; Higginbottom 2020a,b works in Scotland). For the very first time, however, this paper will show convincingly that very specific natural landscapes *surrounding* the Neolithic dolmens of Costa da Morte in Galicia (Figs. 1 & 2), were selectively chosen.

We will demonstrate that individual Neolithic dolmens of this part of Galicia appear to be associated with particular topographical considerations of the landscape. To do so, our main research objective is to show that the horizon visible from each individual site appeared to be selected according to shared criteria, and thus dolmen orientation by itself is not the only significant connection of these monuments to the natural world. To carry out our investigation in this paper we use GIS technologies to uncover the considerations of those people who created the megalithic monuments in the Neolithic in Costa da

43 Figure 1. Costa da Morte region is coloured blue in the NW region of this map, beginning along the coast. The case-study
 44 area is defined by the regional watershed model (outlined in black). This watershed defines a clear geographical region
 45 within Galicia. See § Choosing the study area, below. Created by Maria Gomez Faro.

46 Morte, Galicia, in doing so we reveal that people who built the monuments shared some kind of cultural
 47 ideology related to the relevance of place, along the Atlantic Façade.

48 Background

49 Brief chronology

50 Costa da Morte is a county within the municipality of A Coruña. Within Costa da Morte, we can see
 51 some of the most important Galician dolmens, such as Casa dos Mouros, Arca da Piosa, Pedra Cuberta,
 52 Parxubeira or Dombate (Fig. 3). The dates we have for the dolmens within our study area are few and
 53 even fewer are high-precision determinations from recent excavations. So, for some consideration of
 54 the dates for the construction and use of dolmens within Costa da Morte, we have constructed a table
 55 that includes some sites within the north of A Coruña and one from central A Coruña, the latter is
 56 Chousa Nova (Supplementary Tables 1 & 2). Where there are several dates for one site available, only
 57 those from the original database that were equal-to and over 95% Cal (2σ) BC probability are included.
 58 These were then recalibrated with the most recent calibration curves (IntCal 20). Currently, there are
 59 two sites with very early dates situating their possible construction in the middle of the 5th Millennium
 60 BC (Chousa Nova, Silleda, and Forno dos Mouros no 5a, Ortigueira). The general consensus is that
 61 dolmens were constructed within the 5th millennium to early late 4th Millennium, and that the various

62 Figure 2 a-c. Examples of dolmens found in Costa da Morte. (a) Pedra da Arca (Regoelle), also known as Casa dos Mouros,
 63 at top; (b-c) Pedra da Arca (Malpica de Bergantiños) bottom two images. Images by Gail Higginbottom.
 64

Figure 3 a-c. (a-b) Further examples of corridor-chamber dolmens located in Costa da Morte (A: Dombate; B: Parxubeira), and (c) C: field plans of several of them. Pedra Cuberta is the tomb seen in Fig 2 (a), and Pedra da Arca is seen in Fig. 2 (b-c). Plans by C by Anxo Rodríguez-Paz, modified after Rodríguez Casal: 1990. Image A by Gail Higginbottom, B by Benito Vilas-Estévez.

necropoleis were likely used from ca 4300 BC to around 2000 BC over millennia, with possible new tomb building occurring from second half of 5th millennium up to early beginning of 3rd millennium (see Supplementary Table 1). Whilst not millennia apart in construction, Dombate is a good working example of the incorporation of a previous monument plus the reuse of dolmens through millennia. (Cebrián del Moral et al 2011: 167). The more recent and superlative dolmen of Dombate (the mound of which incorporates the first), was built very soon after the first, possibly causing the likely single use of the first dolmen (Cebrián del Moral et al 2011: 168).

Approaches of megalithic landscapes in the past

The consideration of landscapes and monuments has been widely undertaken along the Atlantic Façade, especially by scholars in Ireland and Britain (Ruggles and Martlew 1992; Tilley 1994; Richards 1996a, 2013a, b, c; Bradley 1998; Cooney 2000; Fraser 1983, 1988; Fraser, S 1996, 2004; Cummings 2002; Cummings and Whittle 2003, 2004; Higginbottom 2003; 2020a,b). We know that the people of

Late Neolithic and Bronze Ages of Scotland, on the north-western façade, erected standing stones and other monuments in very considered landscapes (Burl 1993, 2000; Richards 1996a,b, 2013c; Ruggles 1984, Higginbottom et al 2015). Cummings and Whittle’s work on tombs in Wales and SW Scotland discovered that, similar to Higginbottom’s 2015 work on standing stones: “a whole range of different landscape features were referenced from each monument. 90% of monuments have a restricted view in one direction, whilst 74% have a view of mountains and 59% of the sea. Thus sites were frequently positioned in order to have a ... combination of features” (Cummings and Whittle 2004: 88). It seems clear that these landscapes were already familiar to, and/or inhabited by, the builders (Jones et al 2011; Ashmore et al 2016; Card et al 2018).

Much work has also been done in the landscape studies of Galician megalithic monuments (dolmens), notably spatial networks & visibility (Criado-Boado & Villoch Vázquez 2000, Llobera 2015), visibility, intra-site visibility, astronomy & GIS (González-García et al 2017), and GIS & spatial statistics to investigate further ideas about locational qualities of megaliths in Galicia, with large raw datasets (Carrero-Pazos 2018; Carrero-Pazos & Rodríguez Casal 2019). All papers from this millennium included LiDAR data (post-2000).

