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REPORT

Finding Ashmounds: Identifying Large Buried Homogenous Anthropogenic Features with ERT

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Abstract
Electrical Resistance Tomography (ERT) is commonly used in geophysical and environmental surveys because it allows for rapid and high-quality resolution of large depositional features over a wide area. It is generally less able to resolve small anthropogenic features, however, so it has had a slower uptake among archaeologists despite several promising applications over the last two decades. Traditional soil resistivity (ER) surveys are generally limited to two-dimensional surveys at a given depth based on the probe spacing and array selected. As an extension of our ongoing work using ER to detect shallow but spatially extensive patterns at a large urban site of Brahmagiri in southern India, we experimented with using our Frobisher Tar-3 resistance meter to create a "pseudosection"—a narrow but deep remotely sensed profile of a Neolithic ashmound. Ashmounds are large accumulations of vitrified cattle dung, and as such, are appropriate targets for ERT. In our ongoing work at Brahmagiri, one of the most well-known sites in southern India, we located no fewer than nine ashmounds covering an area of more than 10 ha. First reported here, these features add significantly to our understanding of the South Indian Neolithic. Given the size, distribution, and depositional context of the ashmounds, ERT appears to be a promising method for studying these important features.

Resumen
La tomografía de resistividad eléctrica (ERT) se usa comúnmente en estudios geofísicos y ambientales, ya que permite la resolución rápida y de alta calidad de grandes elementos deposicionales en un área amplia. Sin embargo, en general es menos capaz de resolver pequeños elementos antropogénicos, así que ha tenido una adopción más lenta entre arqueólogos a pesar de sus varias aplicaciones prometedoras en las últimas dos décadas. Los estudios de resistividad del suelo (ER) tradicionales generalmente se limitan a estudios en dos dimensiones a una profundidad basada en el espaciamiento y arreglo de sonda seleccionados. Como extensión de nuestro trabajo en curso usando ER para detectar patrones superficiales pero espacialmente extensos en un sitio urbano grande de Brahmagiri en el sur de la India, experimentamos con el uso de nuestro medidor de resistencia Frobisher Tar-3 para crear una "pseudo sección", un perfil estrecho pero profundo detectado de forma remota de un montículo de ceniza neolítico. Los montículos de ceniza son acumulaciones de estiércol de ganado vitrificado, por lo cual son blancos apropiados para ER. En nuestro trabajo en curso en Brahmagiri, uno de nuestros sitios mejor conocidos en el sur de la India, localizamos nueve montículos de ceniza que cubren un área de más de 10 hectáreas. Estos rasgos, los cuales se reportan aquí por primera vez, son una adición significativa a nuestra comprensión del neolítico en el sur de la India; dados su tamaño, distribución y contexto deposicional, la ERT parece ser un método prometedor para estudiar estos importantes elementos.

Keywords: ashmounds; Electrical Resistance Tomography (ERT); India; Neolithic

Palabras clave: montículos de ceniza; la tomografía de resistividad eléctrica (ERT); India; Neolítico

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Confined to the dry interior of peninsular India, Neolithic ashmounds have been controversial features since their first description (Foote 1887). Ashmounds, which can reach up to 10 m in height, are formed of stratified layers of vitrified cow dung as well as other material. Ongoing discussion of these dramatic and enduring landscape features, however, focuses primarily on a limited sample of the larger and best-known features, with little analysis of formation processes. Newly documented ashmound deposits at the site of Brahmagiri have the potential to significantly expand our understanding of the role of ashmounds in the Neolithic of southern India. In this article, we report on new work, using Electrical Resistance Tomography (ERT) to document the extent, shape, and depth of buried ashmounds—evidence crucial for understanding their depositional histories. This less-commonly used technique is cost effective and portable, providing a viable alternative to other forms of remote sensing.

Ashmounds and Ashmound Research

Ashmounds were described as early as 1887 (Foote 1887, 1916) and are found in a limited region of southern India. The term "ash" derives from early ideas about their role as funeral pyres (Morrison 2016); the more apropos "cinder mound" initially proposed by Foote never caught on. Intensive discussions of ashmound function and meaning (e.g., Allchin 1963; Johansen 2004; Paddayya 1991, 1998) have dwarfed consideration of their formation histories, with most scholars focusing on ashmounds in their completed form and seeing them as prominent landscape features, if not monuments (Johansen 2004). In contrast, Paddayya (2019a:50) has recently highlighted the work of Allchin, noting that "his detailed excavations at the site of Utnur in the Mahbubnagar district of Telangana confirmed its character as a cattle-pen by producing evidence of multiple stages of wooden stockade preparations . . . cattle occupation [hoof impressions], dung accumulation and burning, and ash formation." Rajala et alia (2010) raise important unresolved issues of mobility and seasonality associated with herding and ashmound formation.

