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Geomagnetic investigations at Monte da Contenda, Arronches, Portugal – Results from the 2018 campaign

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Abstract

In light of the current interest in climate change and its effects on modern economies, several projects have highlighted the role of climate forcing on past societies. In particular, there has been focus on the role of climate forcing in the Iberian Peninsula, during the 4.2 k event, which roughly coincides with the Chalcolithic to Bronze Age transition (c. 2200–2000 BCE).

While much of this research has focused on the South-eastern regions, given its long and rich history of archaeological research, some attention has shifted to the Southwest Iberia, which has revealed in recent years a clearer picture of its societies during the Chalcolithic period. More specifically, Southwest Iberia has disclosed very interesting social dynamics when it comes to ditched-enclosure sites, dynamics that came to a rather abrupt end around the same time of the 4.2 k event. The current paper reports the results of the 2018 geomagnetic survey campaign at the ditched-enclosure site of Monte da Contenda, in Arronches, Portugal. While these results are not directly related to climate forcing *per se*, they do provide more insight into the Chalcolithic communities that could have been directly affected by climate events.

Whereas the first campaign, in 2013, revealed a very complex ditch system but was unable to expose the site's full layout, the 2018 campaign was able to reveal the site's ditch systems in their entirety. Many of the assumptions established in the first campaign concerning the layout of the site were confirmed during this second campaign, namely that the ditch system is delimited to the south by the ribeira das Argamassas and that the site contains two distinct ditch systems, comprising a total of 17 to 19 ditches, establishing Monte da Contenda as the site with the highest number of ditches currently known in Portugal.

Introduction

Recent years has seen great progress in understanding the role of climate change, sometimes even specific climate events, on the behaviour of humans. This understanding is, of course, largely driven by the current debate of human-induced global climate change. In turn, archaeologists and historians have been motivated to consider the role of climate change in the history of past societies. This type of archaeological/historical research into past climate change has been enabled first, by the financing of large-scale projects, whether through the European Research Council, or more specifically in Germany, the Deutsche Forschung Gemeinschaft and second, the development of new scientific techniques allowing the integration of new

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datasets and proxies in archaeological analysis (Kristiansen 2014). It is precisely in the framework of a project funded by the Deutsche Forschung Gemeinschaft, that a collaborative research centre titled "Scales of Transformation - Human-Environmental Interaction in Prehistoric and Archaic Societies" has been developed, and in which the results presented in this paper are integrated.

It must be reminded that archaeological research into human-environmental interaction has been around since the heydays of processual archaeology, influenced primarily by the cultural ecology of Julian Steward (1955), and adopted by one of the main voices of processual archaeology, Lewis Binford (1962). More recently, several studies have taken climate more seriously in explaining the collapse of civilizations, such as the Classic Maya (Gill et al. 2007; Hoggarth et al. 2017) and the Akkadian states in North Mesopotamia (Weiss 2015; Weiss et al. 1993). However, both the case of the Classic Maya and the Akkadian states are somewhat exceptional, since both seemed to operate political systems prone to fragmentation and collapse (Lillios et al. 2016, 138). It is with these, and other caveats in mind, that the current research on human-environmental interactions must proceed. Linear causation and simple deterministic explanations (Arponen et al. 2019; Ion 2019) are simply not acceptable at this stage. Whereas some cases like the aforementioned Maya and Akkadian empires can be interpreted as paradigmatic cases of "collapse" (Diamond 2005), other cases require thinking in terms of "transformation", that is to say, where climate induces behavioural changes, such as adaptation to new dietary strategies, migration, and settlement dispersal.