There are also papers that combine cultural and social elements of the megalithic builders in Galicia for interpretive analyses (Criado-Boado & Villoch-Vázquez 1998; Criado Boado et al. 2006; Gianotti et al. 2011, González-García 2018; González-García et al 2019). Criado-Boado & Villoch-Vázquez’s 1998 work, based on the Barbanza peninsula, specifically engages with the landscape in which the dolmens are located. Barbanza, like Costa da Morte, is also located along the Atlantic coast. It contains a sharp inclining landscape upon which sits a sierra, with a highest elevation of 680 metres above sea level, has a flat plateau near the top at around 550 metres above sea level. Criado-Boado & Villoch-Vázquez concluded that the dolmens of Barbanza were deliberately positioned in order to indicate the best route to cross the sierra through the plateau and that particular dolmens were intervisible as you made your way across the sierra. These results were later confirmed using GIS analyses by Llobera (2015). Finally, it should be noted that in their visits they noticed a location trend of the mounds, namely that in general ‘the horizon is closer and higher towards West and North while it is lower and far towards East and South’ (Criado-Boado and Villoch-Vázquez 1998 in González-García et al 2017: 96-97, González-García 2018).

Issues of visibility in Galician dolmen landscapes

Due to the lack of research done in Costa da Morte itself, the clear determination of local land-use and vegetation cover is at this stage unclear. Nevertheless, Kaal et al demonstrate that during the 5th to 4th millennium BC, mountainous or hilly non-sierra areas, like Costa da Morte in Galicia, were primarily covered with mixed deciduous forest, dominated by oak (*Quercus*) with a light under-story of shrubs and herbs (Kaal et al 2013: 1522, fig 4). Such Oak forests tend to be open and lose their leaves in early

winter, creating a very open aspect until late Spring-early Summer. Added to this, the analysis of the fen of Chan da Cruz, Gañidoira, Xistral and Chao de Lagozas (Montes de Buio, Serra do Xistral and Toxiza) show the first clear evidence of forest reduction, the preponderance of the ruderal taxa and any degradative shrub formations at the beginning of the first half of the 5th millennia B.C. In this we have evidence of the reduction of forest and the creation of pockets of grasslands (López Saez et al 2010). The beginning of these activity coincides with the earliest dates we have for dolmens in A Coruña, like Forno dos Mouros 5a (Ua 20009 5635±50 BP, 4590 - 4350 cal BC, 95.4% - see Supplementary Table 1). Therefore, viewing topographical features within the Galician landscapes, the primary topic of this paper, could have been a possibility in the past.

Method

Whilst there is evidence for some sort of ‘symbolically-mediated behaviour’ (Mingo et al 2021) with the wide-spread erection of dolmens in Galicia, from the above we see that little is known about what lies beneath this complex social activity. To further explore this, we investigate the possible relevance of the places chosen for the dolmens to inhabit. As previously stated, our research question asks whether or not particular horizons visible from each individual site appeared to be selected according to shared criteria.

Specifically, we hypothesise that dolmens will exhibit similar horizon qualities and that these similarities or patterns will be systematically different from random locations found across the case-study area. Thus our main hypotheses are based upon visibility criteria, where a 360°-horizon is created from the most distant points that one can see from a particular monument. For this paper, we are working with data from 2D viewsheds. For the project overall, we use a number of digital terrain models with various resolutions (DTM – 5 m, 25 m and 90 m), and we employ the *Horizon* software to build horizon profiles and panoramas (see below for a description of the DTMs, software and how the horizon profiles are calculated and what they represent in terms of data).

Similar to Higginbottom’s previous works (Higginbottom et al 2015; Higginbottom 2020a,b, Higginbottom and Mom 2021) and Criado-Boado and Villoch-Vázquez’s research, we ‘approach the project of building an Archaeology of Perception’ (Criado-Boado and Villoch-Vázquez 1998: 63), which uses a clear systematic strategy for examining the visual features of past landscapes such that we can ‘approach a phenomenology of prehistoric perception without falling into mere subjective solutions’ (Criado-Boado and Villoch-Vázquez 1998: 63). Thus we use specific statistical tools for our determinations as described below.

Choosing the study area: Costa da Morte

Costa da Morte is characterised by several valleys and depressions intersected by rivers that drain to the coast, through rugged terrains. The gentle elevations (e.g. O Facho, 312 m.a.s.l.) of this area are

150 surrounded by valleys such as the Vimianzo or Dumbria (Lema Suárez 2010). For our studies of Ga-
151 lician dolmens, we chose to focus on one core dolmen district and its immediate periphery at a time,
152 after which we shall compare the differences and similarities of each area. Here we have chosen the
153 area of Costa da Morte, a historically well-known core area of Galician megaliths in North-western
154 Spain (Rodríguez Casal 1990, 2000; Lema Suárez 1999). For the clear determination of the geograph-
155 ical research area, please see Supplementary Material (SM1) and images within. In this Supplementary
156 text, the reader will also find descriptions of the software *Horizon* along with information about the
157 forms of ASCII data and the 2D and 3D landscape it creates, both of which are used in our research
158 for this paper. Our works use the 5m and 25m LiDAR data made freely available by the Galician
159 Xunta, details of which can also be found in SM1.

160 Analysis of horizon qualities

161 In the following, we perform a series of statistical analysis on the horizon profiles. The distances be-
162 tween any of the observed sites is always larger than 750 meters. Thus, securing that the horizon pro-
163 files are independent and we can rely on the fairness of our statistical treatment. There are only two
164 dolmens that do not follow this rule, and those are the two subsequently built dolmens in Dombate. As
165 New Dombate was built a few centuries after the old one, hiding it inside the larger mound, and to
166 secure the independence condition, we will consider only one profile in this case. Thus, the final num-
167 ber of horizons is $n = 31$.

168 Analysis 1 – the mean group horizon line and 1-sigma dispersion

169 On a descriptive level, the first analysis of a population or a sample is commonly done by analysing
170 the first moments (i.e. the mean and the variance or the standard deviation). This is the aim of this
171 section. Using the extracted *ascii* data we generated 2D images representing the horizon line sur-
172 rounding each monument defined by azimuth (direction in degrees) and altitude (angular height in
173 degrees) using IDL graphing packages ($n = 31$; Fig. 5). We have calculated the mean horizon line of
174 these 31 sites by calculating the mean altitude at every 0.01° around the horizon (Fig. 5, dashed-line).
175 We then calculated the standard deviation of these altitudes and add this to the mean azimuth of the
176 profiles to give us the 1-sigma dispersion of the 31 profiles, the outcome of which is found in the
177 section, ‘Results and Discussion’.

