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Magnetic Gradient Survey of the Marpole Period Dionisio Point (DgRv-003) Plankhouse Village, Northwest Coast of North America

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ABSTRACT
Architectural reconstructions of plankhouses are central to the study of household and community organization on the Northwest Coast of North America. However, the sample of substantially excavated houses is constrained by their size, stratigraphic complexity, and typically limited surface expression. We present the results of a magnetic gradiometry survey of the Dionisio Point site (DgRv-003) village, occupied ca. A.D. 500–700 on the coast of British Columbia, Canada. Survey of four house platforms reveals patterning of magnetic anomalies consistent with the structure of shed-roof houses, a design recorded ethnographically and identified archaeologically at the site. These results suggest a consistent pattern of spatial and, potentially, social organization of the households. The similarity of patterns suggests that magnetometry may be useful for guiding plankhouse excavations elsewhere on the Northwest Coast, providing a means for expanding our knowledge of houses without relying solely on traditional excavation methods.

KEYWORDS
Geophysics; magnetometry; Northwest Coast; household organization; architecture; plankhouse

Introduction

Architectural reconstructions of houses and settlements play a central role in the study of social organization on the Northwest Coast of North America. Documenting the form, function, and arrangement of houses and the features they contain is directly relevant to the study of group size and composition, sedentism, seasonality, economic organization, and social inequality (Ames et al. 2008; Coupland et al. 2009; Grier and Kim 2012; Lepofsky et al. 2009). Traditional methods of investigating houses through excavation face two key challenges: pre-contact dwellings were large, ranging from 50 to over 400 m^2 and they were typically constructed from perishable western red cedar (*Thuja plicata*), with the result that standing architecture rarely survives. Excavating these structures provides invaluable data, but the process is labor intensive, and investigations are often insufficient in scope to confidently reconstruct household organization, with some exceptions (Ames et al. 1992; Chatters 1989; Coupland et al. 2003; Grier 2001). Conversely, site surface topography can yield important data on house size and spatial arrangement, but provides limited information on internal form and function. Near-surface geophysical methods help overcome these challenges and limitations, since they can provide a rapid, cost-effective, and precise means of recording the number, arrangement, and internal layout of pre-contact house features.

Here we present the results of a magnetic gradiometry survey of four houses at the Dionisio Point site (DgRv-003), a late Marpole Period (ca. A.D. 500–700) settlement in the Gulf Islands of southwestern British Columbia, Canada (FIGURE 1). During its occupation, the village consisted of five substantial (200–400 m^2) plankhouses, today preserved as five large platforms on three separate topographic benches (FIGURE 2). It constitutes an important example of the large, permanent winter villages documented archaeologically and ethnographically (Grier 2001, 2006a; Grier et al. 2013). Excavation of ca. 40 percent (77 m^2) of House 2 by Grier (2001) has confirmed that it represents the remains of a shed-roof plankhouse that housed a large, multi-family corporate group for roughly two centuries (Grier 2006a, 2006b, 2006c). Limited excavation has confirmed the existence of well-preserved plankhouse deposits in the remaining four platforms, but we know less about their architecture and organization. Over a ten-day period in June 2014, we employed a magnetic gradiometer to investigate portions of these remaining structures, generating information on their internal organization. Our results are evaluated against an activity-area model of shed-roof plankhouse use generated from ethnographic descriptions and data obtained through ongoing archaeological excavation.

Our magnetometry survey revealed magnetic anomalies at Dionisio Point that are clearly anthropogenic, adding to the growing body of successful applications of geophysical techniques to the study of pre-contact settlements in North America (Cross 1995; Dalan et al. 1992; Dojack 2012; Eastaugh et al. 2013; Eastaugh and Taylor 2005; Hodgetts et al. 2011; Landry et al. 2015; Prentiss et al. 2008). The spatial distribution of anomalies supports the view that the Dionisio Point settlement consisted of five shed-roof plankhouses (Dolan 2015; Grier 2001; Grier et al. 2013). The results of this study demonstrate the potential utility of magnetometry for identifying Northwest Coast architectural features that are minimally visible from the surface of archaeological sites. Magnetometry compliments traditional excavation in the study of pre-contact house and settlement organization. Future work aims to integrate these data with existing ground-penetrating radar and electromagnetic conductivity data sets to provide a multi-instrument approach aimed at clarifying the site structure of Dionisio Point.

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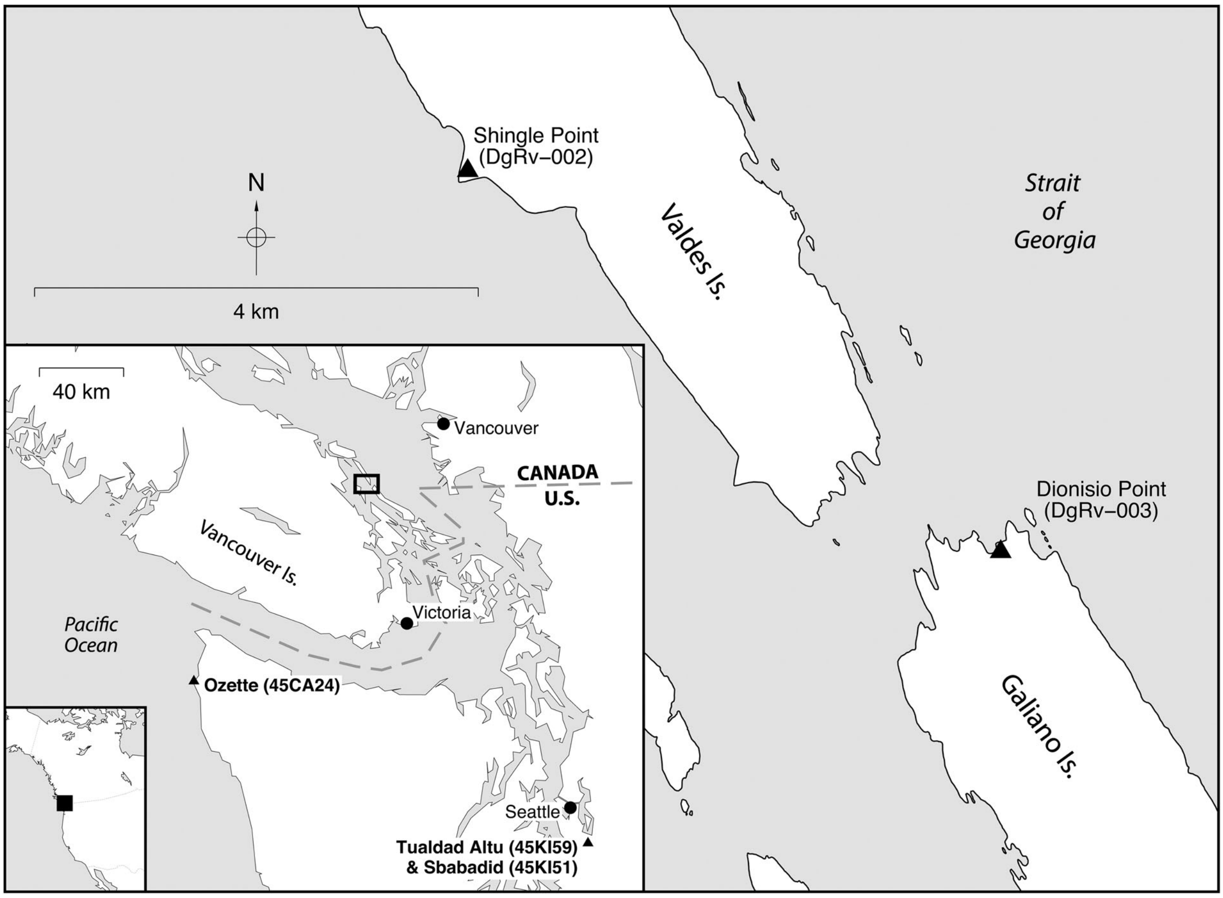

Figure 1. Location of the Dionisio Point site (DgRv-003) on Galiano Island in the Gulf Islands of southwestern British Columbia, Canada and other sites and localities mentioned in the text.

