

**Non- and Minimally-Invasive Methods to Investigate Megalithic Landscapes in the Brú na Bóinne World Heritage Site (Ireland) and Rousay, Orkney Islands in North-Western Europe***Knut Rassmann, Steve Davis, Julie Gibson***Abstract**

The paper summarizes results of an on-going project in the Boyne Valley in Ireland and in Orkney in the north of Scotland. The research of the Romano-Germanic Commission and our partners aimed to investigate the interaction of social, economic, cultural and environmental phenomena in different types of landscapes in a diachronic perspective. Our exploration of the landscapes was based on geophysical prospection, remote sensing and sedimentological analysis, and we adopted a systematic approach that integrated the various approaches in a GIS. In the Boyne Valley large areas were investigated on the periphery of the monuments of Newgrange, Knowth and Dowth. The field work on the Orkney Islands is focussing on tracing settlement patterns connected to chambered tombs, on the Island of Rousay. The use of a similar research design in both regions produces compound databases, something that is crucial for comparing trajectories of change in Neolithic land use, and in understanding those changes.

**Introduction**

Changes during the last three decades in the way megalithic sites have been researched are indicative of broader changes in archaeological research. These changes are characterized by a widening of the perspective from archaeological monuments and sites to a more complex perception of their archaeological background including the surrounding archaeological landscape. Setting sites and monuments in the context of the landscape is not a completely new approach. It originated on a small scale firstly in the 1960s and 1970s, but it was revolutionized by the systematic implementation of GIS in archaeology in the late 1990s.

The implementation of GIS-technology and the increasingly broad use of scientific methods has led to a new level in the investigation of archaeological phenomena that is clearly visible for the archaeological landscapes described in this paper. In the Boyne Valley in eastern Ireland and Orkney in the north of Scotland World Heritage Sites focus not only on exceptional monuments but also on their archaeological hinterland and wider landscape. Consequently, the investigations of the Romano-Germanic Commission (German Archaeological Institute) and our Irish and Scottish partners focus on large areas in these landscapes in which these monuments are embedded to provide essential archaeological context.

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**Authors' addresses:**

Knut Rassmann, Referat für Prospektions- und Grabungsmethodik  
Römisch-Germanische Kommission  
Deutsches Archäologisches Institut  
Palmengartenstr. 10–12  
60325 Frankfurt a.M.  
knut.rassmann@dainst.de

Steve Davis, University College Dublin  
School of Archaeology  
Newman Building Belfield Dublin 4  
Ireland  
stephen.davis@ucd.ie

Julie Gibson, Archaeological Institute  
University of Highlands and Islands  
East Road,, Kirkwall, Orkney, KW15 1LX, UK  
julie.Gibson@uhi.ac.uk



Fig. 1. Field research of the Romano-Germanic Commission 2018: 1 Dowth, 2 Newgrange (Ireland); 3 Navan Fort, 4 Rousay, 5 Birrens, 6 Scalewood, 7 Newstead, 8 Torwoodlee (UK); 9 Falbygden (Sweden); 10 Waldgirmes, 11 Hofheim, 12 Villmar-Weyer, 13 Bleibeskopf, 14 Ruffenhofen (Germany); 15 Reccopolis (Spain); 16 Vrable (Slovakia); 17 Fajsz, 18 Alsónyék, 19 Ócsöd-Kovashalom, 20 Szegvár-Tűzköves, 21 Tápé-Lebő, 22 Hódmezővásárhely-Gorzsa, 23 Hódmezővásárhely-Kökénydomb (Hungary); 24 Teleac (Romania); 25 Bapska, 26 Vrana-Samograd (Croatia); 27 Stolniceni (Moldova).

The new investigations are embedded in European-wide field research programme of the Romano-Germanic Commission (Fig. 1) and contributes to the “Boyne to Brodgar” project, a network of Irish and Scottish researchers focussing on the relationship between Ireland and the North of Scotland in the Neolithic (Sheridon/Cooney 2014). Our main goals are to understand the interrelations of humans and environment and their socio-environmental connectivity during this period. To better understand these variables, we are using a broad interdisciplinary landscape-based approach. This is based on a combination of remote sensing, geophysical prospection, pedological analysis, drilling and GIS modelling (Fig. 2). Similar approaches are being employed in the two study areas discussed. The standardized set of survey methods and research tools on Orkney and in the Boyne Valley will lead to compound databases. Based on comparable archaeological data we are able to investigate trajectories of change in Neolithic land use, and consider those changes in their socio-economical context. This paper will outline the on-going research and workflow used.

## State of Research

Both areas, the Boyne Valley (Brú na Bóinne) and Orkney Islands are famous for their rich record of Neolithic monuments and their long-term research history (Renfrew 1985; Schulz Paulsson 2017). The excavations conducted by George Eogan and his collaborators in Knowth in the Boyne Valley (Eogan 1986; Eogan/Roche 1997) along with those undertaken by V. Gordon Childe at Skara Brae on the Orkney Islands (Childe 1933) are milestones of the archaeology in northwestern Europe. Recent research in Orkney has been synthesized in the monograph on the “Neolithic House Societies” edited by C. Richards and R. Jones (2016). This summarizes recent excavations on Neolithic settlements and on cairns and gives an overview of the chronology of the Neolithic period based on 228 radiocarbon dates (85 settlements, 143 graves; Griffiths 2016, 259 table 10.1). The study of Bayliss et al. 2017, 1174) based on 613 partly published radiocarbon dates propose that differences can be seen in the late Neolithic between the centre (i.e. the World Heritage Area) and further afield. This breadth of approach has also been a trend in Irish archaeology as illustrated by Jessica Smyth’s monograph “Settlement in Irish Neolithic: New discoveries at the edge of Europe” (2014).

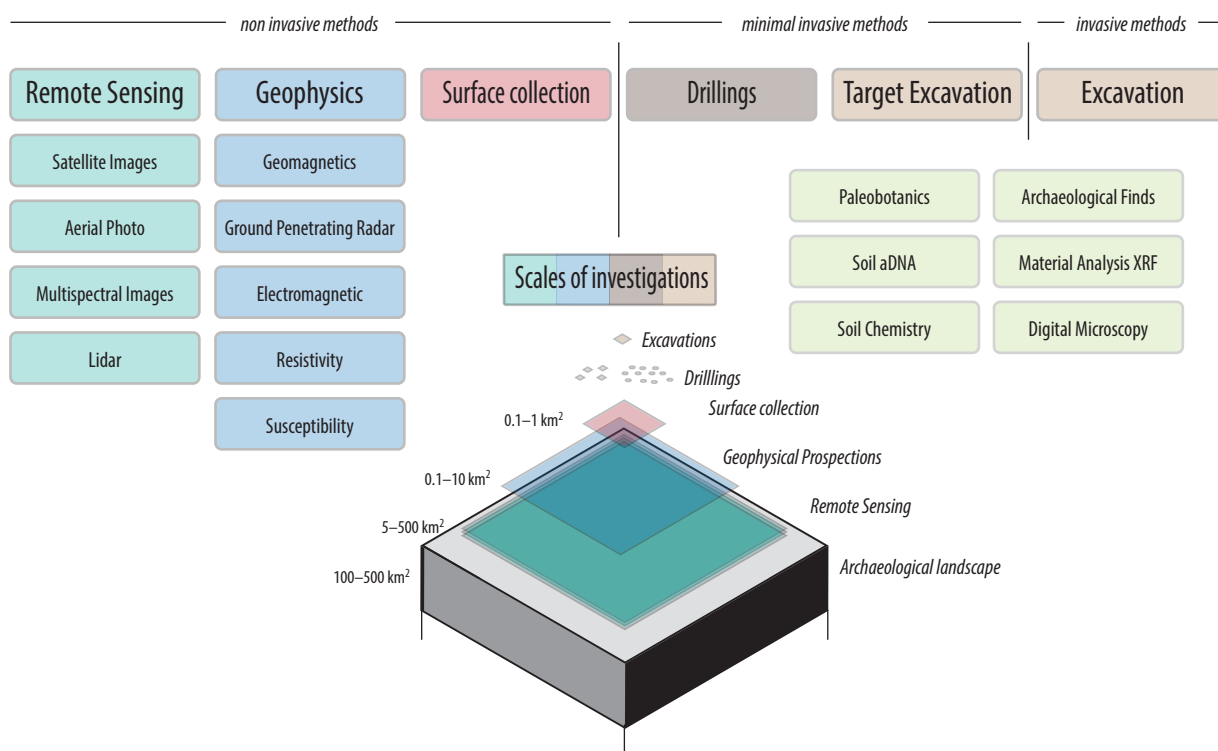


The different archaeological categories – graves, monuments and settlements – were embedded in a complex landscape. Gabriel Cooney (2000) developed a comprehensive landscape perspective for the Neolithic Period in Ireland. His monograph deals with many aspects of the interdependency of man and environment. The crucial point of this paper is the structural perspective including the dynamic processes of changes in the cultural landscape. Cooney perceives the landscape as a highly complex archive, only understandable with a strict interdisciplinary perspective. The human impact on the landscape over thousands of years generated a palimpsest-like picture and numerous complex traces of human action. To date these traces is presumably the most difficult challenge, but essential for reconstructing the changes in the landscape.