178 Analyses 2 - K-means analysis - do sites share the same horizon qualities?

179 Using the *ascii* data, we then performed a K-means analysis on the horizon qualities of each site (clus-
180 ter analysis). The first set of horizon qualities to be tested were points defined by azimuth and altitude,
181 which can be represented by the horizon line itself. Another one was carried out on the distances to
182 the horizon from the monuments connected to direction (azimuth), for the entire 360 degrees around
183 each site. In general, the K-means approach (Everitt 1995) groups the data into clusters by comparing,

184 in this case, the qualities of the profile of each data group with a given seed. The seed is normally
 185 chosen randomly once we set the number of clusters we would like to explore. However, in this case
 186 we have used the approach by Arthur and Vassilvitskii (2006) who proposed an alternative method for
 187 the initial randomization. The first cluster centre, c_0 , is purely random. Then the distances of all other
 188 measurements from c_0 are computed following the Euclidean distance. Now these distances are used
 189 to define a probability distribution and the next cluster is chosen again randomly, but now we used the
 190 probability distribution above (instead of a uniform distribution). The idea was to draw new seeds so
 191 that they are far from the first seed. With this idea, the new clusters will not necessarily be at the very
 192 edges of the measurement space and it is less likely that isolated outliers would be picked. In each step,
 193 the method computes the distance of each distribution to the seeds and then performs the grouping.
 194 The method tries to find by an iterative process, the optimal clustering which minimizes the distances
 195 within each cluster, defined as the sum-of-squares. To do so, at each step of the iteration, the groups
 196 define a new seed by calculating the one in that cluster that is closer to the centroid of the cluster. The
 197 process is iterated until it reaches convergence, i.e. until further iterations result in finally obtaining
 198 the same groups.

199
 200 Figure 5: Horizon profiles for the 31 sites presented in this paper (thin solid lines). Measurements run from 0° (due North)
 201 to 360° , due south would be 180° . The dashed line indicates the mean horizon profile and the dotted line the mean plus 1-
 202 sigma dispersion of the 31 profiles.

203 Analyses 3 – Comparing horizon qualities with random samples

204 In this analysis we tested for a series of systematic differences between the observed horizon qualities
 205 of all of our sites and those of 320 random locations within the area of Costa da Morte (this is one
 206 order of magnitude larger than our sample). We continue to focus on the qualities of azimuth & altitude
 207 and azimuth & distance. We then investigate how might distance be related to both direction and alti-
 208 tude. Again, to secure the independence of the horizon profiles in the random sample, we imposed that
 209 the minimum distance between the random sites was always larger than 250 m.

210 For all horizon azimuths, that is for each line of sight, we considered the 31 values of altitude and
211 distance of each of the observed sites, and from the 320 random sites, thus building a distribution of
212 altitudes and distances for each azimuth entry. Our aim here is verifying if there is any statistical dif-
213 ference between the horizons of the observed and the random sites. First, we run a normality test, by
214 employing the Shapiro-Wilk test under SPSS. The observed profiles show a $p < 0.001$, discarding nor-
215 mality. Under these circumstances we opted to use the Kolmogorov-Smirnov test to compare both
216 samples (observed and random) and to calculate the p-values. For each azimuth, we extracted the ob-
217 served sample altitudes or distances, and compared these to the sample of horizon altitudes or distances
218 of the random sites. So considered, the two samples (for each azimuth), could be modelled by distri-
219 butions. The two-sided K-S test allows us to verify whether or not the two samples are drawn from a
220 common parent distribution. Thus, our null hypothesis is that there is no difference and that the horizon
221 altitudes/distances for 31 sites with exposed dolmens do not differ from the random sites.
222 We employ a rather conservative approach and set a limit of $p < 0.05$. This means that if $p > 0.05$, a K-S
223 test cannot reject the null hypothesis, which states that both samples are drawn from the same parent
224 distribution. Specifically, this means there is no significant difference between the horizon qualities of
225 the monuments and those of the random sites in our study region if the null hypothesis is accepted.

226 Results

227 Analysis 1 – the mean group profile

228 In Figure 5, we can see illustrated the altitude by azimuth of all of the 31 horizons (thin solid lines). It
229 is interesting to notice that there is a general tendency to show slightly higher altitudes towards the
230 western part of the horizon. Also, the 1-sigma dispersion of the 31 profiles indicates that there is a
231 larger variation of horizon pattern for the western horizons found at our sites than found for the eastern
232 horizons, which are more similar to one another (Fig. 5, thick dotted line). This means that there are
233 likely very high horizons as well as very low horizons in the west, while such variations seem to be
234 smaller in the east.

235 This diagram, however, does not allow us to extract much further information. We could discuss the
236 mean horizon, but it would probably turn into meaningless conclusions. We therefore, preferred to
237 verify if there are certain traits within these profiles, and later compare them to those generated by a
238 random sample in the study area.