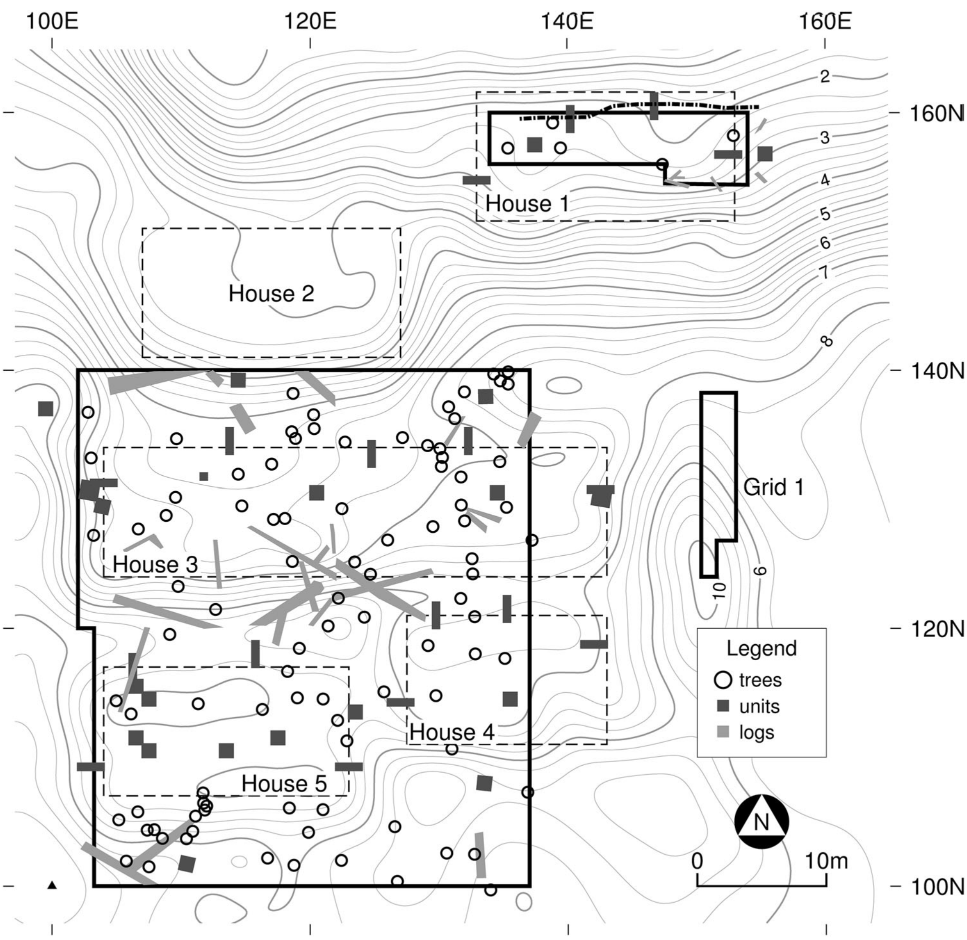

Figure 2. Site plan and magnetometry survey grids (solid lines), existing excavation units, obstructions, and approximate house floor boundaries (dashed lines).

Background

Multi-family, corporate households were essential to the organization of Northwest Coast society and economy before and after contact with Europeans in the nineteenth century. For several millennia, they were the foundation of an economy that demanded regular cooperation to ensure the production of a diverse array of foodstuffs (Ames 1996; Chatters 1989; Coupland 1996; Grier 2001, 2014). They were also the central institution by which these resources were distributed and consumed, and through which household property and rights to resources were transmitted from one generation to the next (Ames 2006; Grier 2006b). For at least the last 2000 years, they have also been a key locus for the production of social inequality (Ames 1995; Coupland 2006; Grier 2006a). Differences in wealth, authority, and power separated household leaders from followers and elite household members from commoners. The household is, therefore, a critical entity through which we can examine the complex social and economic institutions of these small-scale societies.

The social and economic organization of Northwest Coast households was materialized and encoded in plankhouse form and function (Ames et al. 2008; Coupland 2006; Coupland et al. 2009; Grier 2006a, 2006b). Ethnographically, plankhouses throughout the coast were substantial, rectangular, cedar post-and-beam dwellings. Pre-contact houses range from 50 to over 400 m^2. Large, vertical, upright posts supported either one- or two-pitched roof designs, all clad with large cedar planks (Blackman 1990; Halpin and Seguin 1990; Mauger 1991; Silverstein 1990; Suttles 1991).

A specific form of house, the shed-roof house, was common in the Coast Salish region of southwestern British Columbia and northwestern Washington State (Suttles 1991). This form had several salient characteristics: the cedar plank cladding of the walls and roof was typically structurally separate from the post-and-beam frame, and planks could be removed, facilitating seasonally shifting residence by household members and families (Barnett 1955; Drucker 1951; Suttles 1991).

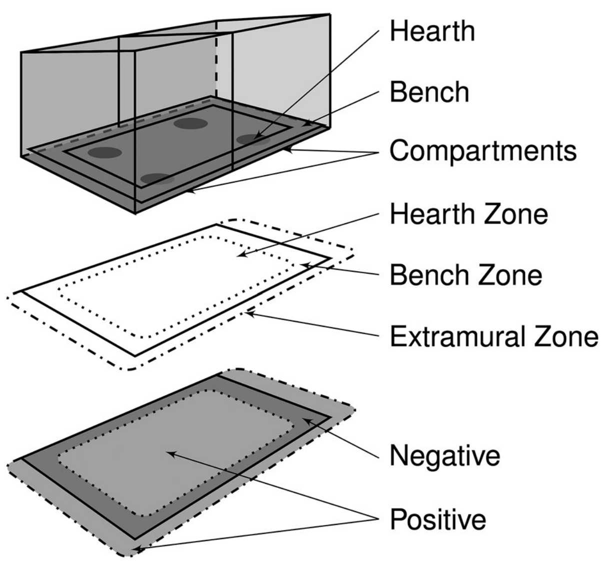

Figure 3. Schematic shed-roof plankhouse architectural mode (upper), associated activity areas (middle), and spatial distribution and expected relative polarity of magnetic signatures under the model (lower).

The floors of shed-roof houses were divided into compartments that each contained one or two hearths, representing one or two domestic spaces. Individual domestic spaces were associated with a single nuclear or extended family (Grier 2001). The interior of these houses was open like a large hall rather than formally subdivided by walls into discrete rooms, though compartments were clearly demarcated by pairs of upright rafter support posts (Grier 2001; Mauger 1991; Samuels 1991). Each compartment typically contained a raised sleeping platform that ran around the interior wall (Drucker 1951; Mauger 1991).

Overall, shed-roof plankhouse design was more modular and flexible than structures used in other areas of the coast, reflecting the flexibility inherent in Coast Salish bilateral kinship systems (Coupland et al. 2009; Suttles 1991). Additional compartments could be added or removed to accommodate changes in household size. Overall house size was largely dictated by the number of compartments, which in turn reflected the number of nuclear or extended families in the household (Samuels 1991: 207). Hearths varied in size and shape in response to a variety of factors, including social status and function. In shed-roof houses, hearths were rarely contained in wooden boxes, rock slab pits, or other formalized features. Instead it was far more common for them to be built directly on the floor (Grier 2001; Samuels 1991).

Pragmatically, reconstructing plankhouse architecture and interior organization and linking these patterns to the social organization of the household continues to be the most significant challenge for household archaeology on the Northwest Coast (Ames et al. 1992; Chatters 1989; Coupland et al. 2009; Grier 2006a; Matson 2003). Village sites with houses are often composed of a complex array of dwellings, storage and roasting pits, midden areas, and other landscape modifications. The high-resolution data on these complex archaeological locations obtained through means other than traditional approach of large-scale, labor-intensive excavation will be critical for advancing the objectives of Northwest Coast archaeology.