In both Orkney and Brú na Bóinne dating programmes incorporating many radiocarbon dates reflect the main stages of change in Neolithic times (Brú na Bóinne: Smyth 2009, appendix IV, Whitehouse et al. 2014, 181 et seq. Orkney: Griffiths 2016, 254–302); however, many chronological questions remain unanswered, such as a precise chronological model of rise and decline of settlements and enclosures, the construction phases of the megalithic monuments and the time span of their use and reuse.

In the Brú na Bóinne Research Framework, Smyth (2009, 96) presents a map with results of magnetic surveys of a core area of the heart of Neolithic Orkney WHS. This example illustrates the investigation of a landscape by non-destructive methods and their great potential very well. The large area of several hundred hectares prospected on Mainland includes the area between Ness of Brodgar and the Ring of Brodgar. Researchers from the University of Highlands and Islands used magnetic prospection for screening the landscapes on a large scale in one of the first such large-scale studies in Europe. Their magnetic prospection discovered numerous archaeological features.

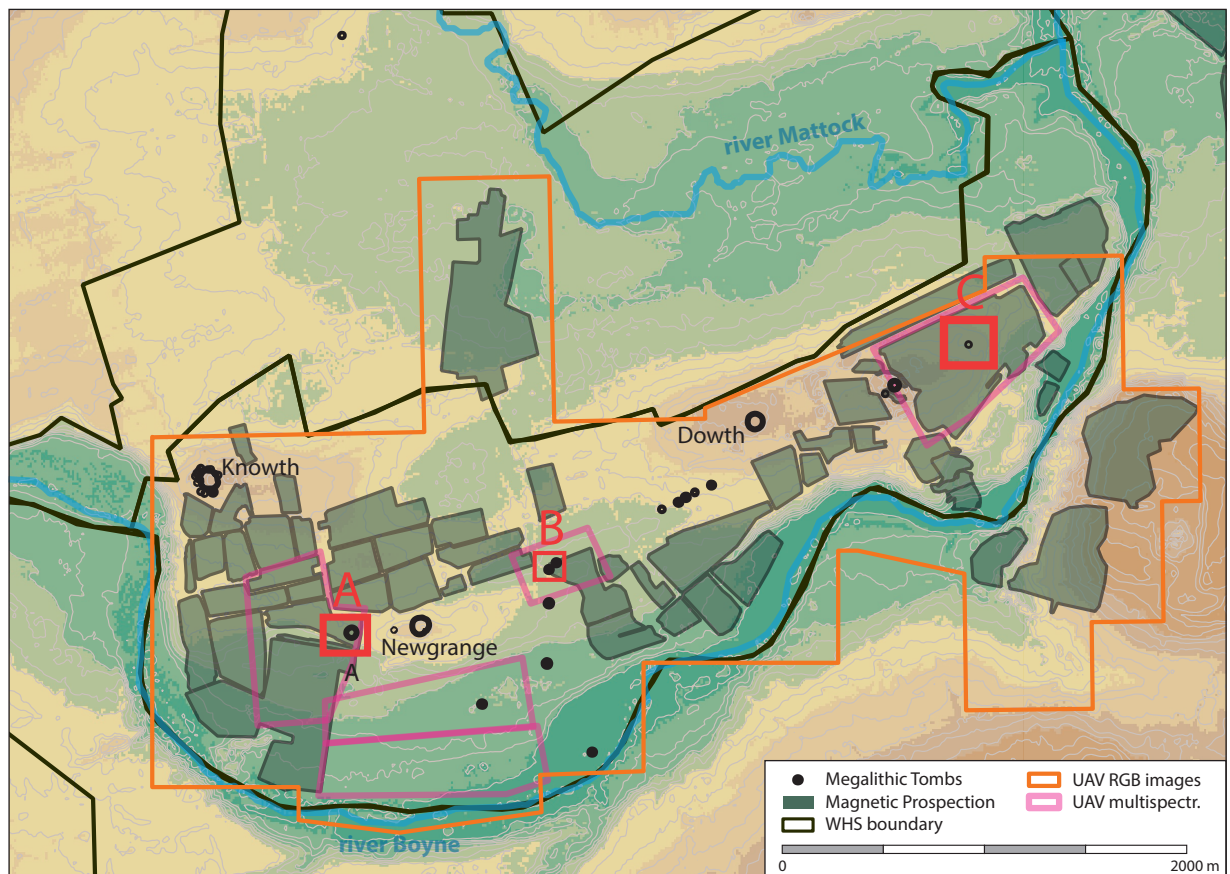
Fig.2. Methodological workflow of non- and minimal-invasive methods from remote sensing, geophysical prospections until excavation and the final analysis of samples and finds.



Such an investigation of archaeological landscapes needs an appropriate definition of boundaries. The framing of research questions depends on different factors as the composition of landscape units, the state and tradition of archaeological research in the region of interest and recent political boundaries. A crucial point should be the archaeological research question. In the case of the Neolithic megalithic phenomena it is critically important to try to understand the social processes and communities behind these phenomena.

Starting from a methodological perspective Andreas Zimmermann et al. (2005, 56 et seq.) discuss different scales of research in landscapes of the Rhineland in western Germany from around 10 km<sup>2</sup> up to several hundred km<sup>2</sup>. Here key research areas in the size of 20 – 100 km<sup>2</sup> are important (Zimmermann et al. 2005, 49). In these areas it is possible to collect and generate precise archaeological data to investigate the changes of settlement patterns and to use these key areas to understand large territories. In a next level Zimmermann et al. assume a form of jointly acting settlement communities (Siedlungsgruppen). For the early Neolithic LBK (*Linearbandkeramik*, Linear Pottery Culture) they estimate up to 1500 people that settled in this region and based on that they calculate territories of 100–200 km<sup>2</sup> of arable land, pastured landscape and forests (Zimmermann et al. 2005, 62).

Fig. 3. Overview on the prospection activities in the Boyne Valley and the boundaries of the World Heritage Site (WHS), showing areas of magnetic prospection. (A c. Fig. 10; B c. Fig. 5; C c. Fig. 12)

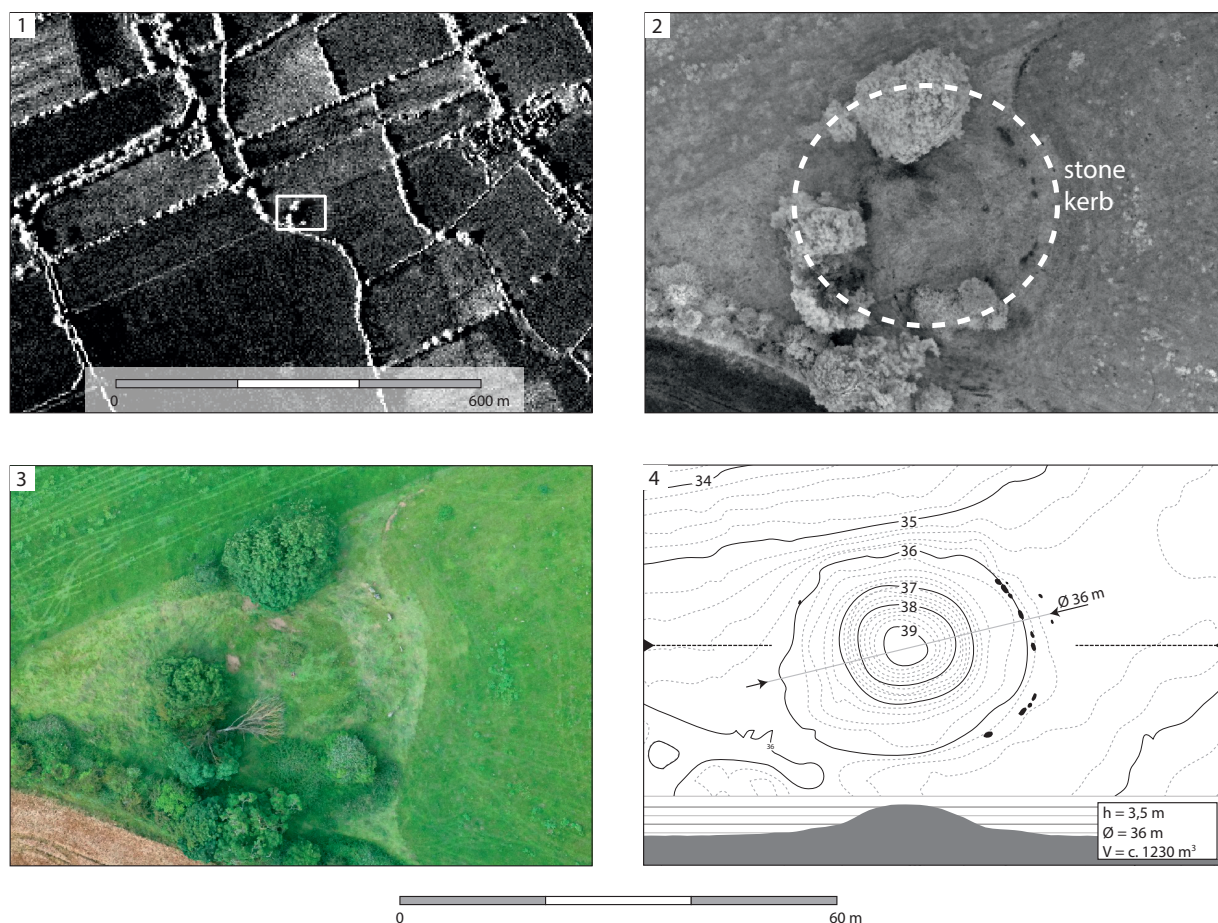


The UNESCO World Heritage Site Brú na Bóinne comprises a core area of around 7 km<sup>2</sup> with a northern buffer zone of 8 km<sup>2</sup> and a southern one with 28 km<sup>2</sup> (Fig. 3). The size of the Orkney Island Rousay is 48 km<sup>2</sup>. That means we are dealing with landscapes in a scale of a typical micro region as described above. In the last decades a number of research projects about megalithic areas took place in northern Germany and southern Scandinavia that are dealing with