In this context, the Iberian Peninsula has stood out as an excellent "laboratory" for the research into the role of climate events on past societies, more specifically, the role of the 4.2 k event (Schirrmacher et al. 2019) on the transition from Chalcolithic lifeways to Bronze Age lifeways, which seems to have occurred around the same time. In this context, there has been considerable progress in the study of the Chalcolithic period of Iberia (e.g. Bartelheim et al. 2017). Additionally, there has also been great advances in the research of climate, paleoenvironmental, and archaeological proxies from Iberia (e.g. Blanco-González et al. 2018; Hinz et al. forthcoming; Lillios et al. 2016; Weinelt et al. 2015). However, this research, especially from an archaeological and paleoenvironmental standpoint has tended to favour Southeast Iberia, since this is the region that has garnered the most attention, especially when it comes to recent prehistory (Gilman/Thornes 1985; Lillios 1997). While it makes sense that there should be a strong focus on this south-eastern region due to its remarkably long and rich history of research, a region that has stood out in more recent years has been the Southwest and many answers to questions concerning the role of the 4.2 k event on the Iberian Peninsula might be found here.

It is true that our understanding of the transition from the Chalcolithic to the Bronze Age in Southwest Iberia (c. 2200 to 1800 BCE) remains very patchy (Mataloto et al. 2013), the work that has been developed in the last couple of decades, especially that which has focused on the late Neolithic/Chalcolithic ditched enclosures (e.g. Garcia Sanjuán et al. 2018; Schuhmacher et al. 2016; Valera 2015), has provided a much clearer picture of cultural and societal dynamics of the past populations in this region.

Southwest Iberia and the ditched enclosure phenomenon

The recent studies on the 4.2 k event on Iberian societies have been based on methods that take into account regional and supra-regional dynamics (Blanco-González et al. 2018; Lillios et al. 2016; Weinelt et al. 2015), the only exception to this practice being the southeast, given the amount of absolute dates and the high quantity of detailed archaeological records for this region. Thus, it is understandable that, at least from an archaeological standpoint, the southeast can correlate the societal processes with the 4.2 k event at a resolution that is unachievable in other regions within Iberia (Lull et al. 2015). Thus, in order to obtain a clearer picture of the relation between climate and society, it is important to understand this relation on several scales in regions other than the southeast.

The southwest has emerged in recent years as a very interesting region in terms of archaeology, especially due to the research on late Neolithic and Chalcolithic ditched enclosures. This region, however, reveals a rather eclectic archaeological landscape. In the Estremadura region, just north of the river Tagus, the Chalcolithic manifests primarily in the form of fortified settlements built of drystone, often with semi-circular towers. Chronologically, these sites were established around 2900 BCE and most were abandoned around 2500 BCE (Blanco-González et al. 2018). One of the few exceptions is the site of Zambujal, which continued to be occupied until the beginning of the II millennium (Kunst/Lutz 2010/2011). In the Antequera region, the Chalcolithic landscape is marked by many open-air low-lying sites, with around 290 sites spread out over an area of 2640km^2, sites that are probably related to the megalithic complexes of this region (Garcia-Sanjuán et al. 2016). Finally, In the Alentejo region, in southern Portugal, archaeologists have come to recognize in the last decades a vast concentration of ditched enclosures (Valera 2015) spanning from the Late Neolithic (second half of the 4th Millennium) to the end of the Chalcolithic (last centuries of the 3rd Millennium), where Monte da Contenda, the site this paper reports on, can be found (Figs. 1–2).

Fig. 1. Location of Southern Alentejo in the context of the Iberian Peninsula. Boxed area corresponds to Figure 2 and the arrow and dot corresponds to the location of Monte da Contenda.

Although there have been great advances in the study of ditched enclosures in the Alentejo region, it remains quite understudied in comparison to other archaeological phenomena of the same period. There are several reasons for this, the first and most obvious reason is their late discovery (Jímenez-Jáimez 2015), and second, their invisibility from the surface, which have made them very difficult to identify in surface prospections. Thus, it comes as unsurprising that the discovery and study of ditched enclosures in the Alentejo region took great strides due to infrastructural ventures in the region from the 1990's onwards (Valera 2013, 96). In addition to infrastructural work, the advent of large-scale aerial photography, made available by Google for instance, has allowed the identification of many more ditched enclosures (Valera/Pereiro 2013). Finally, central to understanding the ditched enclosure phenomenon in Alentejo is understanding their overall layout and on this front, remote sensing technology, namely geophysical prospection has been an indispensable tool (Becker et al. 2012; Valera/Becker 2011; Valera et al. 2014). Whereas ditched enclosures were virtually unknown in the Alentejo prior to the 1980's, at least 65 of them have now been identified in the region (Fig. 2).