239 Analyses 2 - K-means analysis - do sites share the same horizon qualities?

240 K-means analysis on horizon direction & altitude

241 We tried three to seven initial seeds. By comparing the three- and four-seeds analysis we found that
242 two of the clusters or groups in each of these seeds include the same elements, however, the third group
243 in the three-seed analysis is divided into two for the four-seed analysis. The analyses with five, six and

244 seven seeds do not divide any initial group into other separate groups, but merely isolate particular
 245 elements instead. Thus four appeared to be optimal choice, for it appeared to capture the variability of
 246 the *groups* most clearly. The largest group comprises 13 of the 31 sites (this is the green group on Fig.
 247 6, Group 1), while the second greatest in number has eight (red group: Group 4, $n=8$). These two
 248 groups are ones that merge together when considering the three seeds case. The others have 6 and 4
 249 members. For ease of understanding, we can see their average horizon profile for each group in Figure
 250 7 and the regional distribution of these sites is the one seen in Figure 8. At this stage we are still
 251 researching the topographical details of the greater areas around the dolmens, but we can say that the
 252 Group 1 cluster (green, $n=13/31$) is clearly wide-spread across our study area, with Group 4 (red;
 253 $n=8/31$) being the second most wide-spread in terms of location (Fig.8). Group 3, for which we have
 254 the least number of sites ($n=4/31$), tends to be located in the north-western area only, with Group 2
 255 running north-south in the western zone of Galicia.

256 Figure 6: Direction & Altitude. K-means clustering for the horizon direction & altitude, represented by a horizon line or
 257 profile. Each group after the algorithm is shown in different colours. From bottom to top are Groups 1, 2, 3, and 4.

Figure 7: Direction & Altitude. The 'K-means' *mean* representative profile for each group and number of sites in each group. From bottom to top, the data comes from Groups 1, 2, 3, and 4 in Figure 6.

Figure 8: Direction & Altitude. Distribution of sites studied for the K-mean analysis performed on the horizon profile of the site, defined as direction and altitude (Figure 7). Group 1, n=13, Group 2=6, Group 3= 4, Group 4=8. created by Maria Gomez Faro.

264 K-means analysis on the direction & distance to the horizon

265 A similar analysis was done looking at patterns of direction and distances of the horizon. The results
 266 are summarized in the Figures 9a & 9b and 10. Again, we tried several analyses with three to seven
 267 seeds, with four appearing as the optimal choice. There are two main groups, Group 1 with 16 members
 268 (in red in Figs. 9a & 9b) and Group 4 with 8 members (green). Group 1's preference for the great
 269 majority of its easterly horizons (where north and south are the dividing lines) being farther away than
 270 the majority of its westerly horizons, is clear, however, the monuments in our smallest cluster, Group
 271 2 ($n=3$, blue) have the greatest difference in terms of distance between their easterly and westerly
 272 horizons. Group 4 sites are generally closer in the east than those of the west. Group 3 ($n=4$, gold)
 273 seems to have the most extreme ongoing undulation in its average horizon profile, nevertheless we can
 274 see that the horizons due east (that is, either side of, and at, 90°) are closer than those due west (either
 275 side of, and at, 270°). This is also true also for Group 4. In fact, if we focus purely on the cardinal
 276 directions of 90° and 270° , Groups 2, 3 and 4 all have the closer horizon points due east than those that
 277 are due west, unlike Group 1, despite the fact that, overall, Group 1 and 2 share the more general
 278
 279

280 Figure 9a: Direction & Distance. K-means over the distance for the 31 sites. The plot shows the mean distance profile for
 281 each group and the number of elements in each group. Note that the distance scale is logarithmic. Group 1 is red with 16
 282 members and the blue, Group 2, with 3. Group 3 is gold ($n=3$) and Group 4 is green ($n=8$).
 283

285 Figure 9b: Direction & Distance. K-means over the distance for the 31 sites. The plot shows the mean distance profile for
 286 each group and the number of elements in each group. Here we have layered the groups. Starting at zero azimuth we can
 287 see that the green group sits below all the other groups and that close to south (180°) they change positions, with the green
 288 group sitting above the rest.

289 Figure 10: Direction & Distance. Distribution of sites studied for the distance analysis for the 31 sites. Group 1, n= (16),
 290 Group 2= (3), Group 3= (4), Group 4= (8). Created by Maria Gomez Faro.

291 similarity of greater distances between their easterly and westerly horizons, as pointed out above. In-
292 terestingly, Group 2 ($n=3$) can all be found in the eastern part of our study area, and Group 1 appears
293 to have the greatest geographic spread in all directions, perhaps due to its comparative larger number
294 of sites (Fig. 10).

295 Analyses 3 - Comparing horizon qualities with random samples

296 In the following, we will display in the different figures the *mean* horizon profiles as representative of
297 particular qualities (as above), for both the observed and the random samples. It is important to re-
298 member that we are testing values at the level of individual orientations not of the horizon profile or
299 line *as a single unit*. Our assessments will be in line with these individual orientations.

300 Comparing direction and altitude of monument horizons with random sites

301 Firstly, we produced a horizon profile for each of the 320 randomly selected locations within Costa da
302 Morte and then we calculated and created the mean profile of these, defined by direction and altitude.
303 This is shown in Figure 11's top panel as a thick solid line. The mean observed horizon profile (for *all*
304 of the exposed dolmens) is shown as a dotted line. Whilst we are testing the individual orientations, it
305 is visibly clear that the observed profiles (i.e. of the exposed dolmens) are systematically lower in
306 altitude than the (mean) random sites profiles, and whilst *these are the mean profiles, they tend to*
307 *indicate the behaviour of the two samples*.

308 In the lower frame of Figure 11 is the calculated statistical significance of the difference between the
309 observed and random samples for each point observed (every 0.01°). Thus, we are seeing the p-value
310 for each azimuth value plotted in the lower frame. We find that the values are lower than $p=0.05$ for a
311 broad range of directions eastwardly from approximately NNE to just north of SE, while along the
312 western part of the horizon, there are no points that are statistically different from the random sample
313 except next to due north. In fact, just either side and north itself appear significant. In terms of the null
314 hypothesis then, we can *reject* the idea that in terms of altitude, a large part of the eastern horizon of
315 the dolmens are no different from those found at random sites, specifically the part of the horizon
316 found between the stretches of c. 20° - 108° N and c. 130° - 153° N. Therefore, we accept that, in terms
317 of height, the preponderance of lower horizons in the east were clearly of significance to the monument
318 builders of Costa de Morte.