territories in a similar scale as Oldenburger Graben in northern Germany (Brozio 2019, 487 et seq.) and Sarup in Denmark (Andersen 1997). An exception is the remarkable concentration of 255 passage graves on the Fallbygden plain in southern Sweden distributed over an area of around 900 km<sup>2</sup> (Sjögren 2010, 1 et sq.). But here clusters of passage graves clearly indicate smaller territorial groups. Sjögren (2010, 8 Fig. 8–9) is operating with six larger units (“sector”) and 32 smaller units (“groups”).

The size of the area of investigation fundamentally affects the research design, the methods and the way of their use (Fig. 2). Figure 2 illustrates the ideal workflow of field research and the interaction of non-invasive and minimal-invasive methods. Some of the technical infrastructure is available in our institute while some non-invasive methods like Satellite Imagery, Lidar, Ground Penetrating Radar and Electromagnetic Resistivity can be realised with our partner institutions. That is also the case for analysing soil samples from our field work by palaeobotanists and specialists for the analysis of traces of aDNA in soil samples

Fig. 4. Overview on remote sensing data on the Monument019/043E. A TerraSAR XStaring spotlight image of the area around Monument019/043E (location cf, Fig. 3). B Infrared-image recorded by Parrot Sequoia Sensor mounted on Quadcopter. C Orthophoto recorded in a resolution of 2 cm by DJIMavic 2 pro. D DEM based on the 3D-processing of the RGB-images of the DJIMavic 2 pro. (graphic: H. Höhler-Brockmann).



### The first stage of prospection

Remote sensing is a fundamental tool for the largest scale of landscape archaeology. This enables us to survey the complete landscape of a micro region. The access to specific remote and satellite data could be complicated but there are many improvements in the last two decades. Of special importance is the Copernicus Programme of the European Commission in partnership with the European Space Agency that started recently. The aim of the programme is that data and information produced in the framework of the



Copernicus Programme are accessible on a free-of-charge basis to all its users and public in general. In our project we are implementing a pilot study to evaluate Microwave radar images produced by the TerraSAR mission. The trial in cooperation with Thomas Busche from the Radar Institute of the German Aerocenter has been running over a period of several months now producing daily images of test areas in Europe including the Boyne Valley and the Sourin Valley on Rousay.

To complement the satellite data we are generating more data with drones to get high resolution aerial RGB images and multispectral photos. The surveyed areas measured with drones comprise up to 10–20 km<sup>2</sup> (Fig. 3). The limitations by using a drone depend on the capacity of batteries, and the chosen altitude that latter defines the final resolution of the images. In a one 5-day flight mission in the Boyne Valley an area of 10 km<sup>2</sup> was covered by drone RGB images (resolution c. 3 cm) and 1.5 km<sup>2</sup> by multispectral images (resolution c. 3 cm) (Fig. 3).

### The second and third stage of prospection

On the basis of the remote data we are focussing on smaller areas for our surveys with the help of geophysical methods. Initially, magnetic prospection in archaeology has been used on smaller areas on a scale of archaeological sites. The instruments were only hand driven with single and multi-channel systems (Fig. 4A). By that areas up to one hectare were rarely reached. To cover larger areas vehicle towed system can be used efficiently (Fig. 4B – C). With the help of this new generation of systems between 10 and 20 ha can be prospected per day. In the Boyne Valley the prospected area in the World Heritage site comprises around 3.4 km<sup>2</sup> (Fig. 3) and on Rousay 2 km<sup>2</sup> (Fig. 6).

Fig.5. A The 5-channel magnetometer (SENSYS MAGNETO®-MX ARCH) at Dowth in 2014. B The SUV-towed 16-channel magnetometer (SENSYS MAGNETO®-MX ARCH) close the enclosure in Dowth. C The quad-towed 14-channel magnetometer (SENSYS MAGNETO®-MX ARCH) at Newgrange 2017. All systems are working with sensors spaced in a 25 cm distance (Photos: Knut Rassmann).



In both areas numerous archaeological features were discovered.

The relevant archaeological features will be thirdly and finally evaluated by a drilling campaign with a percussion drilling system. The drilling cores will be sampled and investigated by soil chemistry, susceptibility and phytolith analysis.

Finally, the combination of remote sensing with geophysical data and the minimal invasive drillings enable us to specify our research questions. The data are essential for a precise location and evaluation of size of future excavation areas. Such target excavations will help define the extent of larger excavation.

As mentioned above our work is embedded in the initiative “From Boyne to Brodgar” aimed to explore the nature, developmental trajectories and inter-connectedness of Neolithic monuments in Ireland, the Isle of Man and northern Britain. One of the most visible features are the megalithic tombs, particularly in the passage tomb tradition that occur in the Boyne Valley and on Orkney. To explore



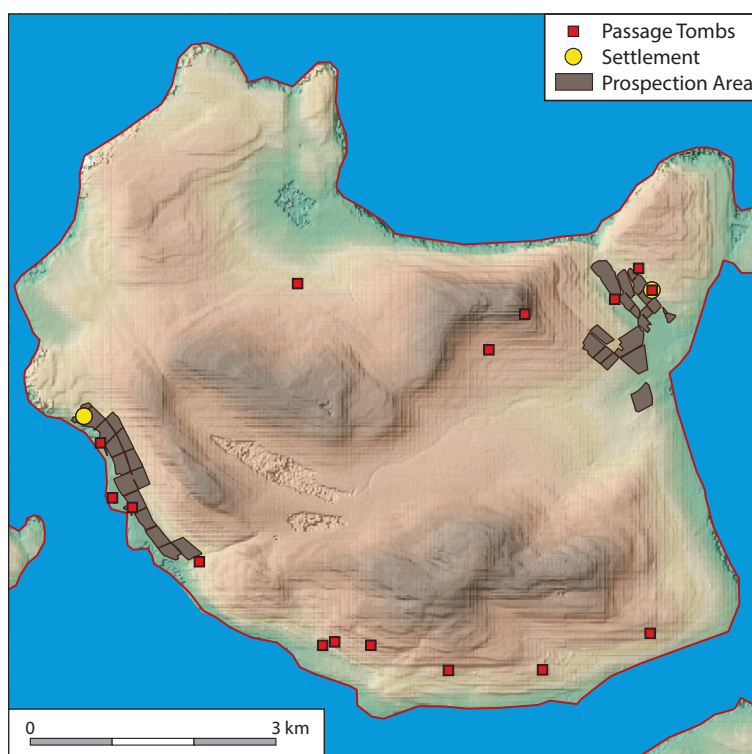


Fig.6. Overview of the prospection area on the Orkney Island Rousay.