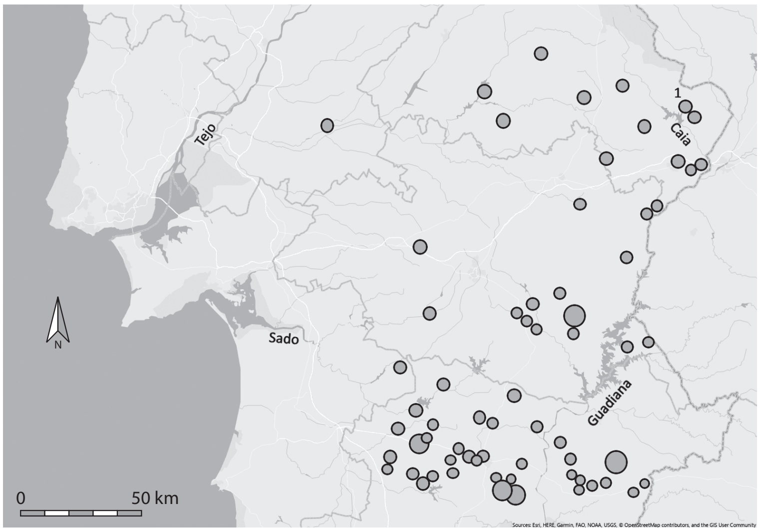

Fig. 2. Closer look at the Southern Alentejo region, with the distribution of prehistoric ditched enclosures identified in recent years (adapted from Valera et al. 2014, fig. 1). 1 corresponds to the location of Monte da Contenda.

Unlike fortified enclosures (e.g. Zambujal), which tend to be located in elevated areas, the ditched enclosures of the Alentejo manifest across a varied number of topographies, such as hillsides, slopes, open valleys, hilltops, etc. As to their dimensions, these can also be quite varied with some ditches of quite small dimensions, such as ditch 1 of Bela Vista 5 being around 0.0034 ha, and the ditch of Salvada being around 17.4 ha, and although not entirely known, the layout of ditches of Porto Torrão are probably even bigger (Valera 2013, 102). In terms of shape, the ditches tend to be circular, although there are also ditches that are oval and ellipsoidal, with lines that can be fairly straight or sometimes sinuous. One thing is certain when it comes to their shape, there is a complete absence of right angles (so far).

The field campaigns at Monte da Contenda

Monte da Contenda is located in the municipality of Arronches, in northern Alentejo. The site is situated west of the N371 between Campo Maior and Nossa Senhora da Graça dos Degolados on the northern slope of the small brook ribeira das Argamassas draining the area to the west into the Barragem do Caia. At a smaller scale the enclosure is situated on the slope of a promontory defined by a steep erosion gully (Valera et al. 2014). The geology is dominated by magnetic and magmatic rocks including diorites in the eastern part