319 We applied the same form of analysis with the combination of the 21 sites included in Groups 1 and 4
320 (red and green) of Figure 6, which, as we explained, formed a single cluster in the 3-seed analysis.
321 Also, *they were the two dominant sets of clusters which together explain the majority of horizon be-*
322 *haviour in terms of horizon altitude linked to direction*. This also creates a larger 'signal' of 21 sites
323 than if used individually.

Figure 11: Direction & Altitude. Top panel, random (solid) and observed (dotted) mean horizon profiles of all exposed dolmens in Costa da Morte. Black dashed vertical lines indicate the cardinal directions. From left to right the yellow lines are: Sun rise at the summer solstice, equinox and winter solstice: then the Sun set at the winter solstice, equinox and summer solstice (see Discussion). The lower frame shows the statistical significance. In this same frame the dashed horizontal line shows the value of $p = 0.05$. Altitude is the angular height of the horizon as viewed from the monument location.

We compared these 21 sites with the 320 randomly selected locations within Costa da Morte (Fig. 12). We can clearly see that the significant majority of altitudes contained within this mean observed profile fall even lower than those contained within mean observed profile of all site horizons seen in Figure 11, across the entire horizon profile. The lower panel in Fig. 12 indicates the probabilities of each point along the mean horizon profile of these 21 sites, these are also below all the limits of those found in Figure 11, now with some possible significance along the western areas. Most relevantly, *the statistical outcomes have not only lowered for both the eastern and western horizons, the azimuthal ranges in terms of significance have expanded*. In the *east*, we now have statistical support for a difference between the observed and the random horizons nearly all the way from NE to south (20° N to 175° N and possibly dead south). Along the western horizons, with significant ranges between $210^\circ - 285^\circ$ N, along with range in NNW and around north slightly to the west. Thus, in terms of the null hypothesis for these 21 sites, then, we *reject* the idea that in terms of altitude (angular height), the horizons of the dolmens are no different from those found at random sites, specifically those parts of the horizon found between the stretches described above. Therefore, we accept that, in terms of angular height, much of the lower horizons in the east and west were clearly of significance to the monument builders of Costa da Morte.

345 The significance of these 21 sites is even clearer when we compare these results with those of the rest
346 of our sample, where the 10 remaining sites from Groups 2 & 3 (from Fig. 6) are combined together
347 for the observed profile data (Fig. 13). This comparison was deemed necessary so that we could pos-
348 sibly observe how the horizons of these sites differ to those from Groups 1 and 4. Testing them indi-
349 vidually was not deemed appropriate due to low numbers; for instance, one Group only had four mem-
350 bers (Group 3). Here it is evident that, unlike the combination of Groups 1 and 4, the remaining sites
351 do not differ significantly from the random horizon profiles to the same great degree (Fig. 13). There
352 are no significant long stretches of unbroken horizon like we find for the 21 sites, but we do see that
353 there are tendencies for parts of the western horizon to be significantly higher in terms of altitude than
354 those found at random sites. The average horizon is also possibly of a greater altitude in the west than
355 those found in the east, thus indicating a possible similarity in this regard with the sites from Figure
356 11.

357 Distance horizon patterns: comparing direction and altitude of monument horizons with ran-
358 dom sites

359 To investigate the possible nature of the horizons surrounding each monument further, we turned to
360 the results of the horizon distance assessment. We selected all those sites found in the two largest
361 ‘distance’ clusters, for these explain the dominant horizon ‘behaviours’ of our monuments in terms of
362 distance and direction (Figure 9a & 9b; $n=16, 8$). Figure 9a & 9b clusters contain the ‘red sites’ ($n=16$;
363 Group 1) which have a further profile along the eastern horizon compared to the western; the green
364 sites ($n=8$; Group 4) are the reverse of this. We then compared each of these distance groups horizon
365 qualities with those of the random locations. The results can be found in Figures 14 and 15, respec-
366 tively.

367 In Figure 14 (Group 1), we can see that the average dolmen profile is clearly lower in altitude than the
368 average random profile, similar to that of Figure 12. However, now that we are testing sites that explain
369 the majority of data in terms of distance and direction, we now see a very clear difference between
370 Figure 12 and Figure 14: For Group 1 sites in Figure 14, almost the entire horizon range in terms of
371 altitude and direction, is significantly different to that of the random sites. In terms of our statistical
372 hypotheses, we can state that for those sites with horizon profiles farther in the east than the west, the
373 great majority of horizon is clearly significantly different from the random sample. Thus, in terms of
374 the null hypothesis for these sites, then, we *reject* the idea that in terms of altitude linked to direction,
375 the horizons of the dolmens are no different from those found at random sites. This contrasts strongly
376 for those sites that have horizon profiles farther in the west than the east (Group 4), where the majority
377 of horizon points are not significantly different from those of the random sites (Figure 15).

378

Figure 12: Direction & Altitude. Random (solid) and observed (dotted) mean horizon profiles, where the observed profiles are the combined profiles of the Group 1 and 4 clusters in Figure 6 ($n=21$ sites). Vertical black and yellow lines are as in Figure 11. The lower frame shows the statistical significance. In this same frame the dashed horizontal line shows the value of $p=0.05$. Altitude is the angular height of the horizon as viewed from the monument location.

Figure 13: Direction & Altitude. Random (solid) and observed (dotted) mean horizon profiles for the sites NOT included in the clusters of Groups 1 and 4, according to the horizon profile patterns, $n=10$. Vertical black and yellow lines are as in Figure 11. The lower frame shows the statistical significance. In this same frame the dashed horizontal line shows the value of $p=0.05$. Altitude is the angular height of the horizon as viewed from the monument location.