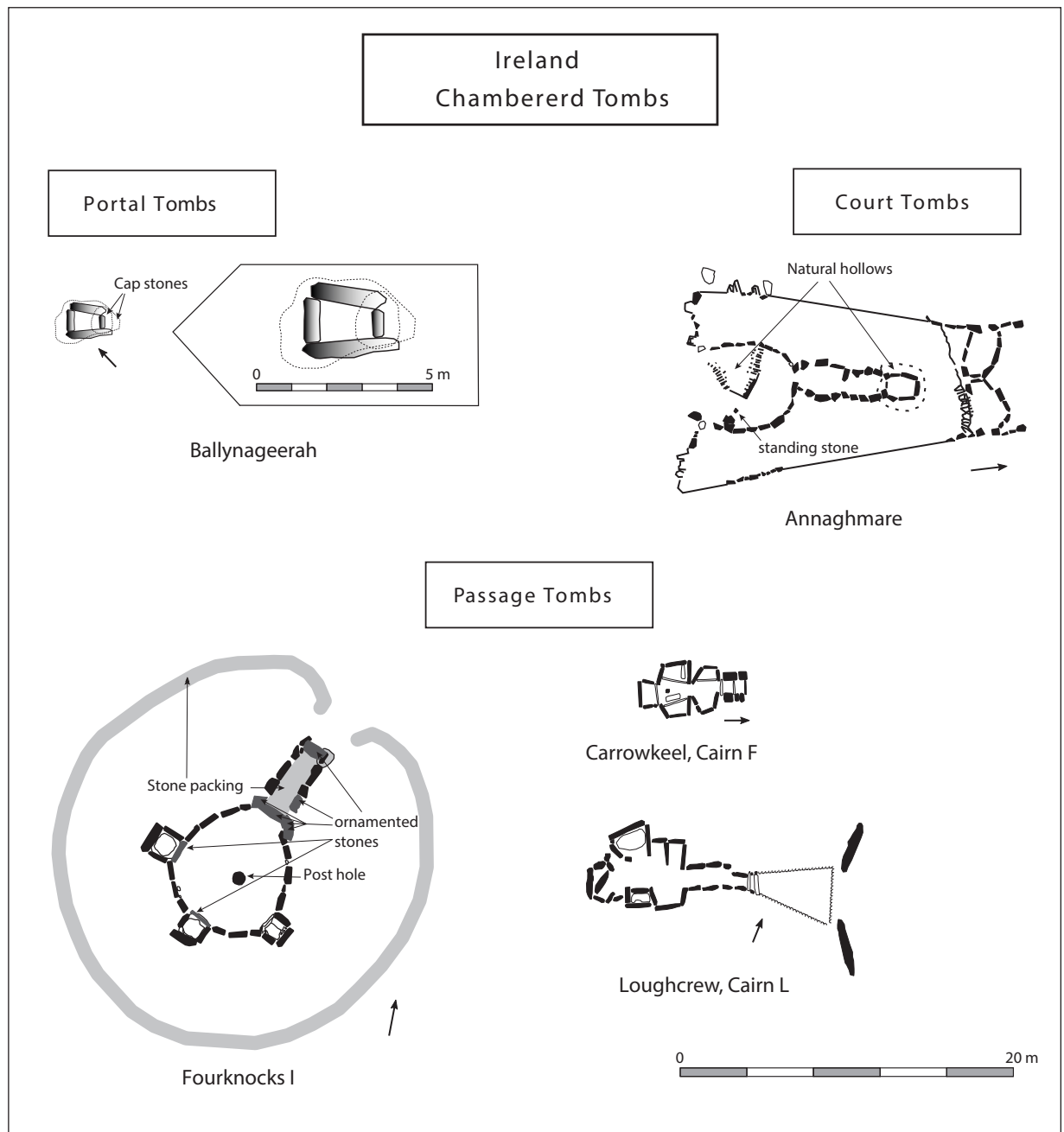
the links between their builders in the centuries around 3000 BCE we need to consider the wide range of archaeological data. The analysis of ancient DNA of human remains will have a great impact in the next years as well as the analysis of stable isotopes. We should also not forget the potential of archaeological objects for answering research questions, their typo-chronological relevance and their specific value in the context of modern scientific methods like chemical material analysis.

The investigation of the megalithic landscapes in the Boyne Valley and on Orkney also has the chance to answer more structural questions: Is it possible to detect already destroyed monuments by using non- and minimal invasive methods? Can we use these observations to quantify the degree of destruction of monuments in the last 5000 years and the decline of their total number? Can we reveal architectural remains in the periphery of known passage graves or unknown archaeological structures as ditches, causeways or ritual avenues?

We are, of course, aware of the limitations of non-invasive survey methods and their outcome. To minimize their uncertainties, the evaluation by invasive methods is inevitable or at least a systematic comparison of magnetic anomalies with the results of archaeological excavation is absolutely essential.

### Overview of the research in the Boyne Valley

In the fourth and third millennium BCE a large number of megalithic monuments were erected in Ireland. Nearly 1500 were recorded and classified in five classes as portal tombs, court tombs, passage tombs, Linkardstown cists and wedge tombs (Fig. 7). The first four classes broadly date to the Middle Neolithic, with early examples of portal tombs and court tombs dating to around 3800 BCE and court tombs very shortly afterwards (McLaughlin et al. 2016 Tab. 1). While construction of portal tombs and court tombs has probably



ceased by c. 3500 BC, passage tomb construction continues until at least 3100 BCE. The wedge tombs appeared at the end of the Neolithic Period around 2500 BCE.

The four classes of megalithic monuments vary in their geographical distribution (Fig. 8). Generally, the northern part of Ireland has the highest density of portal, passage and court tombs. An exception are the Linkardstown cists mainly occurring in the south of the province Leinster and in the north of the province Munster (Cooney 2000, 16). The distribution of the more numerous portal, passage and court tombs is much wider. A Kernel Density Estimation (KDE) indicates regional hot spots in the distribution of megalithic monuments. Portal tombs do have the largest distribution in an area in the north, respectively one in the west and south-west. The passage graves show a similar spatial pattern as the portal tombs. Especially in western Ireland they have a clearer coastal orientation. The spatial distribution of the court tombs shows a clear concentration in the north. For the "Boyne to Brodgar" project

Fig. 7. Schematic illustration of Middle Neolithic megalithic tombs in Ireland.

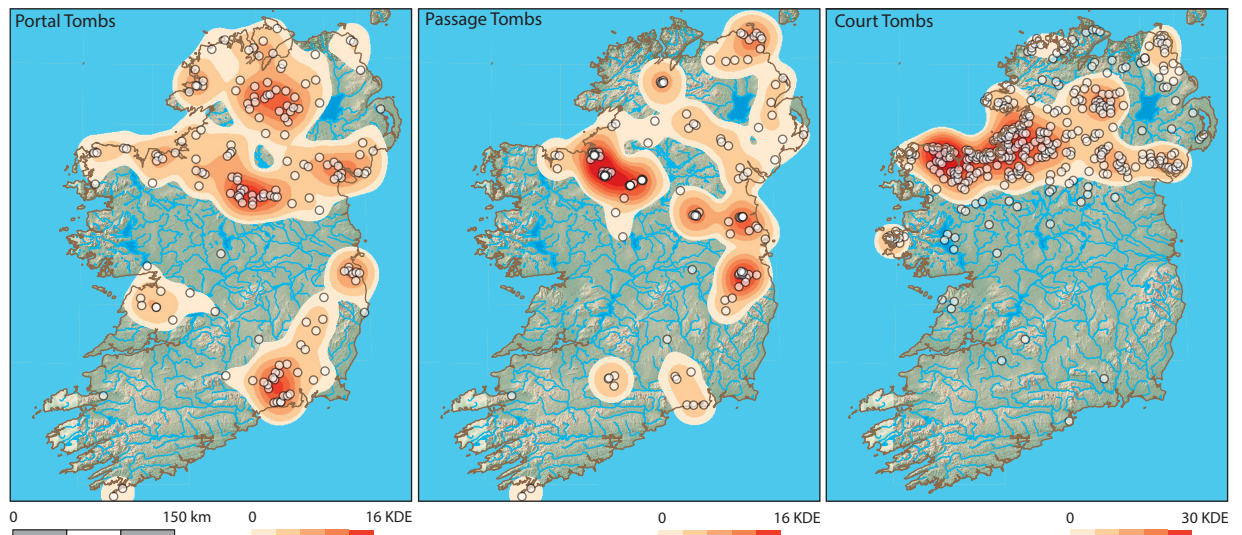


Fig.8. Distribution of portal, passage and court tombs in Ireland. The density map is calculated by Kernel Density Estimation (KDE) and highlights areas with remarkable concentration of monuments. Especially the portal tombs are indicating a special relationship to the sea.

the discussion of oversea contacts of Neolithic communities should consider this high density of monuments close to the coast. The preference of these might indicate the importance of the sea not only as source for multiple food resource but for communication and exchange.

The megalithic landscape of the Boyne Valley is dominated by passage tombs (Fig. 7–8). The building of the first simple constructed passage tombs in Ireland can be dated presumably little earlier than 3600 BCE in MN I as Schulting discussed for chamber 3 in Baltinglass (Schulting et al. 2017 a, 11). Passage tombs with a more complex architecture and larger size such as Newgrange, Knowth and Dowth in the Boyne Valley date to at least 400 years later.

Excavations of megalithic monuments reveal the complex biography of these sites. In the case of the passage tomb in Baltinglass radiocarbon dates indicate a time span of 400–600 years (Schulting et al. 2017 a). For the highly complex late monuments in the Boyne Valley a similar scenario has been described. G. Eogan outlined a model of six stages for Knowth starting in the Early Neolithic and lasting until the Early Bronze Age. The excavation revealed only slight settlement activities for the two earliest stages and significant ones for the late Early Neolithic with traces of rectangular houses (Eogan/Roche 1997, 5 Fig. 1). The construction of the passage grave itself dated in the end of the Middle Neolithic. Following the radiocarbon dates the start of burial activity at the passage grave in Knowth can be dated between 3160 and 3045 BCE (Schulting et al. 2017 a, Schulting et al. 2017 b). The erection of the other focal monuments such as Dowth and Newgrange was presumably within the same chronological horizon. Until now no radiocarbon dates for Dowth are available. One deficit here is the fact that all dated samples are of charcoal; no human bones have yet been dated. For the tomb of Newgrange a Bayesian model of radiocarbon dates suggest that the turf mound was initiated sometime around 3305–3125 BCE, and the overlying and presently reconstructed cairn completed in the range 3190–2865 BCE (Lynch/Schulting 2015).