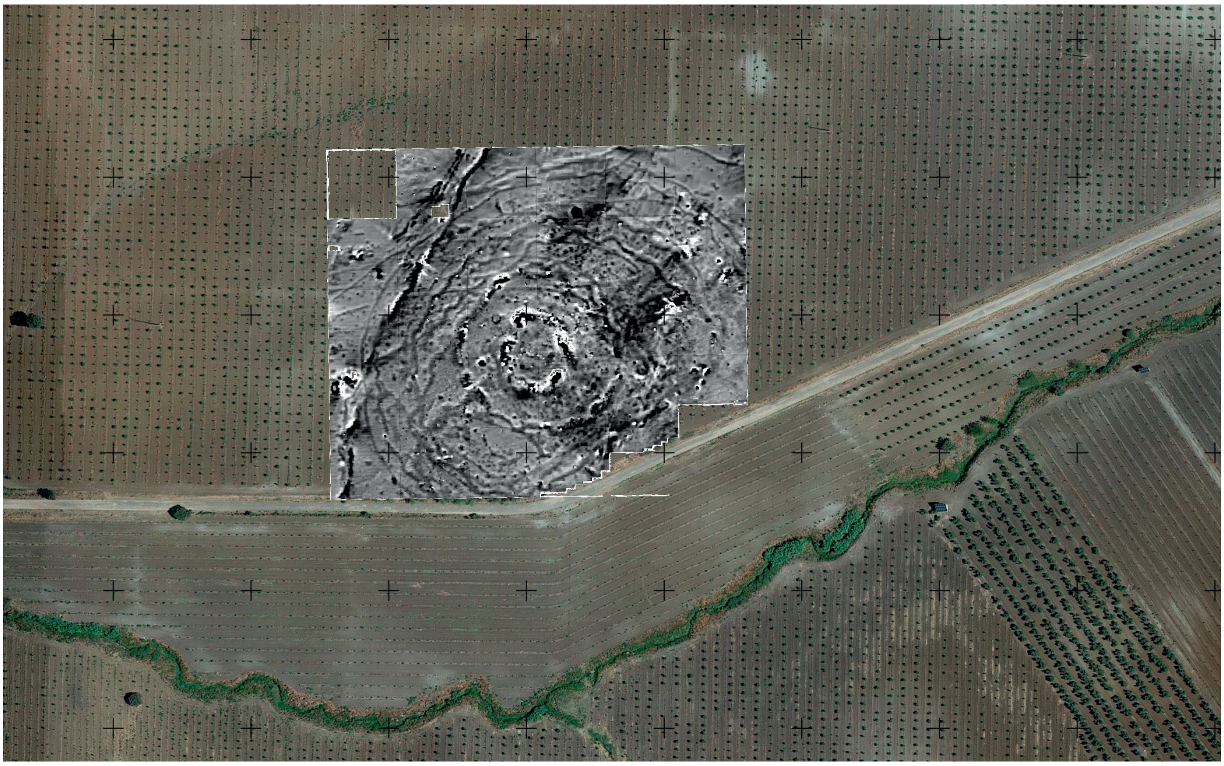

Fig. 3. Geomagnetic survey area from the first field campaign, conducted under the supervision of Helmut Becker.

and a variation with gneisses in the west. Linear fraction zones with granitic porphyry cross the area from the northeast to the southwest. It is very close to the Spanish border, and less than five kilometres away from another ditched enclosure, Santa Victória to the south. The context of its identification comes from a project initiated in 2010 with the aims of studying the cosmological significance of the ditched enclosures of the Alentejo (Valera/Becker 2011). Through this project, several new ditched enclosure sites were identified via aerial photography, some of which were then subject to geophysical prospection such as Monte da Contenda (Valera et al. 2014).

The first field campaign at Monte da Contenda occurred in 2013 and incorporated a geomagnetic survey, and the cleaning of a section on a slope. The geomagnetic survey was conducted under the responsibility of Helmut Becker, over an area of c. 43,200 m^2, of rectangular format, 240 m from east to west, and 200 m north to south. This prospection was conducted on a field without obstacles with a cesio geometric sensor with very high sensibility of 20 pT and a resolution of 0.12 m x 0.5 m. The results of this first campaign were very satisfactory, having revealed a site of vast dimensions, with many ditches, and it was quickly understood that a second geophysical campaign would be necessary in order to grasp the full dimensions of the site (Fig. 3).

In this first geomagnetic campaign, two sets of ditches were identified. One set contains no less than a total of 11 ditches of circular and oval layout, which criss-cross each other, many of which follow a sinuous outline. Given the overlap of so many ditches, it has not been easy to reach an adequate reading of the several layouts and directions of these ditches. There is also a second set of ditches, of more oval shape, which also overlap with the first set, but which seemed to go towards the east and west, considerably beyond the prospection area of the first campaign. It seems safe to interpret that this second set of ditches corresponds to an initial phase of the site, which at the time of the first campaign, seemed to be demarcated in the south by the ribeira das Argamassas (Valera et al. 2014).