389 Horizon qualities - summary

390 In summary, we accept that, in terms of altitude and direction, the preponderance of lower horizons in
391 the east for the majority of sites (n=21) are clearly significantly different to random sites found in
392 Costa de Morte, but more particularly, for those sites that had farther horizons in the east compared to
393 their western horizons, it seems very likely that their entire horizons were considered in terms of di-
394 rection and altitude (altitude = height of the horizon as viewed from a specific location; angular value).

395 Discussion - Landscape choices in the ‘Coast of the Dead’

396 The tests on the horizon profiles of the monuments demonstrate that the monuments are located at
397 higher local elevations, for the horizon profiles appear generally lower for the monuments than those
398 of the expected or random profiles (Figs. 11, 12 & 14). These results reinforce the findings of previous
399 studies, which showed a general preference for monuments to be located at higher than average eleva-
400 tions in their local areas (Criado-Boado & Villoch-Vázquez 2000; Carrero-Pazos & Rodríguez Casal
401 2019).

402 Added to this, for those sites with greater horizon distances in the east (compared to the west), this
403 pattern more or less remains firm, especially along the eastern section (Figure 14). Thus, there is a
404 statistical consistency for *a specific interest in the eastern horizons*. Of interest, too, are the apparent
405 systematically lower altitudes for the eastern horizons compared to western (27/31; Fig. 7), which is
406 clearly the *opposite* to random sites found in Costa de Morte. However, it seems that altitude and
407 distance *may* not be inter-related variables. For, unlike Criado-Boado and Villoch-Vázquez’s 1998
408 study of Barbanza, where horizons are ‘closer and higher towards West and North (and) lower and
409 farther towards East and South’ (Criado-Boado and Villoch-Vázquez 1998 in González-García et al
410 2017: 96-97), there is no unique choice regarding which type of horizon in terms of altitude, should be
411 closer - the eastern or western. The lack of this unique quality is clearly illustrated by 27 out of 31
412 horizons, where 11 (Groups 3 & 4) had a distinctly closer eastern than western horizon and the remain-
413 ing 16 had a distinctly closer western than eastern horizon. Nevertheless, with the revelation of Bar-
414 banza’s mean horizon profile of all monuments being systematically lower towards the eastern part of
415 the horizon than west (González-García 2016), we can at least see a similarity with one of the two
416 families of horizon profiles found for the dolmens in Costa da Morte. From all of this, we can see that
417 it is very likely that the horizon altitudes are sort after for their unique qualities in comparison with the
418 rest of the naturally occurring landscapes.

419 Every single dolmen faces the eastern part of the horizon in Costa da Morte (Vilas-Estévez 2016), that
420 is, the chambers or corridors open towards the east (more specifically, they tend to open between due
421 east and the SE). Most curiously, then, and possibly of the greatest cultural significance for this project
422 so far, is that the statistically significant horizon sections contain the area for the entire solar sunrise

Figures 14: Direction & Altitude. Random (solid) and observed (dotted) mean horizon profiles for the sites with a further distance to the eastern side of the horizon (Fig. 9, Group 1 – red). Vertical black and yellow lines are as in Figure 11. The lower frame shows the statistical significance. In this same frame the dashed horizontal line shows the value of $p=0.05$. Altitude is the angular height of the horizon as viewed from the monument location

Figure 15: Direction & Altitude. Random (solid) and observed (dotted) mean horizon profiles for the sites with a further distance to the western side of the horizon (Fig. 9, Group 4 – green). Vertical black and yellow lines are as in Figure 11. The lower frame shows the statistical significance. In this same frame the dashed horizontal line shows the value of $p=0.05$. Altitude is the angular height of the horizon as viewed from the monument location.

range (Figs. 11& 12; indicated by the dotted yellow lines). This could perhaps indicate a search for a horizon with preferred qualities that connects with the dolmen's orientation preferences. If this is the case, what does this mean for our sites that also include lengths of statistically significant horizon in the west (Fig. 12) or indeed almost entire horizons that are significantly different to the general lie of the land (Fig. 14). The first quality that particularly connects Figures 12 & 14 is the combination of horizons that are *significantly* lower than the random sites in the east *and* the west, most particularly in the east. The second quality that connects these groups of dolmens are the fairly symmetrical topographical features which centre on cardinal east and cardinal west. Now clearly, these are average profiles, but what this indicates is a possibility to investigate in the future whether or not such topographical features (in terms of altitude and direction) occur at individual sites, and whether or not they contain the area for the entire solar sunrise range in the east *and west* (Fig. 14), or as in the case of Figure 12, the Sun from the SW to the west. Regardless, just including the significant data we already have, it is clear that altogether these variables of distance, direction and altitude accomplish a raft of complex landscape characteristics for the 'ideal' position(s) upon which to position a dolmen.

Other remaining challenges need to be considered for Costa da Morte. For instance, further research is required to discover what might be significant about the areas outside of the solar ranges along the significant horizon ranges. More work on the topography between the monuments and the horizons is also clearly required. Finally, until a much more thorough investigation is completed regarding the complex astronomical factors that might be connected to dolmen orientations and the types of horizon choices, it is not possible to say what might underlie any horizon type differences in the east or west, in relation to astronomy.

Conclusion - a symbol of cultural continuity

This paper has shown that very specific natural landscapes are connected to the Neolithic dolmens of Costa da Morte in Galicia. These were highly likely to be selectively chosen. The people who created them appear united through similarities of community practices through time and place, indicating that these dolmens are symbols of cultural continuity and provide some sense of cultural cohesion. The dolmens, through their location, 'present' this information to us. Due to their association with the dead, we suggest that their observable locational and visibility patterns are likely connected to more intangible concepts, where entire dolmen landscapes likely contain shared cosmological belief systems. For all of these reasons, we hypothesise that the dolmens of Costa da Morte are 'enduring manifestations (of) a whole body of practices that served as a memory repository' (Mingo et al 2021).