The ongoing importance of cattle and their dung in contemporary India has inspired many scholars to posit ritual motivations for ashmound construction (e.g., Boivin 2004; Boivin et al. 2005, 2008), though Paddayya (2019a:57–59) also adds to this additional utilitarian factors, such as the value of burning to reduce dung volume, the "clean and hygienic appearance of burnt surfaces" and, with reference to a contemporary festival in which cattle are led though dung fires, potential veterinary hygienic effects.

Excavated ashmounds at Utnur, Piklihal, Palavoy, and Budihal (Allchin 1961; Mujumdar and Rajaguru 1966; Paddayya 1998, 2019b; Reddy 1976), among others, show complex stratigraphic histories with both thick and thin layers of fired dung and other material, indicating multiple episodes of deposition and burning. Ashmounds are found both in isolation—without evidence for permanent settlement—and in association with Neolithic villages, and they are restricted to the semiarid interior of peninsular India (Paddayya 2019b). Allchin (1961, 1963) reported the presence of "vallums" (walls or enclosures) of ashmound material at some sites, but most or all of these seem to have been destroyed by the late twentieth century (e.g., Morrison 2009). Foote (1916) also noted vallums of ashmound material, referring to them as "cinder camps." These "walls" (Allchin 1961:69) are interesting as examples of ashmound material formed into nonmounded shapes, but for the most part, ashmounds have been conceived as isolated hills or mounds.

In a recent reevaluation of ashmound chronology, Fuller et alia (2007) argue that ashmound construction typically took place over a relatively short period of time—100 to 200 years, only a few human generations—with specific construction dates varying by site but generally occurring between 2500 and 1250 BC. Their arguments are based primarily on their own excavations of two ashmounds, Sannarachamma and Hiregudda, and on Bayesian modeling of existing dates from several other sites, most notably Budihal (Paddayya 1998). Although Paddayya (1998) saw Neolithic settlement at Budihal as contemporaneous with ashmounds there, reanalysis of the Budihal dates suggests that the ashmound may predate those settlement deposits, as they also did at Sannarachamma. Fuller et alia (2007) argued that (later) Neolithic settlements were attracted by (earlier) Neolithic ashmounds, suggesting that ashmound construction predated the establishment of permanent villages across the Southern Neolithic. This argument is based on a small sample, given that most other excavated ashmounds are not well dated.

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The connection between ashmounds and settlements has been widely disputed (Allchin 1963; Fuller et al. 2007; Paddayya 1991, 2019b), as has the very nature of Southern Neolithic land use, with interpretations ranging from highly mobile pastoralists practicing some farming, to agropastoralism, to settled village agriculturalists keeping large flocks (which possibly grazed at some distance from the village). Although we should certainly expect strategies to vary across time and over the large region covered by Southern Neolithic sites, few studies have focused specifically on seasonality and mobility, making it difficult to define the range of past land-use practices beyond the general understanding that Southern Neolithic people grew dry-farmed millets and pulses and kept herds of sheep, goats, and cattle. However, see Fuller (2005) for a discussion of the relationship between seasonality and agriculture in the Southern Neolithic and Korisettar et alia (2002) for arguments about the potential relationship between ashmound deposits and seasonal transhumance.

Site Background

The archaeological site of Brahmagiri, in the Chitradurga District, Karnataka, is one of the most famous sites in South Indian prehistoric archaeology. It occupies around 3 km^2 on a granitic outcrop more than 100 m higher than the surrounding plain and is adjacent to the Chinna Hagari stream. Brahmagiri gained early prominence as the location of several Ashokan Minor Rock Edicts of the third century BC—proclamations about Buddhism made by Ashoka, ruler of the distant north Indian Mauryan empire (Rice 1903). Initial archaeological fieldwork by the Mysore State Archaeological Department (Krishna 1934, 1941) established the presence of substantial deposits from what is now known as the Southern Indian Neolithic (ca. 3000–1200 BC), as well as later deposits extending to the sixteenth century AD. In many places on the site, deposits from these later towns cover those of the Neolithic, making spatial analyses of earlier periods challenging.

In work that has continued to define the basic sequence of South Indian prehistory, Brahmagiri was excavated for a single season by the Archaeological Survey of India (ASI) under the direction of R. E. Mortimer Wheeler in 1947 (Wheeler 1948). On the east side of the Brahmagiri outcrop, Wheeler's (1948) excavations in what he called the "town site" of Isila (mentioned in one of the edicts) exposed strata that he interpreted in terms of three successive cultures: the Stone Axe Culture, the Megalithic Culture, and the Andhra Culture—periods now known as the Southern Neolithic, the Iron Age, and the Early Historic. Much of Wheeler's (1948) focus at Brahmagiri was on dating the extensive megaliths at the site, using the units in the Early Historic "town site" primarily to situate the kinds of ceramics associated with the megaliths into a stratigraphic sequence. Although ashmounds had already been objects of study for more than 50 years at the time of excavation, Wheeler (1948) did not recognize the layers of ashmound material exposed in the "town site" excavation units as such—an oversight made clear during our section cleaning of units Br-17 and Br-21 in 2023. Wheeler's enduring impact in the field (Morrison 2025; Ray 2007) may account for the long oversight of these deposits.