In both monuments indication for construction activities in Late Neolithic were found. At Knowth the chronology provides evidence of human activity from the Early Neolithic until the Medieval Period, while at Newgrange significant later Neolithic and Early Bronze Age (Beaker) activity has been noted immediately south of the tumulus (Sweetman et al. 1985; Sweetman et al. 1987; O'Kelly et al. 1983). Excavations mean that it





is likely that in the two dimensional magnetic data there is often a mixed picture and overlapping of archaeological features of different periods. This is a general challenge if we are operating on sites with diachronic histories. So far, information out of archaeological excavations are indispensable for interpreting and understanding the magnetic map.

Fig.9. View from Southeast to the Northwest. A Newgrange. B In the background the monument of Knowth. C The left the oval circle highlighted the position of the 2017 discovered monument (c. Fig. 10–11).

### Some Results of the Prospection in Brú na Bóinne (World Heritage Site)

Geophysical surveys have taken place the Brú na Bóinne WHS since 1991 (Brady/Barton 2015, 82 Fig.2; Stout 1991). Our magnetic prospection started 2014 and focused firstly on the Dowth estate in the Eastern part of the World Heritage site and later extended into the other areas. The goal of the magnetic prospection was to continue to the work of Conor Brady, Kevin Barton and Joseph Fenwick in gaining representative data for the WHS at large. Significant areas of the WHS are under intense agricultural use mainly as pasture land with some arable cultivation. Access to most of the relevant prospection areas is possible, but planning and organisation sometimes need considerable effort. These occasional difficulties, in addition to areas of arable cultivation not yet surveyed explain the visible gaps in our prospection map (Fig.3). The size of the parcels is variable, and not always ideally suited to take full advantage of the four-meter-wide vehicle towed instrument (*SENSYS MAGNETO®-16MX ARCH* – Fig.5 B). Since 2018 we have utilized a smaller 14 channel system with a width of 3.3 m (*SENSYS MAGNETO®-14 MX ARCH*- Fig.5 C). The system is more flexible and more appropriate for smaller areas and narrower meadow paths.



Many areas are very rich of archaeological features belonging to different periods. Most numerous are features of the Early Medieval Periods (400–800 AD). We also found indication for Bronze Age ring ditches, in addition to Neolithic enclosures and timber monuments. The most clearest hints of a monument of the Neolithic Period came from a field close to Newgrange (Fig. 9 C, 10–11). A feature was found in the centre of the enclosure in the Dowth estate in the eastern area of the Brú na Bóinne WHS (Fig. 12).

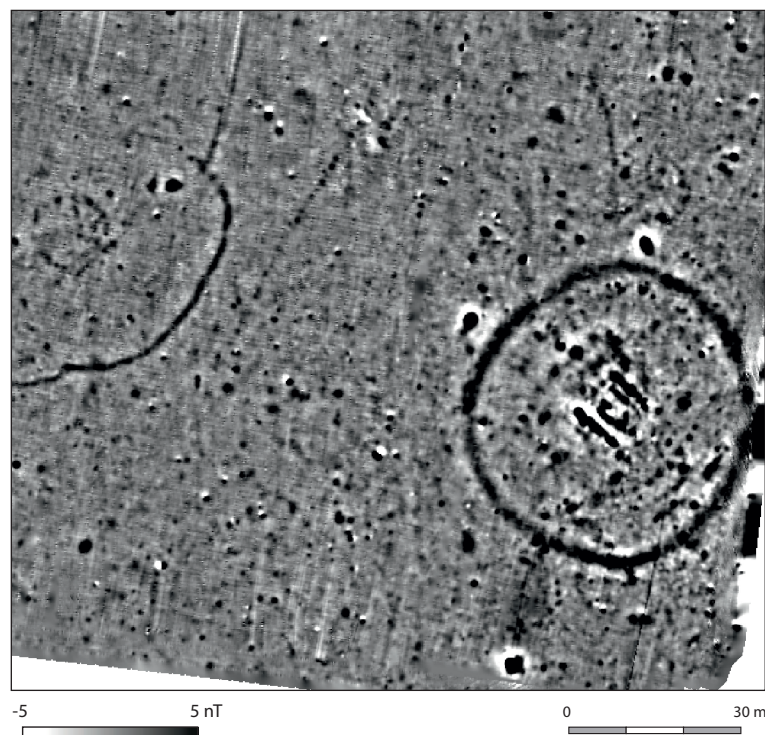
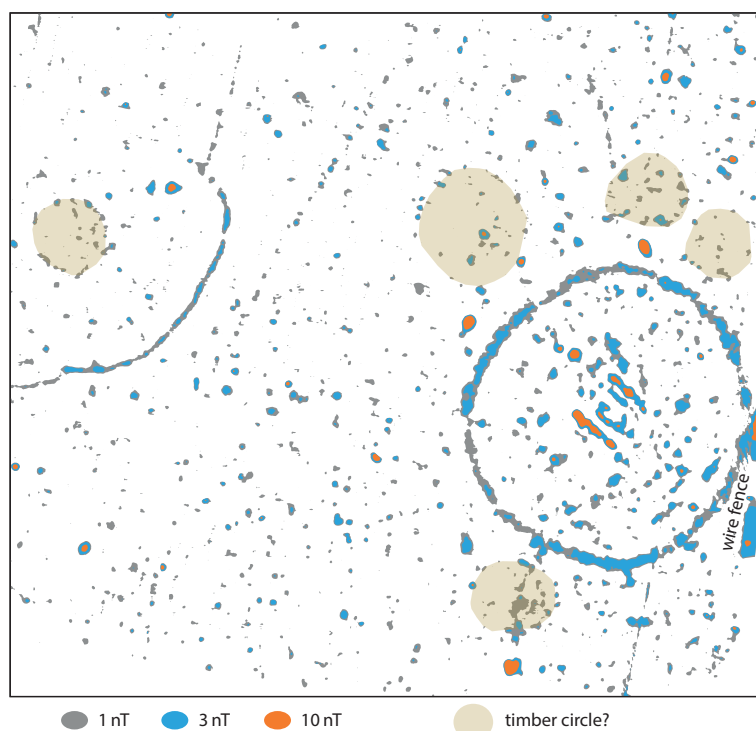


Fig. 10. Late Neolithic monument with a circular ditch and remains of a chamber (?) in the centre and indication of timber circles. A magnetic map with data visualized as greyscale. B Contour map of the dynamic in the raster map of the magnetic data.



The magnetic data in the area close to the monument of Newgrange reflect a high dynamic of nT-values up to more 20 nT (Fig. 10–11). The anomalies of different range nT-values are indicating different archaeological features of a hidden monument. The main element is a round ditch with a diameter of 50 m. The contour map of the nT-values enables us to differentiate these values more precisely and to interpret them in a more reliable way. This is shown most clearly in the interpretation of the circular ditch within which we see considerable variation, with some segments with values from 5–10 nT and others below 3 and 5 nT. The seven segments are all of similar length (c. 35 m). The circular ditch encloses numerous features, which can be classified as hidden stones or postholes. Anomalies with values above 10 nT could represent burnt remains of a wooden construction in the centre, or less likely a stone-built chamber. These anomalies are in the centre of the circle and the shaping a chamber-like structure. Taking in account the fact that a magnetic field of an object is much larger than the object itself, a size of this chamber might be reconstructed with a length of slightly more than 10 m (Fig. 10). The red contour polygons of more than 10 nT can be separated based on the internal variation or dynamic in smaller units, namely single posts or orthostats, with a dimension of 1–2 m. Besides the wooden construction some postholes within the circular ditch are clearly visible. These are almost certainly packed with burned material as at the similar site excavated at Ballynahatty (Hartwell 1998).