A Geophysical Model of Shed-roof Plankhouse Architecture

Geophysical techniques provide a rapid, non-destructive alternative to traditional excavation for documenting architecture (Hodgetts et al. 2011: 1755). Permanent structures, even if constructed of perishable materials, produce the kinds of structured, large-scale disturbances of natural soils and sediments that are common targets of geophysical survey. Magnetic gradiometry, specifically, excels at identifying the accumulation (or removal) of burned and organically-enriched sediments, which can persist long after the decay of the superstructure (Kvamme 2003, 2006). Previous applications of magnetometry to plankhouse sites have produced mixed results (Cross 1995). Difficult site conditions certainly play a role in this situation, but it also reflects a lack of clear model-derived expectations for the ways in which plankhouse characteristics should be expressed in geophysical data. Analyses of other hunter-gatherer villages suggest a number of general associations between magnetic signatures and underlying architectural features (e.g., Eastaugh et al. 2013; Hodgetts et al. 2011; Prentiss et al. 2008). These patterns, in combination with reconstructions of shed-roof plankhouse construction and use, form the basis for an activity area model of plankhouse magnetometry that can be applied to the situation at Dionisio Point (FIGURE 3).

At Dionisio Point, plankhouse remains are visible on the surface of the site, appearing as large, flat, rectangular platforms embedded in the undulating slope that descends 10 m in elevation down to the modern beach. The result is a series of artificial terraces separated by 2–3 m of vertical relief. Houses 1, 2, and 3 each occupy their own terraces, while Houses 4 and 5 share the highest elevation terrace at the back of the site. This layout of houses is partly conditioned by the local topography. Sandstone bedrock outcrops to the east and west of the site constrained any potential expansion of settlement in these directions. The resulting village plan is compact. At least one-third of the ca. 0.4 ha site core area is interior house space.

Our spatial model is founded upon Samuels' (1991, 2006) analysis of activity areas at the Ozette site, a well-preserved proto-historic shed-roof plankhouse village on Washington's Olympic coast (FIGURE 1). Samuels (1991: 208) distinguishes three types of interior space: bench, hearth, and central zones. We modify and extend his model in two important respects. For the purposes of our magnetometry application, we combine his central zone with the hearth zone reflecting their shared qualities as generalized domestic space (Grier 2001, 2006b). We also extend his model beyond the house floor by adding an extramural zone that includes outdoor midden deposits, which were not considered in his activity area analysis.

Hearths are often magnetically visible in archaeological sites as positive anomalies relative to the background magnetism (Eastaugh et al. 2013; Prentiss et al. 2008) although not always (Hodgetts et al. 2011: 1761; Prentiss et al. 2012: fig. 6). This effect is produced in large part by the concentration of burned material and organic matter refuse (Kvamme 2006). In shed-roof plankhouses, the hearth zone consists of hearths and the remains of resources processed through domestic activities, including soft tissues, skeletal elements, fats, and oils. It typically also contains some artifacts and, more germane to magnetometry, copious amounts of thermally-altered rock (TAR) (Chatters 1989: 172–174; Samuels 1991). Shed-roof hearth zone deposits are, therefore, expected to produce positive magnetic anomalies.

Excavations in House 2 at Dionisio Point revealed three compartments containing a ca. 8 m × 3.6 m wide high-traffic hearth zone that included four hearths (Grier 2001: fig. 29). A pair of hearths was identified in the western compartment, one near the front and one near the back of the house, suggesting two domestic units inhabited this area. A similar situation exists in the east end of the house, though only a single hearth near the front of the house was conclusively identified during excavations. The central compartment of the house includes one hearth, larger than the rest, located slightly closer to the south wall. Similar hearth zones are present at other well-documented pre- and post-contact shed-roof plankhouses, including Ozette, Tualdad Altu, and Sbabadid, where front-back hearth pairing is present and hearth zone widths fall within a few meters of that observed in House 2 (Chatters 1989: 171–174; Samuels 1991: fig. 99–101).

Bench zones are located along the interior perimeter of the house. Sleeping benches were typically situated here (Grier 2001; Samuels 2006; Suttles 1991). The area was subject to limited foot traffic. Food, tools, and other goods were stored here and, as seen archaeologically, occasionally lost or not recovered (Samuels 1991: 233–240). Organically-enriched and burned materials in this area were also likely redeposited from elsewhere in the house (e.g., the hearth zone) through foot traffic, maintenance, floor cleaning, and sweeping (Matson 2003: 88; Samuels 1991: 232). Hearths, if present, should be small and contain less TAR than domestic hearths (Chatters 1989; Dolan 2015; Grier 2001; Prentiss et al. 2012). In general, this means that these areas should not be as magnetic as hearth areas.

The bench zone is 2 to 3 m wide in House 2, delineated by bench support post features and, in the northeastern portion of the house, a continuous, raised gravel feature containing numerous postholes (Grier 2001: fig. 30). Similar bench zones have been identified at Ozette and Sbabadid on the basis of the distribution of post features and, in the former, preserved bench planks (Chatters 1989: 171; Mauger 1991: fig. 61; Samuels 2006: fig. 7). In the absence of preserved architectural elements, for example at Tualdad Altu, the bench zone may also be inferred from the presence of a hearth-free zone encircling the interior perimeter of the walls (Chatters 1989: fig. 2, 4).

The extramural zone is the area immediately outside houses. Deposits here are the product of house maintenance, general discard, and natural formation processes occurring during and after the occupation of the village. Refuse was deposited immediately outside the house walls at Dionisio Point. These deposits form visible berms or rims that run along the front and, to a lesser extent, sides of these structures. Similar rim midden deposits are characterized by positive magnetism at other long-term settlements where excavations confirm the connection of positive anomalies to accumulated organic and burned domestic debris (Hodgetts et al. 2011; Prentiss et al. 2008). In excavated shed-roof houses, these deposits appear to be largely comprised of dumps of TAR, faunal material, and larger discarded artifacts, but, notably, contain few in situ hearths or post features (Chatters 1989: 171, 174; Samuels 1991: 191).

Excavations at the toe slope immediately south of House 2 suggest that accumulations of cultural debris behind houses was produced in part by erosion of sediments further upslope (Grier and Angelbeck 2007: 23; cf. Archer 2001). In most areas of the site, deposits behind houses appear to be an in situ midden rather than transported secondary deposition, though the relative contribution of these processes likely varies across the site. For example, an extensive and steep slope exists immediately behind House 1, and deposits at the back of this house may be composed of secondarily transported material. In contrast, the topography behind Houses 4 and 5 is flatter, and in situ features have been identified in the midden rims behind these two houses (Grier 2003).

Methods

Magnetic gradiometry

Magnetic gradiometers passively measure the local magnetic field below them at a given location. The gradiometer measures the sum of both induced and remanent magnetizations (Dalan 2005). Remanent magnetism is the permanent magnetization of a material that occurs during its compositional, thermal, or depositional history (Heimmer and De Vore 1995). These materials remain magnetic in the absence of a magnetic field. Magnetometry surveys can be particularly successful in detecting anthropogenic activities that utilize or create materials with remanent magnetism. The success is partially due to the remanent magnetism of thermoremanent materials that often appear as robust anomalies in magnetic data. Most sediments naturally contain 1–10 percent iron oxides. Thermoremanence occurs when iron oxides contained within soils, clays, or rocks are heated (Kvamme 2006). The iron oxide particles at first have low net magnetic properties, but when heated to the Curie point (about 600°C), their magnetic domains align and re-magnetize at the time of cooling to the current geomagnetic field (Clark 2001). Many processes of heating were common in prehistoric and historic settlements including pottery production, cooking, and the destruction of structures through burning (Kvamme 2006).