Geolocation

As explained in the paper, our study area is Costa da Morte, a county within the municipality of A Coruña within Galicia, Spain. A pin point a map that is fairly central is: 43° 5'22.82"N, 8°59'3.47"W.

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Supplementary Material

Supplementary Material 1

Choosing the study area: Costa da Morte

Costa da Morte is characterised by several valleys and depressions intersected by rivers which drain to the coast, through rugged terrains. The gentle elevations (e.g. O Facho, 312 m.a.s.l.) of this area are surrounded by valleys such as the Vimianzo or Dumbria (Lema Suárez 2010). For our studies of Galician dolmens, we chose to focus on one core dolmen district and its immediate periphery at a time, after which we shall compare the differences and similarities of each area. Here we have chosen the area of Costa da Morte, a historically well-known core area of Galician megaliths in North-western Spain (Rodríguez Casal 1990, 2000; Lema Suárez 1999). For the clear determination of the geographical research area, we adopted the mound clustering models created by Carrero-Pazos & Rodríguez Casal for Galicia, using Kernel density analyses, (2018: figs. 6A&B). Figure 4 shows the different density clumps, where we have chosen the ‘Costa da Morte’ one. There, we have analysed the 32 sites where there are exposed dolmens.

Figure 4. Kernel Density Analysis for the megalithic monuments of Galicia. (After Carrero-Pazos & Rodríguez Casal 2018: figure 6B, see this paper for full explanation of the model).

To determine the boundaries of the case-study area, we modelled the river catchment zones in this area (Fig. 1). The underlying assumptions are that areas where water is captured and maintained within and by the natural environment could potentially be considered as viable areas for human congregation and habitation, and megaliths would be a kind of territorial marker as they tend to locate close to the watershed edges, areas which, naturally, have high visibility (Martín-Torres 2001; Carrero-Pazos et

638 al. 2019). In this way, we confirmed a possible coherent ‘territory’ of dolmens that contains all the
639 sites that fall into the high, medium and low clustering designations of Costa da Morte determined by
640 Carrero-Pazos & Rodríguez Casal for Galicia (Fig 4). The advantage of this is that we will approach
641 each of the areas in Galicia in a consistent way, producing comparable results.

642 Horizon

643 The primary aim of the software Horizon is to combine topographical data with atmospheric and as-
644 tronomical calculations to produce accurate two and three dimensional landscape information to aid
645 archaeoastronomical surveys and data analysis (Smith 2013). This includes the ability to create 2D
646 horizon profile images and rendered 3D landscape panoramas for each site. Apart from the location,
647 Horizon allows you to choose epochs, astronomical phenomena and dates far back in time. The paths
648 of astronomical phenomena like the Sun on the longest day and the shortest day and those of the Moon
649 at the times of its most extreme rising and setting points in its cycle, are then mapped onto the land-
650 scapes. The main difference between the 2D and the 3D images, is that the latter uses all of the topo-
651 graphic data between the viewing position and the horizon to render the entire landscape, whereas the
652 2D option *draws the visible horizon line only*. Nevertheless, the 2D profiles are co-created with an
653 *ascii* data file containing the distance and direction between the point of origin or monument to all
654 points on the horizon and the altitude of each of these horizon points. Within Horizon you can view an
655 interactive 2D image and by clicking on this you can obtain data about the horizon profile related to
656 these variables. You can also output the *ascii* data file in order to use this data for quantitative analyses
657 as well as the postscript image file that contains two linked graphs vertically positioned: (i) the horizon
658 line (x=direction-azimuth; y= altitude) and underneath this (ii) a logarithmic graph (x= direction-azi-
659 muth; y=distance to the horizon). Azimuth is the number of degrees from north. Altitude is the value
660 in degrees given to the height of the horizon as viewed from a specific location or rather angular height
661 measured in degrees. This is used in landscape archaeology/archaeoastronomy for two main reasons
662 (i) it is measure that relates to the height of the horizon as viewed from a particular point, like a mon-
663 ument location, that is, the height in degrees *from the location’s ground level or the observer’s eye-*
664 *level*. We use an approximation of the later for past peoples in our software calculations of 1.5m. The
665 advantages of using this value is that everything *relates to the viewing location* and differing horizon
666 heights surrounding a monument are simpler to compare than trying to imagine how they literally
667 experienced from the viewing position when using elevation; (ii) altitude is one of three values used
668 to calculate a location value on the horizon that can be compared with the value for the path of astro-
669 nomical bodies, known as declination. To calculate this value, three pieces of information are required:
670 your viewing point in geographical terms such as UTM (like centre of the tomb/tomb corridor), the
671 azimuth of the horizon point towards which you are facing and the altitude of the horizon in the direc-
672 tion of the azimuth. This is because where ‘you stand’ and the height of the horizon effects at which

point an astronomical body can be seen to rise and set. This converted or calculated value, declination, can then be compared to the value given to the paths of astronomical bodies, which is also expressed as a declination, so that we can see if these two ‘points’ coincide at the horizon. This stems from the fact that celestial bodies on a particular date maintain constant declination, making the comparison more direct. If the two declination values of the horizon and the body coincide, we can say that this body can be seen from a particular viewing position, along the horizon in a particular direction.

Data for the Horizon creations

For this project, we use a be-spoke version of Horizon. It was created to use 5m and 25m LiDAR data made freely available by the Galician Xunta. It contains, eastings and northings and height data, and distances can be calculated between points in the landscape using geometry. These data had to be converted and tested for use for our be-spoke version of Horizon, by the software engineer and designer of the program, Andrew Smith (University of Adelaide). We used the converted 25m LiDAR data for the horizon profiles and the concomitant ascii data. Ultimately, our project as a whole also considers astronomical events viewed along the horizons as well as 3D landscape panoramas for various qualitative assessments.