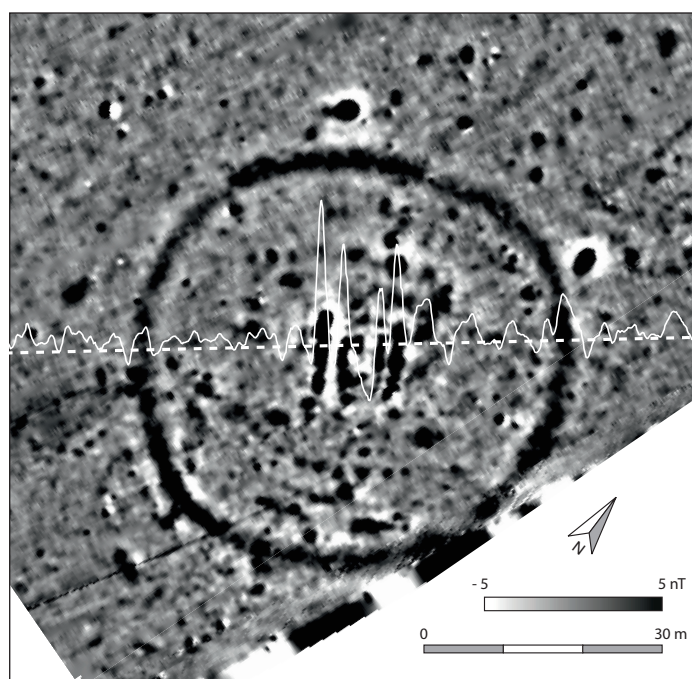
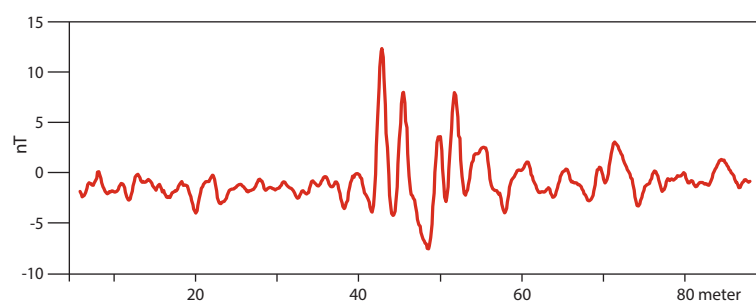


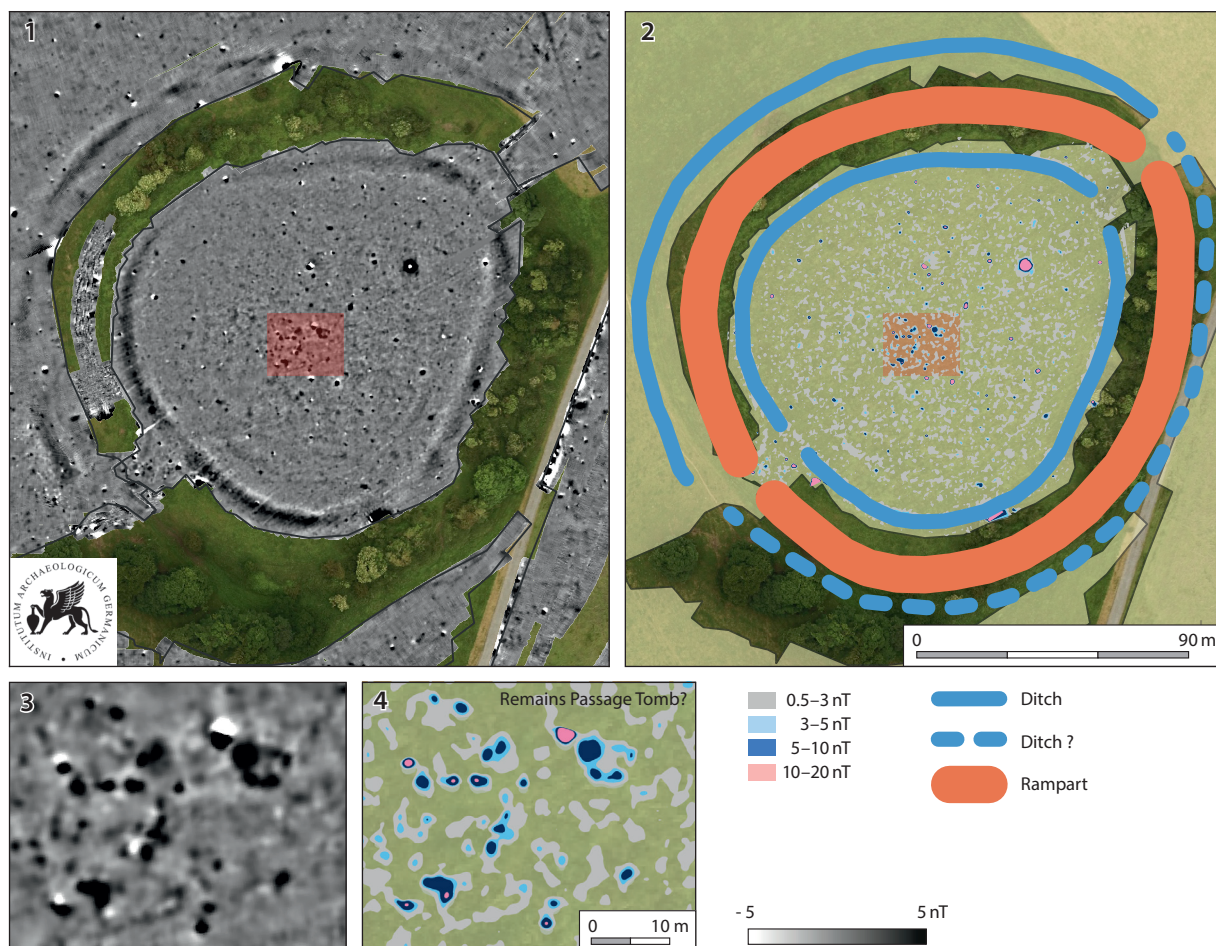
Fig. 11. Magnetic map and diagram of nT-values along a section through the central part of the monument.





The variation and dynamic of the magnetic data varies widely and it is clear, that all of this information cannot be visualized in greyscale map alone. An alternative is the implementation of contour maps in the analysis of the data (Fig. 10B), and the use of cross sections (Fig. 11). The cross section through the monument shows much more clearly the dynamics of the magnetic values. It is clearly possible to evaluate every relevant anomaly in our prospection in this way.

Fig. 12. Prospection of an enclosure in the Dowth estate with traces of a passage grave in their middle.



Within the circular ditch some postholes or stone sockets are clearly visible. In the Eastern part these form a 12 m long arc. This structure might be further enclosed within a larger one.

Outside the circular ditch we find in the magnetic data indications of a smaller circular structure, probably of timber construction, with a diameter of 12 m.

These structures are very similar to the small timber circle adjacent to the large monument in Knowth. In our data the circle of postholes of the objects in the neighbourhood of the ring ditch are not completely visible. Only 40% of them are visible in the magnetic map. But more than 50 m westwards a structure of exactly the same size and frequency of postholes is completely preserved (Fig. 10). We count 15 postholes with a space of c. 3.8 m between them. Inside there is no clear evidence of other features.

These structures almost certainly belong to the group of monuments known as "Four Poster structures" - associated with Grooved Ware pottery and closely allied with passage tombs (Carlin/Cooney 2017). Similar structures have so far been identified at Knowth and Newgrange, a parallel that highlights the importance of this position in the immediate post passage tomb area.



A second probable passage grave was discovered in the centre of the enclosure in Dowth (Fig. 3, 12). The prospection revealed a ditch inside the rampart and another one outside. The chronological seriation of the three elements, ditch outside the rampart and a ditch inside the rampart is unclear; however, this is an unusual design in an Irish context as it might be in Ballynahatty (Fig. 13). The same temporal uncertainty concerns the chronology of the passage grave. It has a certain degree of probability, that the enclosure elements are younger than tombs. Almost no Irish ones are dated, but UK dates are summarized in (Harding 2003).

These examples illustrate a first level of investigation by magnetic prospection. They are helpful to discover archaeological monuments and revealing their internal structure in a specific resolution. The goal of large-scale magnetic prospection in Brú na Bóinne is investigate wide parts of a landscape in a size of square kilometres in. These new data not only improve the number of known objects but also significantly enhance our understanding of the structuring of Neolithic landscape (in addition to that of other periods) in Brú na Bóinne WHS.

Fig.13. Passage grave in the middle of the enclosure Ballynahatty in Northern Ireland.

### **The Island of Rousay and the Monuments on Orkney**

As mentioned above the Orkney Isles are well known for their rich record of megalithic tombs (Fig. 14; Henshall 1972; Renfrew et al. 1979; Fraser 1983). The interconnection between Orkney and Ireland is clearly visible in similarities of the architecture of the megalithic monuments, their megalithic art and their ceramic typologies (Müller 1990, Sheridan/Pétrequin 2010). These therefore, are fundamental to the “Boyne to Brodgar” research initiative. The megalithic monuments on Orkney are diverse (Fig. 15). Henshall (1963, 61) described three variations of the Orkney-Cromarty group by the layout of the plan, the rectangular, polygonal chamber and the Camster-type chamber, the latter are of an oval elongated layout.