Induced magnetism only exists in the presence of a magnetic field. The potential of a material to become magnetized is a function of its magnetic susceptibility. This is dependent on the presence and quantity of hematite, magnetite, or maghemite, the iron oxides available in small quantities in most soils and rocks. Top soils tend to be more magnetically susceptible than their parent materials. This is the case for several reasons. There is a tendency for iron minerals to accumulate in topsoils due to their relative insolubility in comparison to less magnetic materials. Magnetotactic bacteria and other bacteria also tend to concentrate magnetic compounds in top soils (Fassbinder et al. 1990). Anthropogenic or naturally occurring fires contribute to the mineral content of the top soil, as well as refuse of organic and thermally altered materials during prehistoric occupations.

The magnetic gradiometer has two sensors aligned vertically and measures the difference between each total field value, or the magnetic field gradient (Kvamme 2001, 2006). The unit of measurement for magnetic surveys is the nanotesla (nT) and most gradiometers used for archaeological applications are sensitive to magnetic variation on the order of 0.1 nT in Grid Mode. Gradiometers allow for quick, high-density, yet sensitive surveys. The distance of sensor separation determines the sensitivity of the instrument; a standard distance is 0.5–1 m (Clark 2001). The farther apart the sensors are, the closer the instrument approaches the sensitivity of a total field measurement. Data is collected in grids, where spatial resolution is determined by transect intervals and samples per meter along those transects.

Data collection

Galiano Island is composed of interbedded conglomerates and iron oxide-cemented sandstones of the Gabriola Formation of the Upper Cretaceous Nanaimo Group (Katnick 2001: 115; Mustard 1994). Despite their iron-rich composition, natural magnetic materials did not overwhelm the anthropogenic signatures of the village occupation. The results discussed below demonstrate that even in this magnetic landscape, magnetometry is an effective tool for the recording of anthropogenic signatures of considerable antiquity.

Three survey reference grids were tied into an existing site grid system using a Nikon DTM-520 total station (FIGURE 2). The largest of these covered Houses 3, 4, and 5 in a continuous grid measuring 37 m east–west by 40 m north–south. A second, smaller grid covered the House 1 platform, while a third (Grid 1) sampled a mound located east of Houses 3 and 4. No data collection was completed in the platform that contains House 2. Several years after the 1998 excavations in House 2, a cedar tree located at the northeastern corner of this house toppled into the house, obstructing survey in this part of the site. Twentieth century logging, construction of a number of ephemeral historic cabins in the area of the site, and current recreational foot traffic have added recent metal objects to the site area (BC Parks 1995). Metal located with a metal detector was removed prior to survey in most areas, but in House 2 significant amounts of buried metal made data collection impractical during the time available for survey. Also, a BC Parks fence, erected to deter visitors from entering the site, runs along the northern edge of House 1 and affected data recovery in this area.

Terrain and forest cover proved a challenge. Standing flora, fallen debris, and steep topography reduced the rate at which data could be collected. They also introduced a number of unavoidable gaps in the final data set, most notably in the eastern ends of Houses 3 and 4. Here, abundant dead-fall and brush that made survey impractical could not be cleared due to Provincial Park restrictions limiting environmental disturbance. Nevertheless, data were collected across about 30 percent of the site core, representing the complete or near complete coverage of the four houses that have not seen intensive excavation. When estimated from surface topography and excavations around each of these structures, there is more than 50 percent coverage of Houses 3 and 4, and complete coverage of House 5.

The House 1 platform was surveyed first. At about 115 m^2, it is the smallest at the site. Excavations confirm that intact house floor deposits are present, partially buried beneath later shell middens (Grier and Angelbeck 2007). These deposits extend over about 20 m parallel to the shoreline, indicating that the dimensions of the original house were comparable to those of Houses 2, 4, and 5 (about 200 m^2). The relatively narrow platform may be the product of post-depositional processes. It lies at the foot of a 15 m long slope that drops 5 m from a higher terrace. The unexcavated southern edge of the platform may be obscured by colluvial deposits. We surveyed more than three-quarters of the existing platform. The previously mentioned BC Parks fence prevented greater coverage (FIGURE 2). In addition to being a physical barrier, the large metal nails used to hold it together obscured archaeological magnetic signatures within at least a 50 cm radius (e.g., Kvamme 2006: 228). Given these factors, we estimate that our survey provides 50 percent coverage of the original house floor.

Vertical magnetic gradient measurements were collected using a Bartington Grad601-1 fluxgate magnetic gradiometer in single-sensor mode, which permitted greater control and continuity of data collection over a single transect under dense trees and brush. Most cultural deposits at Dionisio Point lie within 1–2 m of the surface, within typical limits of detection in North American sites (Kvamme 2006: 222). Eight data points were collected every meter along 50 cm wide transects in Grid 1, and the House 3, 4, and 5 grid. Data were collected along 25 cm wide transects in House 1.

Results

Examination of magnetic data from the three survey grids reveals considerable pattern repetition across the Dionisio Point village that maps onto the identified house platforms (FIGURE 4). The grid covering Houses 3, 4, and 5 gives near-comprehensive coverage of indoor and outdoor space and provides the clearest evidence of architectural patterning consistent with plankhouse surface topography and excavated features. Patterning across House 1 is less interpretable. The effects of modern obstructions and post-depositional disturbance are apparent in the lower quality of the results from this house. Highs and lows are interspersed with a number of irregular dipoles related to historic-period metal refuse. As a result, House 1 is difficult to compare with the rest. For completeness, we include the non-house Grid 1 data but leave aside discussion and interpretation of its patterning, since data collection across this mound was exploratory and unconnected to our current focus on plankhouse organization.

Magnetic anomalies range from less than −30 to more than 30 nT. Some of the extreme values at Dionisio Point represent modern disturbance, including historic metal (dipolar anomalies) or backfilled excavation units (rectangular, lower magnetic signatures). Prominent examples of both are visible in House 5 (FIGURE 5). Several rectangular negative anomalies at the western of this house are the remains of excavation units. Further to the west, two dipoles represent historic metal refuse. However, these recent disturbances have not obscured patterning associated with the occupation of the village.

Hearth zones

The most conspicuous features in the magnetometry data are groups of positive anomalies that cluster within the center of the floors of Houses 3, 4, and 5 (FIGURE 6). Individually, they vary in shape from amorphous or globular to circular and even linear (A in FIGURE 6). Several are large, ranging from 0.6 to more than 3 m^2. These are typically separated by between 1 and 4 m of lower (ca. −20 to 15 nT) anomalies. Excavations have not yet verified whether these measurements accurately reflect the dimensions of the underlying archaeological features, and they should be considered approximate representations.

More distinctive than their individual characteristics is their spatial organization. Clusters of large (>0.6 m^2) positive (>15 nT) anomalies form structured bands several meters wide that extend down the centerline of these houses for much of their length. In places, the anomalies are well organized, consistent with the structured use of indoor space. In House 3, for instance, a cluster of five anomalies defines a square space roughly 3 m on a side (A in FIGURE 6). Two linear features delineate its northern and southern boundaries while a trio of circular anomalies lie along its western side. Farther east in the same house, a pair of anomalies defines a space the same width and orientation (B in FIGURE 6). Similarly, a cluster of five anomalies in House 5 delimits a rectangular indoor space 9 m long and 3 m wide (C in FIGURE 6). Like the cluster in House 3, four of these anomalies are grouped into two north–south aligned pairs, one located at either end of House 5. The tight cluster of anomalies in the center of House 4 is distinctive. However, even here, two anomalies form a north–south pair (D in FIGURE 6) not unlike those seen in the other houses.