As can be seen from Figure 3, the bottom half of the site is sectioned off by a modern access road. During the first campaign, there was an archaeological intervention on one of the prehistoric ditches, which was visible in the slopes of the access road. This intervention involved cleaning the slope and straightening it, in order to obtain a profile of the ditch (Valera et al. 2014, fig. 7). Since this intervention was not a full-scale archaeological excavation, there is not much that can be extrapolated about the site itself from this ditch alone, however, this intervention did provide both diagnostic archaeological and faunal material, which were radiocarbon dated (3336–3024 cal BCE 2σ and 3340–3030 cal BC 2σ [Valera et al. 2014, 207]), placing the contents of the ditch in later centuries of the 4th Millennium, so towards the Late Neolithic. In terms of archaeological material, the ditch contained pottery fragments and both polished and knapped stone material. Concerning the pottery morphology, several forms could be ascertained, and these were primarily closed spherical and globular forms, commonly associated to the Neolithic. The material that could be found on the surface, however, points heavily to a Chalcolithic occupation, especially when it comes to the pottery forms, which tend to be open forms with thickened rims (Valera et al. 2014, 205).

The second phase of the fieldwork campaign, which the current article reports, was a collaboration between Kiel University and Era-Arqueologia, in the context of the Collaborative Research Centre project Scales of Transformation. This second campaign was carried out in September 2018, under the technical responsibility of Christoph Rinne. In light of the results of the first campaign conducted by Becker in 2013, it was the aim of this second campaign to obtain the complete layout, or as complete as possible, of the ditch system of the site. This was not an easy task, given that in the period between the first and second prospection campaign, the area previously prospected by Becker was used as planting ground for almond trees, which meant that only the area between trees could be measured. Nevertheless, the aims of this second campaign were attained.

Methodology of the 2018 campaign

In terms of methodology, the fieldwork was conducted with the following measurement methods:

- Differential GPS (Leica Viva) with a local base station providing the RTK signal for the rover mounted on an 8-sensor geomagnetic device. The position of the base station was defined by GPS-Position only, the position of the rover was defined by the gps-position, and a correction transmitted from the base station (local Real Time Kinematic).
- A differential GPS (Stonex S9) was used but without RTK to measure five fixed points for the first positioning of the total station and the recording of surface finds. The errors are recorded for each measurement and are about 1.059 m with a variation of 0.129 m (mean and standard deviation for the HSDV). Without a correcting information device, the given height refers to the ellipsoid model and was not used for geographic tasks.
- A total station (Leica TS02) for the setup of the grids for the 4-sensor magnetic device. The first setup with the function "free station" was based on five GPS points (ID 1001–1005) revealing a mean error of less than 3 cm within the global error of the GPS-Points. Due to the ellipsoid height of the gps data, the height was set to 1000 m for 1001 to obtain a local height. For further measurements the fixed points were measured again (PtID 1001N-1005N).

In terms of geomagnetic devices, the second geomagnetic campaign operated with two devices: a 4-sensor device that was used primarily in the southern section of the intervention area and an 8-sensor device used in the north. The measurements were conducted with gradiometer sensors from Förster, FEREX® CN 650, with a sensibility of < 1nT (nano Teslar). Compared to the technique of the previous campaign, Fluxgate sensors measure only the vertical component of the magnetic field with relative values, thus providing a different but appropriate information for archaeological needs. The sensors are mounted in wheeled systems that can be pushed in straight lines. The x-coordinate is defined by the starting position on a tape measurement at the start and stop line, the y-coordinate is defined with an odometer adjusting variations in the walking speed by interpolation. The measured resolution is x: 0.25 m x y: 0.1 m. The width of the grids depended on the space between the vegetation, and the general length was set to 40 m but varied depending on the local situation. The data recording started with the 1st sensor on x=0 thus reaching 0.75 cm with the 4th sensor. As a result all the measured fields have a width of x.75 m although the fields were set up as full meters (this was taken into account during georeferencing). All grids have been measured bidirectionally in zig-zag from east to west or vice versa. During georeferencing the data was interpolated to 0.25 m by 0.25 m. This technique was applied to the area between the road and the brook, separated into an eastern and a western part (monte-se, monte-sw) according to the orientation of the road and the vegetation.