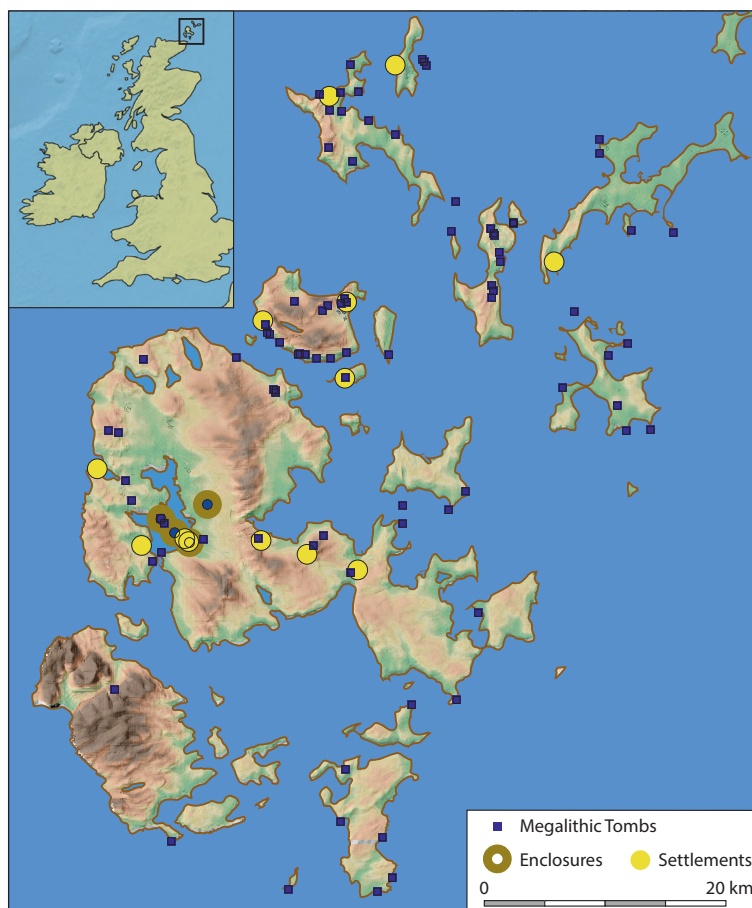


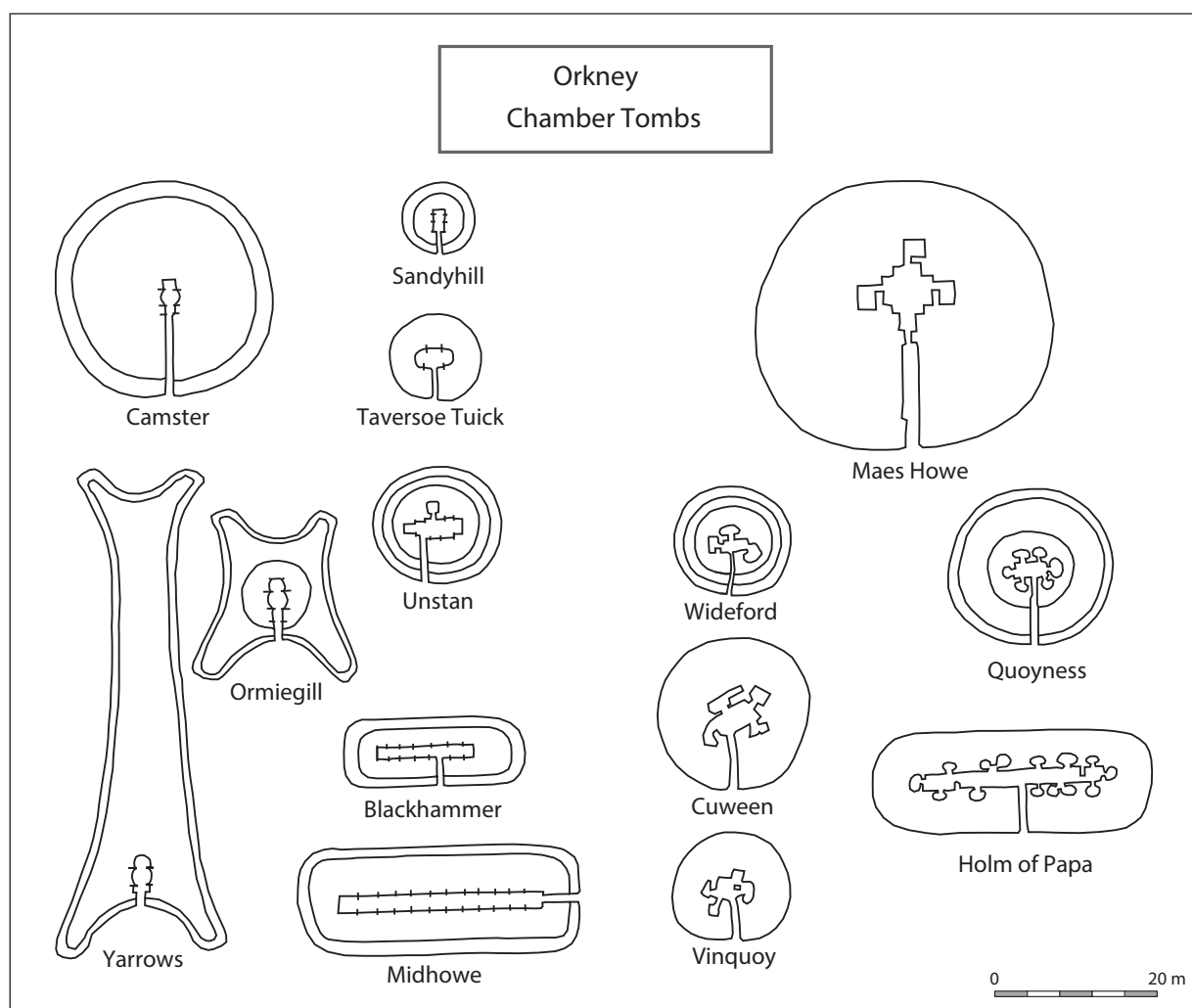
Fig. 14. Distribution of megalithic tombs and Neolithic settlements on Orkney.

The Camster-type chamber formed a starting point for the genesis of the stalled cairns and Bookan-type chambers. The majority of chambers are covered by round cairns but in some cases by long cairns. If the latter are covering polygonal and Camster-type chamber then these may have horned forecourts. The tombs of the Orkney-Cromarty groups vary in complexity from 2 to 14 compartments (total chamber 5–50 m<sup>2</sup>). The tombs fall into three closely related classes: the tripartite chambers with three compartments arranged down the main axis formed by two pairs of divisional slabs and a pair of portal slabs, the stalled chamber, similar to the tripartites but with more compartments and the Bookan-type chamber which have relatively small oval chamber surrounded by orthostats (Davidson/Henshall 1989, 19).

Especially characteristic for the megalithic monuments on Rousay are the stalled chambered cairns, divided in different compartments by tall slabs such as at Blackhammer and Midhowe (Fig. 15). The chambers of the Maes Howe group are immediately distinguished from the stalled cairns of the Orkney-Cromarty group. These have generally a rectangular plan and are not divided in compartments. The chambers are accessed through low entrances and the chamber is arranged symmetrically, leading to smaller cells. The chambers are covered mostly by round cairns (Davidson/Henshall 1989, 37).

The chronology of the Neolithic of Orkney is despite the number of 613 radiocarbon dates relatively poorly defined (Bayliss et al. 2017, 1174). The majority of data are from old excavation with contextual uncertainties. Only a small part comes from recent excavations as from the settlement Ness of Brodgar (Card et al. 2017, 217 et seq.).

The chronological tendencies were outlined by Bayliss et al. 2017, 1182 Fig. 5). The construction of stalled chambered cairns started



around 3500 and indication of burial activities lasted until 2800 BCE. First activities at the monument of Maeshowe can be dated in the middle of the 4<sup>th</sup> Millennium BCE and continued until the end of the 3<sup>rd</sup> Millennium BCE. The radiocarbon dates from some settlements are tendentially younger than from graves (Bayliss et al. 2017 1182 Fig. 5: Skara Bray 3500–3100 and 2900–2500 BCE; Barnhouse 3100–28850 BCE; Ness of Brodgar 3000–2700 and 2600–2300 BCE). Radiocarbon dates from the Ring of Brodgar are from 2600–2200 BCE (Fig. 16). Different is the situation in the Bay of First. Here the settlements are earlier than the tombs. It would seem that only when the occupation of these site became well established the construction of the passage grave begun. C. Richards emphasise that this is not a general pattern, and in places settlements do not have a related passage grave<sup>2</sup>.

### First results of the magnetic Prospection f from Westness and the Rhinyo-Valley

The scale of Rousay with nearly 38 km<sup>2</sup> offers the chance to quickly prospect large areas of the island to get reliable and representative data. In two campaigns in 2018 and 2019 three relevant areas Westness, Rinyo and Saviskail Bay were prospected (Fig. 6), one aim being to locate undiscovered settlements and burial monuments. Campaigns in Quandale, the southern coastal zone and Sourin close to the Rinyo-Valley were to follow.