The position and pattern of paired anomalies is reminiscent of shed-roof plankhouse hearth layouts, in which compartments were shared by two domestic groups, each with their own hearth. The high temperatures achieved by large domestic hearths can produce thermoremenant anomalies such as these in the archaeological record (Kvamme 2006: 216–217). Verification of many of these anomalies as hearths awaits additional ground-truthing; given their size and number, testing has been completed in only a few cases. Excavations in cluster A (FIGURE 6), in the western end of House 3 (131.5N111.5E), provide a small window on the trio of anomalies in this location that were discussed above (FIGURE 4). Below 20 cm of post-village deposits, sediments contained considerable quantities of TAR, burned artifacts, and ash. These deposits were 10 cm above hard-packed basal sands, possibly cemented by the oxidization of trace iron in the underlying till. These are in several respects similar to hearth features excavated in House 2 prior to our magnetometry survey. The distinctive cluster of positive anomalies comprising cluster A (FIGURE 6) at the western end of House 3 likely indicates a hearth complex or a hearth associated with other non-hearth features. Another partially excavated hearth at the eastern end of House 1 (FIGURES 4 and 7A) may be associated with a large, positive anomaly but further excavation is necessary to clarify this relationship given the presence of a nearby cluster of magnetic dipoles.

Positive anomalies may reflect several other types of features typically found in plankhouses. Pits and postholes filled with magnetically-enriched sediments can produce magnetic anomalies with characteristics similar to those produced by hearths. For example, a second anomaly at the eastern end of House 1 (156.5N153E) closely maps on to a deeply-buried bench support post centered immediately to the northwest (FIGURE 7A). However, the association between post features and positive anomalies is not yet established. An adjacent post feature, which is considerably larger but otherwise possesses the same characteristics, is not associated with a magnetic anomaly. Post features, and other types of pits and depressions, are typically infilled with house floor deposits, either as a result of the removal of the post at the time of abandonment or in situ decay. Floor sediments from Dionisio Point are highly enriched in organic matter relative to underlying culturally sterile basal gravels (Dolan 2009; Grier 2001). The accumulation of these sediments within post features would likely not consistently produce marked differences from the magnetic readings of house floors, unless densely filled with hearth sediments. Hearth debris was not identified in House 2 pits and post features despite intensive excavation of more than half of the house floor.

More excavation will establish whether there are consistent associations between hearth zone anomalies and specific house features. Large positive magnetic anomalies in this zone are expected to be hearths based on their location, distribution, and similarity in size and shape to the excavated sample in House 2 and elsewhere. Although variable along the coast, almost all excavated plankhouses have some form of hearth complex. This suggests the clustering of large, positive anomalies down the center of Houses 3, 4, 5, and, to a lesser extent, House 1, is likely associated with cooking, food preparation, and other daily domestic activities expected in a hearth zone in a shed-roof plankhouse. As such, it reflects a potentially useful starting point for provisionally identifying house remains in archaeological sites where little or no surface expression of houses is evident.

Bench zones

Cultural and natural processes have combined to produce the low magnetic signatures that encircle the periphery of the

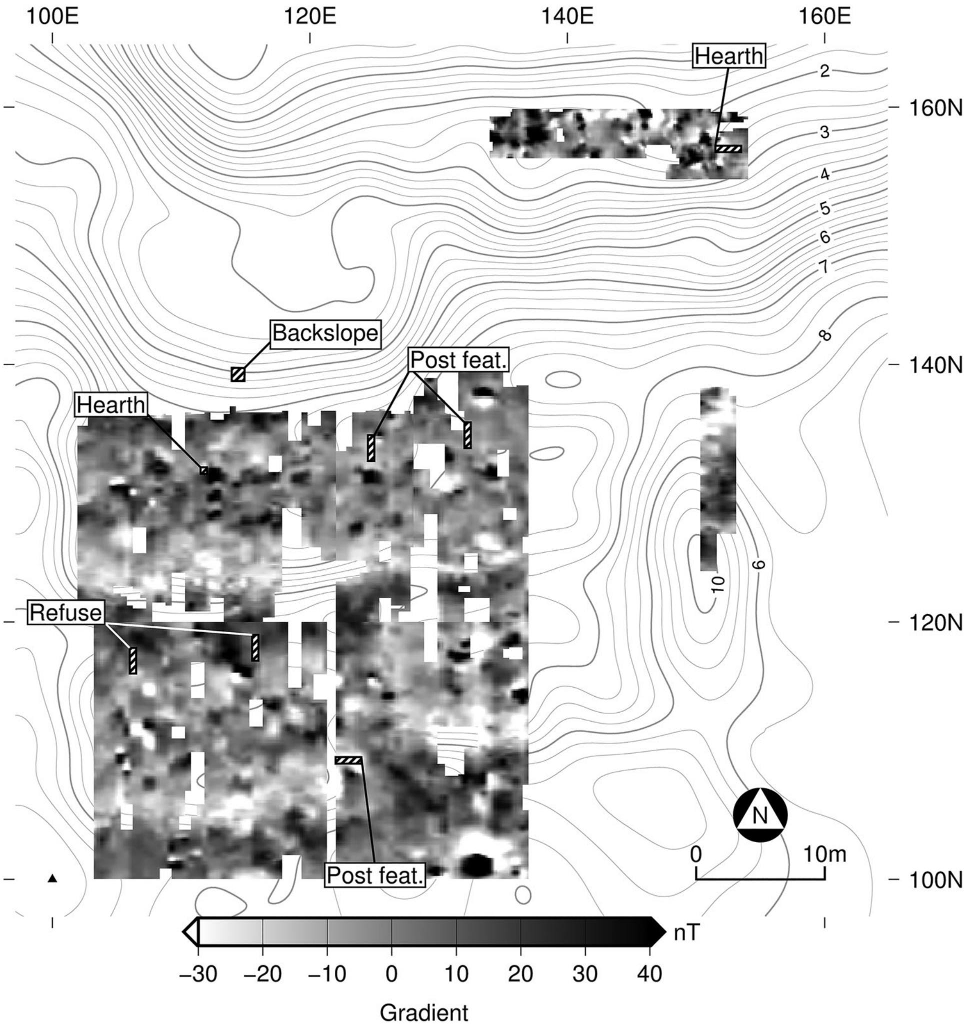

Figure 4. Magnetic gradient survey plan map of the site core with excavation units mentioned in the text.

platforms of Houses 3, 4, and 5 (FIGURE 6). These readings appear more pronounced on the northern and southern edges than either end. It is notable that the negative band along the southern edge extends from the relatively level house platforms, interpreted as indoor space on the basis of previous excavations, up the steep terrace slopes behind the houses. Excavations conducted prior to the magnetometry survey suggest that these slopes were primarily outdoor space during the occupation of the village. The evidence for this is examined further in the following discussion of extramural zone patterning. Briefly, the negative band along the southern edge of the house platforms represents both indoor and outdoor space with respect to the locations of inferred house walls. Minor slumping of some of slope deposits has occurred, but does not appear to extend far past the inferred house walls (Archer 2001). Because it remains unclear how much of this signature was created by cultural activities associated with the occupation of the village, we limit our discussion of bench zone patterning to the northern areas of the houses.

Low anomalies (−30–0 nT) are distributed along the front of Houses 3, 4, and 5. This band of negative anomalies measures 2–3 m wide and extends along the northern boundary of each house platform for its entire surveyed length. Units in these areas were excavated prior to survey and, therefore, do not preserve their original magnetic patterning. They do, however, provide a picture of the archaeological characteristics of these deposits, and suggest several cultural processes to which the magnetic patterning might be attributed.

The locations of these negative magnetic bands are consistent with the positions of previously excavated bench deposits. Bench deposits were extensively tested along the northern boundaries of Houses 3, 4, and 5. Like bench deposits uncovered in House 2 (Grier 2001), large, in situ combustion features are rare and post features are common, a pattern consistent with the scarcity of large positive magnetic anomalies in these deposits. These patterns are illustrated along the northern perimeter of House 3, where bands of negative anomalies are associated with bench deposits identified during the excavation of two 2 m long trench units prior to the magnetometry survey (FIGURE 7B, C). Repeated identification of bench deposits along the front of House 3 during excavation suggests that these were largely continuous features, mapping onto the same space as the band of negative anomalies along the front of this house. Cultural deposits were shallow and poorly stratified, containing little evidence of in situ ash, charcoal, or TAR concentrations characteristic of hearth zones. Seven post features were identified in these m^2 alone, ranging in size from ca. 20 to 50 cm in diameter. All but one fall into the same size class (>26 cm in diameter) as wall and bench support posts within House 2 (Grier 2001: 171). Given their size and position, they likely served the same function. Bench support posts have been identified along the perimeters of Houses 4 and 5 (FIGURE 7D, E), also associated with clusters of negative anomalies.