Smith (2013) has produced an entire manual on how the software makes its calculations for the 2D profiles and 3D panoramas and how to use the software *Horizon*. Some key points in relation to the creation of the 2D horizon profiles includes:

1. These are simply the apparent elevation of the horizon for a hypothetical ‘observer’ located at a specified point within the landscape, sampled at regular intervals (of 0.01°) in azimuth around the full horizon, which gives you 36,000 x and y co-ordinates.
2. The distance of each azimuthal point is also calculated at the same time as ascii data and displayed in the logarithmic graphs of the postscript file output.
3. The algorithm which is used to generate horizon profiles is capable of processing DTM datasets of unlimited size.
4. The accuracy of the profiles is directly linked to the accuracy of the DTM data used.
5. Here, the horizon is defined as the point with the greatest elevation in a given direction which an observer would be able to see if the atmosphere was perfectly transparent.
6. The curvature of the Earth and (ultimately, but not in the current version) atmospheric refraction are taken into account when calculating this.
7. The assumption of perfect transparency (but there is an optional distance toggle; e.g. you can confine it to a hundred kilometres or so, our approximate maximum distance a human can usually see; refer to §‘3.3.3 The DTM Tab’ in the *Horizon* manual for further explanation).

This assumption can be used because

- a. The Sun and the Moon are also dimmed as they approach the horizon, but they are so bright to begin with that they remain quite visible until they are obscured by the curvature of the Earth or some other landscape feature such as a mountain.
- b. Landscape features (such as a distant mountain range) which might rarely be visible to an observer under normal daytime conditions are often clearly visible in silhouette at sunrise or sunset, and there have been reports from mariners of land being visible over two hundred kilometres away when the Sun was behind it.

714 We initially created 32 2D ascii files containing the azimuth, altitude and distance of every point along
 715 the horizon for every 0.01°. These outputs were used as described below to do our analyses.

716 Supplementary Tables

	Laboratory Nº	BP	Cal (2σ) BC OxCal 3.10	Cal (2σ) BC probability	Reference
Chousa Nova, Silleda	Beta-277240	5450 ± 40 BP	4350-4240 Cal BC **	No information	Domínguez-Bella, María José Bóveda 2011 **calibración del laboratorio a partir de la curva de calibración INTCAL04, Reimer et al. 2004.
Dombate, second tomb	CSIC 939	4410±25	3100 - 2920	93.8%	Bello 1995; Alonso y Bello 1995. 1997: 519.
Dombate second phase, second tomb	CSIC 962	4020±30	2620 - 2460	95.4%	Bello 1995: Alonso y Bello 1995. 1997: 519;
Dombate, second tomb	CSIC 963	4380±35	3100 - 2900	95.4%	Bello 1995: Alonso y Bello 1995. 1997: 519;
Dombate, second tomb	UtC 3201	3950±60	2620 - 2280	94.2%	Bello 1995; Alonso y Bello 1997: 519;
Dombate, second tomb	UtC 3203	4950±70	3950 - 3630	95.4%	Bello 1995; Alonso y Bello 1997: 519;
Dombate, first tomb	CAMS 101903	4900±40	3770 - 3630	95.4%	Steelman. Carrera et al. 2005.
Dombate, first tomb	CAMS 101904	4890±40	3770 - 3630	95.4%	Steelman. Carrera et al. 2005.
Forno dos Mouros 5a	Ua 20009	5635±50	4590 - 4350	95.4%	Mañana 2005
Forno dos Mouros 5a	Ua 20010	5500±50	4460 - 4250	95.4%	Mañana 2005
Forno dos Mouros 5b	Ua 21687	3565±40	2030 - 1860	76.4%	Mañana 2005
Forno dos Mouros 5b	Ua 21688	4390±45	3120 - 2900	88.1%	Mañana 2005
Pedra Cuberta	CAMS 77923	5010±60	3960 - 3660	95.4%	Carrera y Fábregas 2002; Steelman. Carrera et al. 2005.

717 Supplementary Data Table 1: The dating examples of dolmens in A Coruña. The information for the first three columns
 718 and the last, except that for the site of Chousa Nova, is taken from Prieto Martínez et al 2012 and their contribution to the
 719 volume's major data table at the end of the book: for data on Galicia see pages 585-589. OxCal dates provided by Andy
 720 M. Jones.
 721

Dolmen Name	UTMX	UTMY
Dombate	502487	4781930
Pedra Moura do Monte Carnio	501803	4769844
Dolmen Arca da Piosa	501573	4765872
Pedre da Lebre I	501300	4768580
Mina de Recesindes	494026	4777221
Mina Folias	494309	4774664
Mina d'Aquela banda	493685	4776030
Pedra da Arca (Malpica)	514780	4793766
Mina de Espiñaredo	515125	4749833
Dombate antigo	502487	4781930
Seconde	503938	4774078
Reparada	503913	4773982
Mámoa do Rei Penide	526955	4689614
Mamoas do Rei	529981	4679203
Gándara da Barca	499533	4762080
Pedra Moura Aldemunde	532245	4777251
Forno dos Mouros Silvosos	539950	4783517
Pedra Cuberta	501256	4770760
Pedra da Arca de Regoelle	498823	4761922
Casota de Freans	492966	4766132
Arca de Rabós	498363	4764983
Arca de Ogas	495642	4769752
Necropole das Caxadas	496334	4769533
Pedra Vixia	504537	4776870
Dolmen de Fontemoureira	503700	4738409
Fornela dos Mouros	499409	4779427
Anta da Gandara de Baiñas 1	500077	4762161
Anta do Alterio	499541	4762067
Arquiña de Vilaseco	493916	4769065
Mina da Parxubeira	505178	4754164
Dolmen de Axeitos	498625	4716405
Casiña dos Mouros	502418	4744283
Dolmen de Cabaleiros	536590	4771671
Monte das Mamoas	514829	4747992
Parxubeira 2	505305	4754378

Supplementary Data Table 2: Site List of 35 monuments with UTM (N29) locations.