The measurements of the 8-sensor device were conducted with 0.50 m within the sensors and a recording frequency of 20 Hz, which results in app. 0.08 m of distance depending on walking speed. The coordinates are retrieved from the base station depending on the position of the sensor within the array and the movement of the device. Due to this movement, the measured data was interpolated for display to 0.20 m by 0.20 m.

A local coordinate system was defined for both southern areas independently. Area SE consists of F001–F054 and was measured from 2018/09/10 to 2018/09/14, the SW area consists of F055–F88 and was measured from 2018/09/14 to 2018/09/17. Although each area uses one coordinate system, the origin of each row was rounded up to full meters despite the real position at the border of the olives. This was done in order to facilitate the work and to avoid errors. The posterior georeferencing of each row was based on the original measurements of the total station. Due to the intense measuring work caused by the small rows between the olives, the system was changed to grids of three rows in the western area. The error derived from measuring the distance of 18 m along the slope and not horizontal can be estimated to 1 cm ($\mathrm{sqrt}(18^2 - 0.5^2)$) and can be ignored. The x-start coordinate of each row was rounded to full meters in the western area as well. The obtained 88 grids of the geomagnetic prospection south of the road were individually calibrated to the median of each grid taking into consideration variations in measuring level due to the zig-zag-measurement. The grids of each line were combined according to the local coordinate system used and georeferenced afterwards by the positions measured with the total station.

In the area north of the access road, geomagnetic measurements were performed in areas with varying lines between the almond trees going from south to north. With a spacing of approximately 4 m between the trees measurements, which resulted in stripes of 3.75 m (8 x 0.5 m incl. 0-line) with gaps of app. 2.25 m between the lines. In order to obtain a complete image of the site we interpolated the gaps with kriging in Surfer (ver. 9, Golden Software) using a linear variogram model. Independent from the original measurement of 0.20 m x 0.20 m, the resulting raster was calculated with a resolution of 0.25 m x 0.25 m and georeferenced according to the absolute coordinates obtained from the base station of the gps system.

Results of the geomagnetic campaign of 2018

Despite some initial problems in the field, it was nevertheless possible to obtain a satisfactory results at Monte da Contenda during the second field campaign. Most of these results focus on the area north of the access road, where the 8-sensor was used. In this area, it is in fact possible to gain a better picture of the two systems of ditches at Monte da Contenda (Fig. 4).

Fig. 4. Magnetogram of the 2018 campaign.

Here, it is possible to recognize several anomalies (in black and white) that cross the surveyed area from northeast to southwest. It is assumed that these lines are geological fracture zones, which correspond to magmatic layers that are a common presence in the region. In the eastern most section of magnetogram, it is also possible to recognize a ditch that crosses from northeast to southwest, but given its misalignment with the ditch systems, and the fact that it is a straight line, it is safe to assume that this might be a more modern structure, perhaps from the Roman period or perhaps even later.

As established by Valera and colleagues (2014), there are two systems of ditches and the full extent of these systems was revealed in the 2018 campaign (Fig. 5). In the centre of the magnetogram, it is possible to recognize a system composed primarily of circular ditches, and most of these were visible in the magnetogram produced by Becker (Valera et al. 2014, 198). What was more difficult to visualize, was the oval ditch system, of larger dimensions, that extended towards the east and west of the first magnetogram. The results of 2018 confirmed that the general outline of these ditches, obtained by overlapping Becker's Magnetogram onto aerial photos obtained from Bing Maps, was largely correct (Valera et al. 2014, 199). Furthermore, it confirmed that the oval ditch system does not extend south beyond the ribeira das Argamassas, which we can now safely assume serves as the natural delimitation of the oval ditch system. Of particular note, there is a small ditch towards the north (Fig. 5) that is isolated from the systems of ditches, but that nevertheless could have been part of the entire Monte da Contenda complex. This assumption, of course, will remain speculation until further investigation in this area of the site.