Low magnetic signals can be produced where magnetically-enriched soils have been removed and underlying,

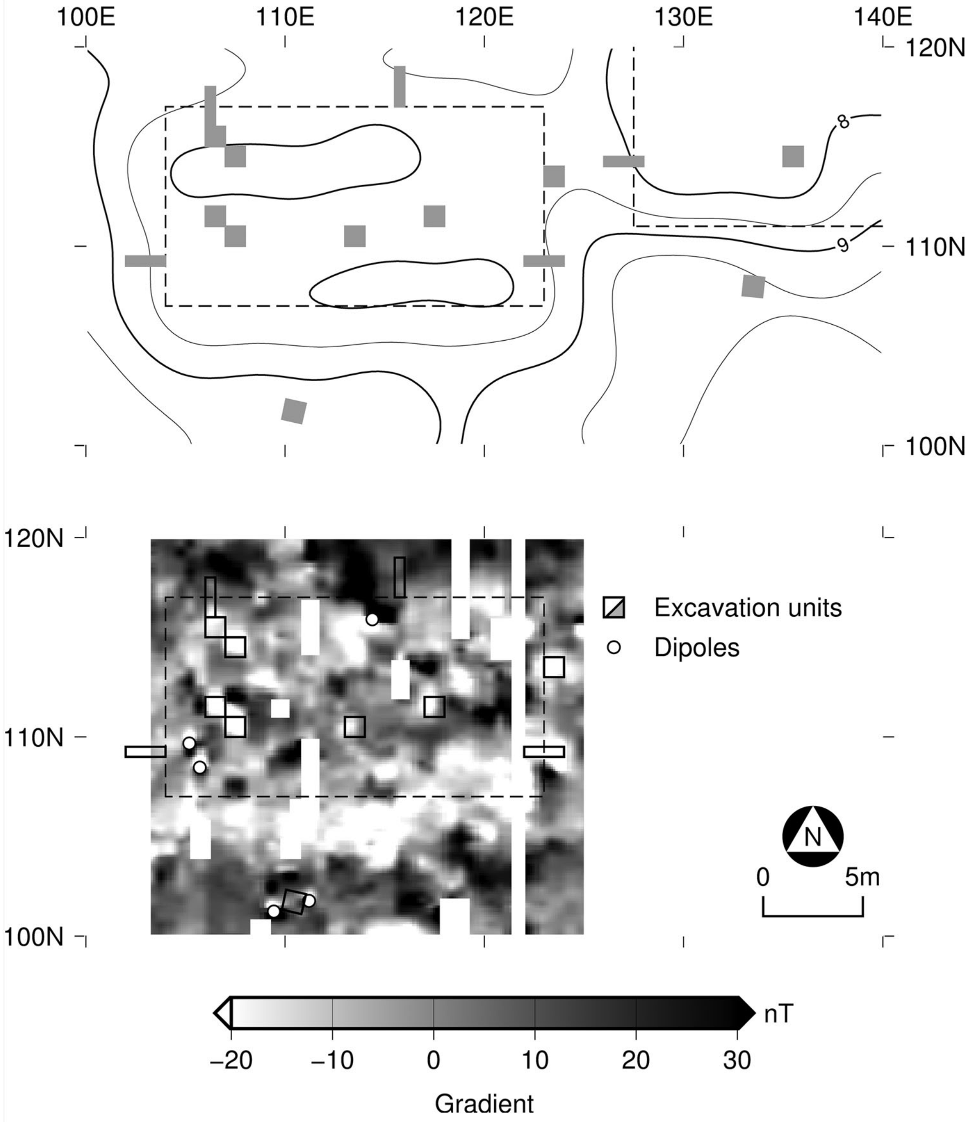

Figure 5. Examples of magnetic anomalies caused by prior excavation units and historic metal in House 5. Topographic map with approximate house floor boundary (upper) and magnetic gradient survey plan (lower).

inorganic sediments are exposed (Kvamme 2006: 219). While this process may account for the magnetic character of some bench deposits, it cannot account for patterns across the site. Construction of house foundations at Dionisio Point appear to have started with leveling of the natural slope, removing existing top soil and exposing basal gravels (Dolan 2015; Grier 2001). Excavations sometimes reveal these inorganic sediments lying fairly close to the modern ground surface with little anthropogenic overburden and sometimes corresponding to bench deposits. A portion of the House 2 bench was underlain by a built, gravel feature capped by thin bench deposits (Grier 2001: fig. 26, 30). In House 3, inorganic, culturally-sterile basal deposits cut by post features also lie close to the ground surface, likely contributing to the negative signature of the bench zone. Our limited excavations in this area could not determine whether this is because they are built features as in House 2. At present, this explanation appears specific to portions of House 3. The same processes cannot account for negative bench zone signatures in the remaining houses, where bench deposits are considerably thicker. There, the relative scarcity of large, strongly magnetic fragments of burned organic and inorganic debris from thick bench deposits suggest that differences in function and house maintenance practices played a role in generating their lower magnetic signatures. These patterns may be weighted towards the later or last plankhouse occupation, in which case negative anomalies would have been produced by the last instance of bench refurbishing prior to abandonment (e.g., Grier 2001, 2006b). However, long-term formation processes may also have played an important role, reflecting the action of discrete suite of plankhouse bench-formation processes we discuss above (Grier 2006b). Verification of these process requires more ground-truthing excavation, but are implied by excavations in House 4, where bench deposits nearly 1 m thick are associated with the band of negative magnetic anomalies running along the inside of its northern perimeter (FIGURE 7D).

There is evidence that many plankhouses were differentiated into low and high traffic areas, the former associated with spaces for resting, storage, and, oftentimes, benches. In shed-roof plankhouses this zone was generally located along the inner perimeter of the house wall, similar to the positioning of the clusters of negative anomalies around the perimeter of Houses 3, 4, and 5 at Dionisio Point. In this respect, these