Fig. 15. Typological seriation of the megalithic monument of Orkney (after Pigott 1954).<sup>1</sup>

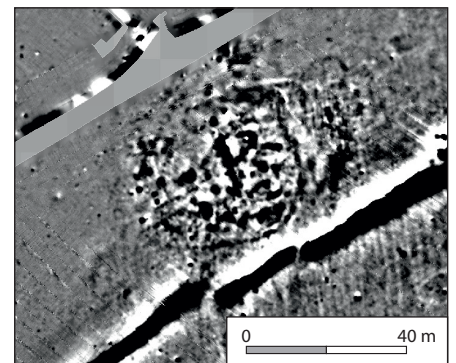
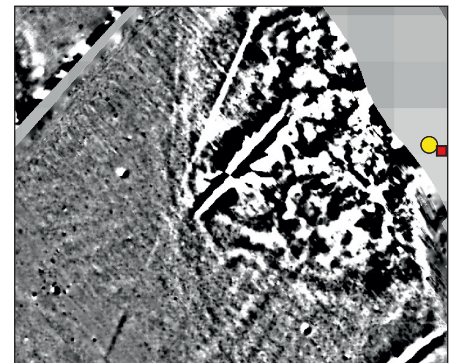
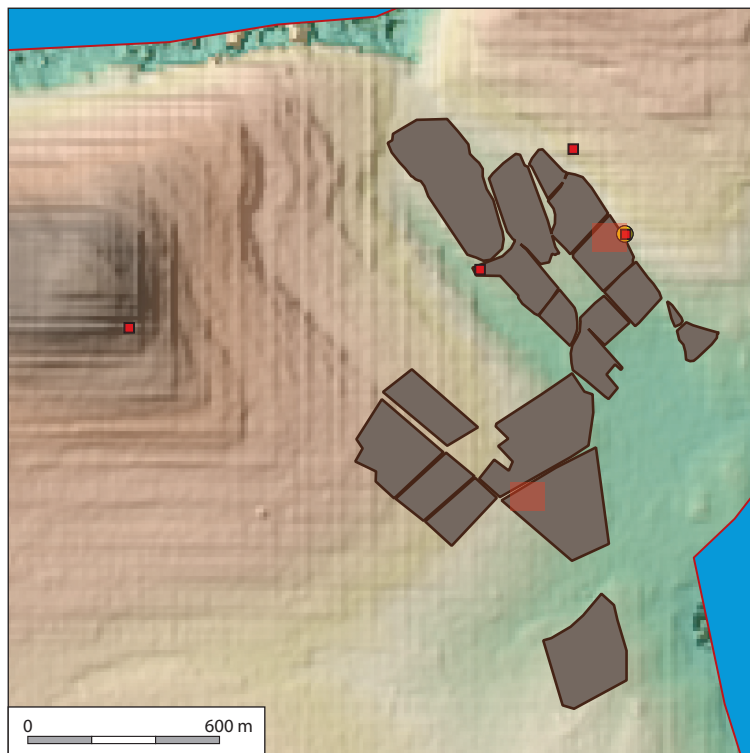
- 1 Crozier et al. 2016, 197 de-bunks the seriation of these monuments in rechronology, and in terms of diffusionism. Instead he divides the chambered cairns of Orkney into 2 types, stalled cairns and passage graves, and agrees with Piggott only in as much as he recognizes the presence of passage grave architecture along the western sea.
- 2 This then is a dilemma which this study hopes to shed some light on.

In the last decades a number of geomagnetic surveys have taken place on Rousay by the Orca research Center and the Archaeological Institute of the University of Highlands and Island (UHI). Their prospections focused on archaeological sites. For some places the prospection results of both the Scottish resaeachers and the Frankfurt team are available. Despite the different Instruments – the German team is using equipment from Sensys GmbH and the Scottish a hand-held Bartington the results are absolutely comparable. Results presented here illustrate our work and indicate the value of larger windows, contextualising the results, as opposed to a monument-centred approach.

The Rinyo Valley is well known since V. G. Childe's excavation of a Neolithic settlement here in 1938 (Childe/Grant 1938). In this part of the Island we prospected an area of c. 60 ha (Fig. 16). The most significant place being the field where Childe's excavations took place. The house remains are clearly visible in the magnetic data. The stone material of the buildings generating a strong magnetic contrast. The comparison with the excavation plan (Childe/Grant 1938 Plate 1) indicates that the stone settings of the Neolithic houses are still in the ground. The magnetic data can be used to reconstruct the general size of the settlement of 0.3 ha.

600 m southwards of the settlement indications of a destroyed megalithic monument were found. The magnetic contrast is similar as in the settlement, we assume indicating widely distributed stones. Some of the stone anomalies are large enough to reconstruct some stones in a size of more than one meter (Fig. 16).

Fig.16. The prospection area in the Rinyo-Valley with the remains of the Neolithic settlement and indications of a destroyed megalithic monument.



Westness is an area with a high density of archaeological monuments in the southwestern part of Rousay (Fig. 17). Earlier magnetic prospection undertaken by James Moore (Moore 2013, 174 Fig. 6.17) in uncultivated ground close to North Howe Broch discovered traces of a pre-broch roundhouse settlement, seen as likely dating to the later Bronze Age, or Early Iron Age.





In 2018 in Westness our magnetic prospection investigated large areas of the coastal zone (Fig. 18 A). One group of anomalies show clear similarities to the Neolithic settlement in the Rinyo Valley. The size of the settlement at c. 0.2 ha is nearly of the same scale with the internal structure of the house remains similar too. The results of the prospection especially of the settlement indicate generally a high probability of finding traces of settlements in the magnetic data.

A similar structure was revealed at Muckquoy, Redland on Mainland in a distance of 3 km to Knowes of Trotty. There a scatter of surface finds that indicates a Neolithic settlement site and the magnetic prospection discovered a Neolithic settlement with round houses and traces of a boundary enclosed the settlement (Richards et al. 2016, 250 Fig. 9.37)

The clear magnetic contrast of Neolithic stone architecture as in Muckquoy, Rinyo and Westness indicates the great potential of magnetic prospection to detect Neolithic settlements on Orkney.

Beside Neolithic monuments the magnetic prospection discovered detailed information on Iron Age monuments namely North Howe Broch as well as South Howe Broch. The main courses of the stone walls of the brochs are well visible in our data. A lot of other anomalies which indicate human activities from Neolithic, Bronze, Iron Age and Medieval Period as from Viking Age and the last few centuries were revealed in our prospection (Fig. 18).

Some of the revealed structures were already found in earlier magnetic data of our Scottish partners as traces of burnt mounds of the Bronze Age Period (Fig. 18 B). Thanks to the large prospection area of the recent prospection the number of archaeological features on Orkney will rapidly increase. The new quality of observation has consequences for heritage management on Orkney as the modelling

Fig. 17. Overview on the prospection area in Westness, Rousay, including North Howe (distant) and Midhowe Broch and chambered cairn (under the shelter building).





of ancient settlement processes and the reconstruction of a ritual landscape becomes more possible. The short exemplary presentation of the prospection on Rousay indicates the richness of the archaeological record and the great potential of magnetic prospection to reveal hidden archaeological remains.

## Conclusions

The ongoing prospections in both the areas of Rousay and the Boyne Valley have contributed already in this early stage on the investigation of both landscapes. One aspect of our work is the increase of the quantity of the archaeological record and the second one to use this new data to optimize the process of defining of our research design. Especially in this stage of work, latter aspect is important. In which way we will extend the magnetic prospection in the landscape? Which part of the microregion should be prioritised for prospection to ensure we have representative data for modelling the archaeological landscape. A third aspect is the use of the magnetic data to carry out quantitative analysis on the number of archaeological features and their chronological seriation to calculate the human impact in a diachronic perspective.

In our workflow the magnetic data should be carefully compared with the remote sensing data. The first results of the multispectral and TerraSAR missions helping the focus on areas with clear archaeological evidence. Comparisons of magnetic with remote sensing data enable us to explore limitations and potentials of these methods under the specific conditions in landscapes in North-western Europe.

The new data produced some insights but many questions too. There is a need to validate the potential archaeological features firstly by drilling and secondly by targeted excavation. The evaluation of relevant structures and the gain of samples for soil analysis, radiocarbon dating and palaeobotanical studies defining the next

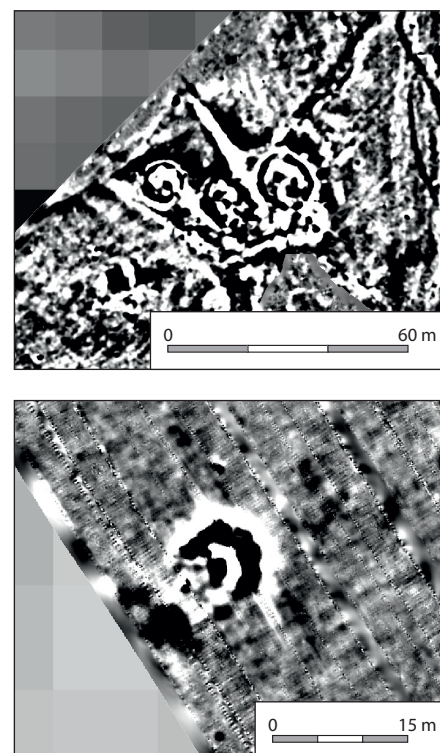


Fig.18. The prospection area in Westness. A Remains of the Neolithic settlement. B Indications of a destroyed burnt monument (likely to be a Bronze Age burnt mound).

step of research. Sampling regimes will include analysis of features ecological data that will contribute to the wider landscape study. The generated data are embedded in a widely discourse with our partners. Therefore, we are organising open data exchange platforms and the use of a similar methodological approach in GIS with our collaborators. This last point is of particular relevance for our intention to contribute the new data to the discourse between the researchers in Northwest- and Central Europe. A discourse not only on field work and methodology but that will have added to the socio-archaeological interpretation to joining the knowledge and different research traditions.

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