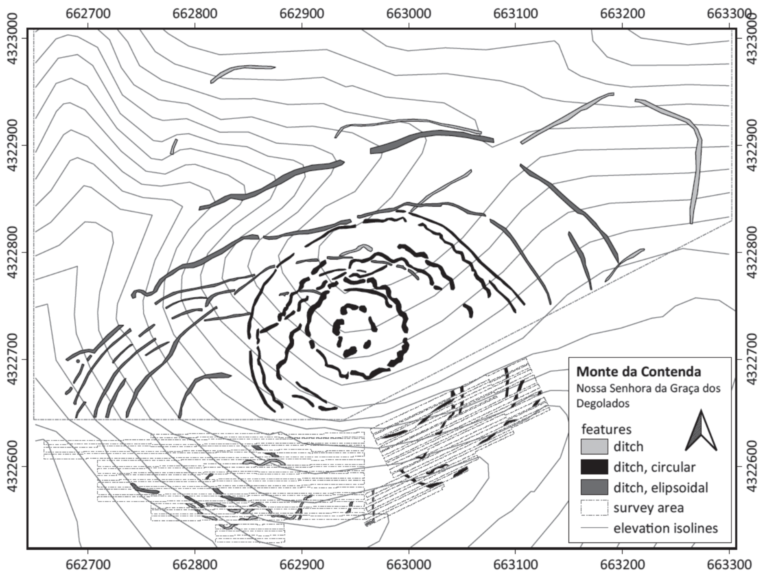

Fig. 5. Outline of the two ditch systems visible in the magnetogram of the 2018 campaign.

The area south of the access road revealed a more fragmentary picture. Nevertheless, it was possible to identify a series of ditches to the east belonging to the smaller circular ditch system, whereas more towards the west, there are series of ditches that are probably the southern extension of the larger oval ditch system. In this same area, there are several ditches of small dimensions, following relatively straight lines, which are hard to interpret: they can be sections of larger oval ditches, but they might simply be remnants of more modern constructions, perhaps from the Roman period, given that this area revealed surface pottery of Roman origin.

Overall, the geomagnetic survey of 2018 has confirmed that the site contains at least 17 distinct ditches, perhaps up to 19, although in some areas, like further west, it is not entirely clear if they are actually different ditches or just sections of the same ditch (Fig. 5). As had already been established, there are ditches of both straight and sinuous layout (Valera et al. 2014), although the ditches with sinuous layout seem to be concentrated in the smaller circular ditch system. Of exceptional interest is the circular structure at the centre of both ditch systems (Figs. 3; 4; 6), of very strong magnetic signal (visible in strong black and white tones), which might indicate a ditch that was filled with stones of magnetic/magmatic origin. It is not unlikely

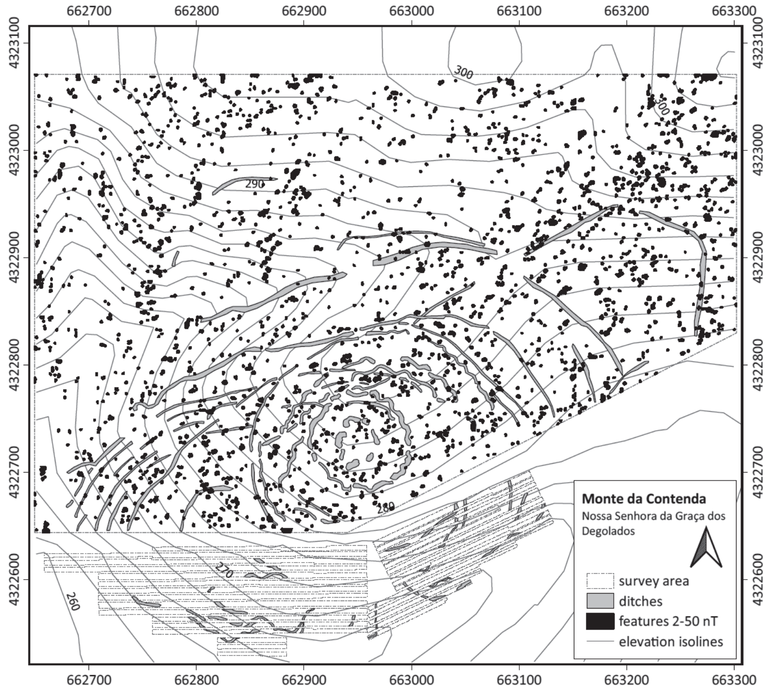

Fig. 6. Outline of all possible archaeological features. The black dots indicate anomalies with magnetic susceptibility.

that there might be something here even more complex, perhaps a structure for ritual purposes, which also involved material that has no magnetic register, not dissimilar to the central structures present at Perdigões (Valera 2018, 28) or the funerary structures found within the ditched-enclosures of Valencina de la Concepción (Garcia Sanjuán et al. 2018).