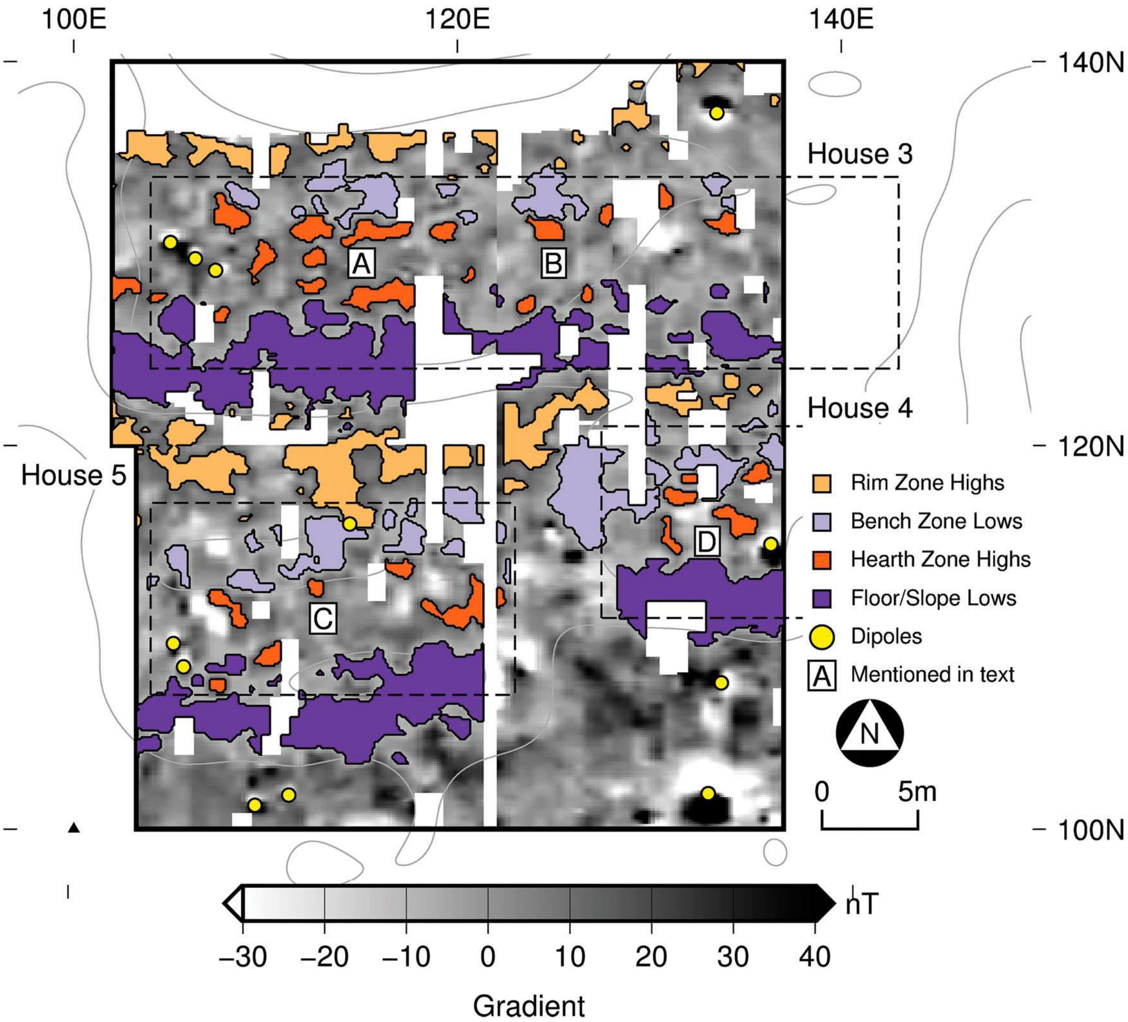

Figure 6. House 3, 4, and 5 magnetic survey grid overlaid by zonal gradiometry interpretations. Colored areas denote anomalies affiliated with particular activity zones, not the magnitude of those anomalies. Letters indicate particular clusters of hearth zone anomalies mentioned in the text.

signals may be especially useful in delineating the boundaries of plankhouses where they cannot be identified on the basis of surface topography.

Extramural zones

No single magnetic signature characterizes platform deposits outside of the inferred house walls (FIGURE 6). North of each structure, high magnetic signatures form bands that appear to extend, largely uninterrupted, from one end of the platform to another within the boundaries of the survey area. To the south, low magnetic signatures again form continuous bands that appear to run behind the houses from one end to the other. Patterns at the western and eastern ends of platforms are more difficult to characterize; the overlap of survey and excavation coverage of these areas is less complete than elsewhere on site.

Natural formation processes appear to be at least partly responsible for the presence of negative anomalies lying to the south of the hearth zone. One possibility is that erosion of these slopes has denuded them of magnetically-enriched sediments (Kvamme 2006: 218–219). As previously described, some of the strongest negative magnetic signals recorded on site extend south from the boundary of the hearth zone partway up the 2–3 m slope that separates each terrace from the one above it. Consequently, the magnetic signatures do not correlate with the distinctive indoor and outdoor deposits that have previously been identified through topographic mapping and excavation behind houses.

Although outside the geophysical survey area, a 1 by 1 m excavation placed at the terrace backslope south of House 2 (138.75N113.9E) (FIGURE 4) reveals both northward-dipping strata and substantial accumulations of organic sediments and artifacts (Grier and Angelbeck 2007: 22–25). Both patterns are consistent with the influx of sediments from the erosion of the adjoining slope more so than the intentional deposition of refuse behind the house. This space, more than 3 m beyond the nearest recorded roof support post feature (Grier 2001: fig. 28), was likely unroofed. Ethnographically, shed-roof plankhouse roof planks did not extend far past the walls (Suttles 1990, 1991). Given other architectural similarities between the remaining houses at the site and the similar gradient of their terrace slopes, it seems likely that they were subject to similar natural formation processes. This may also account for the somewhat higher (but still negative) anomalies that occur near the break in slope at the back of house platforms where eroded soils would have been deposited, although the pattern is not consistent across or even within platforms. Future excavations can profitably target terrace toe slopes to further clarify the possible relationship between slope and magnetic signatures.

High magnetic signatures north of house floors correspond to excavated rim midden deposits forming small topographic rises that extend along the front of each house

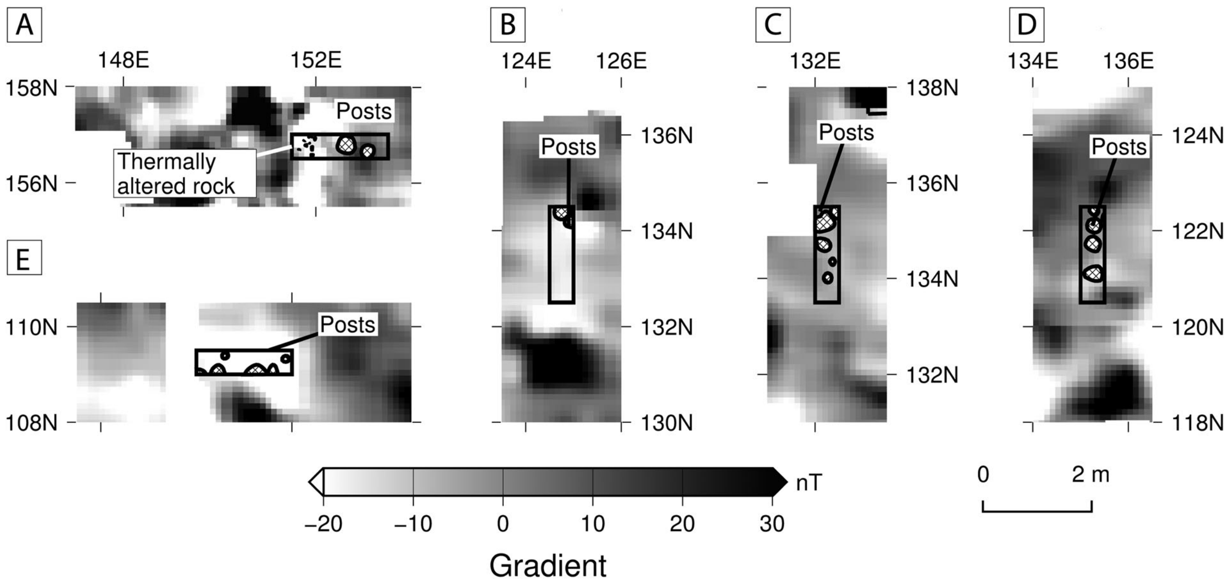

Figure 7. A through E: selected magnetic anomalies and associated archaeological features referred to in the text.

platform. Excavations confirm that they are anthropogenic rather than natural changes in elevation (Dolan 2015; Grier 2001). Accumulation of burned materials and soil formation may both play a role in the generation of positive anomalies through this part of the site. This is best illustrated along the northern edge of the House 5 platform, where a rim midden rises more than 50 cm above the surface of the house floor. Two trench excavations conducted prior to our magnetometry survey (116N106E and 117N115.5E) (FIGURE 4) reveal approximately 60 and 90 cm of poorly stratified village deposits containing broken tools, burned and fragmentary faunal remains, and abundant lithic debitage and TAR. Yet, there is little evidence of hearths (e.g., ash lenses or charcoal concentrations) or preserved floors or post features (cf. Grier 2001: 154, 2006b). Excavations demonstrate that, in many respects, rim middens are composed of the same suite of domestic debris that concentrate magnetically-enriched materials in and around domestic hearths, but intact hearth zone features are rare. In the absence of excavated hearths or other magnetically-enriched features, these characteristics are consistent with the slow accretion of these deposits through primary and secondary refuse disposal and not the in situ formation of floor deposits or natural accumulations of sediments. Similar deposits have been encountered adjacent to Houses 2, 3, and 4.

Magnetic signals can also be produced by the accumulation of magnetically-enriched top soil (Kvamme 2006: 217–218). The concentration of these natural deposits alone would be insufficient to generate the distinctive magnetic signals observed in Dionisio Point's extramural zones. Natural top soils are typically quite thin in this temperate rainforest soil system if unmediated by cultural refuse and debris (e.g., Dolan 2009: 72–77; Green et al. 1989: 69; Grier and Angelbeck 2007: fig. 17). Where they are naturally thicker, they are often the product of erosion, forming colluvial deposits at toe slopes behind houses. Rim middens are subject to natural erosion rather than accumulation. Any thickening of rim middens was driven by the displacement of organically-enriched hearth and floor deposits, which would have introduced burned materials and organic debris and encouraged the activity of magnetotactic bacteria. Available data are not sufficient to separating these two processes in rim midden deposits. Trends in soil organic matter content in House 5 indicate that weathering has affected approximately the upper 40 cm of house floor deposits, suggesting that concentration of magnetic materials by soil fauna is a factor in the signature of some areas of the site (Dolan 2009), but their relative contribution to magnetic patterning has yet to be determined.

Discussion

The structured use of space at Dionisio Point is recorded in variation in the magnetic gradient at the site. With the exception of House 1 and its complex depositional history, the magnetic gradient plan map reveals considerable pattern repetition across the settlement. Houses 3, 4, and 5 produced a similar sequence of magnetic zones: (1) a highly positive zone extending down the central area of the floor, characterized by concentrations of burned sediments and TAR; (2) a surrounding moderately negative zone, with basal post features characteristic of bench and wall support posts; and (3) an extramural zone of variable polarity (generally positive to the north of the platforms and negative to the south). The three-zone shed-roof plankhouse activity area model accounts for these patterns, and supports our interpretation of the site as a village composed of similar, substantial dwellings with high levels of architectural investment, clear organizational structure, and patterned human activity.

Given the complex formation history of floor deposits and duration of occupation (e.g., Grier 2006b), the boundaries between these zones are, in general, remarkably distinct and consistent with shed-roof architecture. Excavations of these zones, both in House 2 and elsewhere at the site, suggest long-term architectural continuity of the shed-roof pattern, despite the two-century long lifespan of the households that likely involved regular renovation and refurbishing of houses (Dolan 2015; Grier 2001; Trieu Gahr 2006). Grier (2006a, 2006b) observed architectural continuity in House 2 at Dionisio Point. Major hearths remained in the same locations for several generations. Economic specializations were also consistent through time, implying that that household succeeded in reproducing its spatial organization for as long as two centuries (Grier 2006b). Excavations within and around the perimeters of the remaining structures reveal similar continuity. Large domestic hearths have not been identified within areas identified magnetically as bench zones where large post features are common. Similarly, positive anomalies falling within the hearth zone have been confidently identified as domestic hearths and associated domestic debris. While it is possible that magnetic patterning reflects only the terminal occupation of these structures, the spatial patterning of excavated features is stable through the occupation of the houses implying that the same may be true of magnetically identified activity areas. These patterns are consistent with the long-term reproduction of a household occupying a shed-roof plankhouse (Ames et al. 1992; Marshall 2006).

Finer-grained reconstructions of architectural organization remain a challenge. While candidates for hearths were identified (several as front-back pairs), the magnetometry data were coarse and could not, at least at this level of inspection, be used to determine their specific number, arrangement, or exact size. These data are relevant to establishing household demography, economics, and social organization (Ames et al. 2008; Coupland 1996; Grier 2001). House 2 excavations identified an especially large, domestic hearth in the center of the house floor (Grier 2001). This hearth is not a member of a pair. Instead, the floor north of this feature is open, suggesting that this portion of the house was used by a single family. Sumptuary goods recovered nearby indicate that this domestic group was probably of higher status than the rest of the household (Grier 2001, 2006a, 2006b, 2006c). Integration of the magnetometry data with excavation and additional forms of geophysical survey and excavation may yet reveal distinctive socially and economically significant distributions of domestic groups in the remaining houses at Dionisio Point.

Conversely, amorphous, globular anomalies may match the architectural reality of shed-roof plankhouses. It is possible, for instance, that the absence of clear, geometric patterning of hearth signatures reflects the short-term flexibility of shed-roof plankhouse hearth arrangements. These hearths were not formally enclosed, and so could have been moved over time. Over the long term, their general position was determined by the presence, size, and status of the associated hearth group, as appears to be the case in House 2 (Grier 2006a, 2006b). However, over the short term, they could be moved or removed for pragmatic reasons or to facilitate social events (Suttles 1991). The end product may often be the smears of burned materials that are typical of hearths in House 2 (Grier 2001: 175). Small-scale variability in bench and extramural zones likely also reflects the flexibility and longevity of shed-roof plankhouses. In contrast, magnetic survey may be better able to delineate architectural features where these are large, permanent house fixtures, such as the box-hearths of the lower Columbia or the large communal hearths typical of substantial North Coast plankhouses (see Ames et al. 1992; Coupland 2006).

Conclusions

Magnetic gradient survey results support our interpretation that the Dionisio Point site represents the remains of a residential community composed of five shed-roof plankhouses similar in overall construction and use to House 2. These results, obtained in ten days, demonstrate its effectiveness in providing a rapid and cost-effective method not only for identifying plankhouse size and location, but also in yielding distinctive signatures that map onto common kinds of domestic activity areas. That said, magnetometry is not a replacement for excavation. The data it generates are fundamentally different from those of traditional excavation-based approaches to the examination of plankhouse architecture. Relevant architectural elements may or may not be visible in the gradient map. Anomalies can be obscured by strongly magnetic antecedent or subsequent cultural and natural deposits. Metal objects are problematic, but pre-contact features surrounding house deposits are also capable of reducing, masking, or creating signatures that we may falsely identify as evidence of the presence or absence of architecture. These may be especially common in deep, multicomponent midden sites present on the coast. Under these conditions, magnetometry can complement ground-penetrating radar and other technologies capable of producing vertical data profiles. Ultimately, interpretations of magnetic features that are potentially of interest are ideally ground-truthed with confirmatory testing.

Results of this study have important implications for household archaeological investigations on the Northwest Coast. Excavation of plankhouses remains methodologically challenging and labor intensive, as plankhouses are large and stratigraphically-complex features (Ames et al. 1992: 276; Lepofsky et al. 2009: 261). As a consequence, house excavations are often initially exploratory, seeking first to delineate the extent and depth of house deposits and delineate major interior features. We demonstrate that magnetometry can potentially be used to identify major activity areas and the organization of interior space prior to excavation, expediting the exploratory phase. It also allows for more targeted excavation of particular areas of interest, in order, for example, to identify particular features, clarify stratigraphic associations, and obtain datable materials (Eastaugh et al. 2013; Prentiss et al. 2008).

The consistency of patterning at Dionisio Point suggests that magnetometry survey (in combination with other geophysical techniques) may be able to expand our database of known plankhouse sites. Despite millennia of use of large houses in the Salish Sea, few sites with houses have been identified and investigated. Many additional house remains are likely buried and have yet to be identified because they have no surface expression. Geophysical techniques in general and magnetometry specifically should aid in the construction of a better record of the number, size, location, and antiquity of plankhouse settlements in the region. Coupling magnetic gradiometry with additional methods, such as ground-penetrating radar, electromagnetic conductivity, and magnetic susceptibility, among others, can provide a multi-sensor approach to elucidating site structure.

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