The 2018 campaign also involved a brief surface survey, but that did not encompass the full area covered by the geomagnetic survey, but rather the area directly south of the access road, close to where the road describes a curve. In this survey, several artifacts ascribable to the Chalcolithic period were identified (Figs. 7–9), but were not recovered and studied in depth. Individually, many of these artifacts can also be ascribed to the Neolithic, but as an assemblage, it shares more similarities to Chalcolithic assemblages, especially given the ubiquitous presence of thickened rim pottery (Fig. 7). In general, we identified polished stone tools in amphibolite (Fig. 8), knapped lithics in jaspoide schist (Fig. 9), several ceramic sherds, loom weights, and the occasional grinding stone. One must also take into consideration that the entire area north of the access road was planted with almond trees between the first field campaign in 2013 and the second one in 2018, and also the fact that most of the soil in the southern area seemed to have been moved. With this in account, it seems fair to assume that there is a good number of Neolithic finds, mixed in with Chalcolithic ones. Thus, we also remain sceptical if find distributions could be correlated with any of the archaeological structures identified in the magnetogram. During the 2018 campaign we also did a brief survey of the area south of ribeira das Argamassas and we found no artifacts on that side, further supporting the idea that the ditch systems do not prolong south of the ribeira.

Fig. 7. Sherd fragment (thick-rimmed pottery) identified in the surface survey. Scale: 1 : 2.

Fig. 8. Amphibolite polished stone tool identified in the surface survey. Scale: 1 : 2.

Fig. 9. Jaspoide schist knapped lithic identified in the surface survey. Scale: 1 : 2.

Final considerations

Although not much can be said about the site itself until it is intervened archaeologically, the geomagnetic surveys at Monte da Contenda provide us nonetheless with considerable information as to the spatial layout of the site, something that an archaeological intervention would unlikely be able to show. In particular, Monte da Contenda's intricate ditch system might indicate a prolonged occupation, as it has been shown in other sites, such as Perdigões (Valera 2015) and Valencina de la Concepción (Garcia Sanjuán et al. 2018), from the Neolithic until the final stages of the Chalcolithic, thus coinciding with the vicissitudes enacted by the 4.2 k climatic event.

It is important to recognize that just because there are several ditches, it does not derive that there is a linear evolution to the site. As the site of Perdigões has demonstrated, ditch construction, their abandonment, and their re-opening do not necessarily respond to functional or even what might seem to us pragmatic reasons (Valera 2015; Valera et al. 2014, 212). The social dynamics and cosmologies that have motivated the usage of these ditches remain understudied.

This leads to a topic that also remains understudied, especially when it comes to prehistoric Europe, the relation of environmental events, such as the 4.2 k event, with cosmologies and ideologies of the societies under investigation. Whereas most studies of climatic events on prehistoric societies focus on how these might have affected society in terms of demography and economy (e.g. Blanco-González et al. 2018; Lillios et al. 2016), little information has been gleaned in terms of their effect on symbolic life. The final centuries of the 3rd Millennium in Valencina de la Concepción for instance, reveals a series of rituals of quite elaborate character, and to a certain extent, more violent (Garcia Sanjuán et al. 2018), which might indicate some form of ideological *angst* in face of more difficult environmental conditions (Garcia Sanjuán, pers. comm.). What seems patently clear in Southwest Iberia is that the final centuries of the 3rd Millennium reveal a total abandonment of the exuberant symbolic productions of the Chalcolithic (Valera 2015, 419), something that cannot simply be explained by exogenous influence or migration, nor by epidemics – but by the intentional revamp of the Chalcolithic lifeways entirely.

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