Although no previous excavation at Brahmagiri identified ashmounds, the presence or possible presence of ashmounds at the site has been mentioned in the literature (Fuller et al. 2007), with ashmound deposits directly noted by Arjun (2022). One of the goals of new survey work at Brahmagiri by the South Indian Landscape Trajectories (SILT) project has been to identify the distribution of ashmound features across the site. This was accomplished through multiple approaches: mapping visible features via satellite and drone imagery, surface artifact survey via transect walking, intensive feature recording and documentation, and remote sensing.

Based on our preliminary work, we estimate that Brahmagiri has at least nine distinct ashmounds and perhaps as many as 10. All of these are located close to the high rocky outcrop that dominates the site. Because of this, several of the ashmound deposits lie underneath a layer of colluvial overburden washed from upslope, material that has partially protected them from erosion. We traced the Brahmagiri ashmounds in part by their exposure in recent drainage channels, though some also outcrop slightly above the present ground surface and can be documented by surface observation alone. Ashmounds farther away from the outcrop have been exposed by recent field leveling, terracing, and plowing. Our analysis of exposed sections in both farmers' channels and old excavation trenches suggests a complex stratigraphy with multiple ashmound layers alternating with layers of brown fill. Only some of these

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features are accurately described as "mounds," but all consist of fired dung—what we refer to here as "ashmound material." Hardness varies significantly, with some deposits that are soft enough to be cut with a trowel and others that are rock hard. In softer areas, ashmound material is visibly fibrous, and in all cases, it is white in color. The presence of multiple ashmounds at Brahmagiri is significant, in part because Brahmagiri is also the location of Neolithic habitation deposits, including discrete Early Neolithic levels and an as-yet unexcavated later Neolithic settlement.

The Brahmagiri ashmounds are highly unusual in that most of them cluster along the base of the high granitic outcrop rather than being scattered about. Many lie close together, either overlapping or nearly overlapping; in total, they cover an extremely large area (Figure 1), though the presence of later, overlying deposits makes it difficult to estimate this precisely. Unlike many studied ashmounds, some of the Brahmagiri ashmounds appear to be relatively flat rather than mounded, although others exposed in recent cuts may be more mounded, with deeper (higher) deposits more than 3 m thick. Despite the challenges posed by this large and complex set of deposits, the Brahmagiri ashmounds present us with a critical opportunity to resolve many outstanding issues about the South Indian Neolithic, such as the relationship between (1) the timing of megaliths and ashmounds and (2) ashmounds and settlements (Morrison 2005).

Methodology

New work at Brahmagiri as part of the SILT project began in 2023, with a focus on surface description, mapping, photography, remote sensing, and cleaning of already exposed sections, laying the groundwork for future test excavations. As part of the planning for future work at the site, we focused our limited remote-sensing work on resistivity mapping.

Archaeologists have been using soil resistivity to remotely identify anthropogenic features for decades (Atkinson 1953; Carr 1977, 1982; Clark 1990; Gaffney 2008; Kvamme 2003). It is a powerful and cost-effective tool that can be deployed relatively easily to map landscapes. However, traditional soil resistivity surveys are generally limited to two-dimensional surveys at a given depth based on the probe spacing and array selected. Less common in archaeological research has been the use of resistivity to explore deposits at depth. Although the idea of recording vertical resistivity profiles is not new (Clark 1990) and has been used extensively in geology and related environmental research (Edwards 1977), the use of pseudosections to investigate archaeological data has been relatively less common. Electrical Resistance Tomography (ERT) is commonly used in geographical and environmental surveys because it offers excellent ability to resolve large depositional features over a wide area (Arjwech et al. 2020; Gourdol et al. 2018). Because it is generally less able to resolve small anthropogenic features, ERT has had slower uptake among archaeologists—although it is being deployed with increasing frequency, often in conjunction with other remote sensing techniques with finer resolution, such as ground-penetrating radar (GPR; Balkaya et al. 2018, 2021; Casana et al. 2008; Rabbel et al. 2015; Ullrich et al. 2008).

In our first season at Brahmagiri in 2023, we undertook a small ERT test in the hopes that large ashmound deposits would be resolvable. For this survey, we used a Frobisher Tar-3 resistance meter. The Tar-3 is designed to be used primarily in twin-probe or Wenner-array traditional surface surveys, but it can be configured for pseudosection (ERT) recording. This two-dimensional visualization of apparent resistivity is called a "pseudosection" because it assumes a constant relationship between probe spacing and depth (Schmidt 2013). In this mode, an ERT transect is laid out with a tape measure and then metal stakes are placed at the designated spacing—in this case, 0.5 m along the transect. The four cables of the Tar-3 are then connected, in order, to every combination of pins to create the overlapping readings necessary. We opted for 7 m max spacing, which should have the potential to visualize a depth of up to 3.5 m.

We were not sure if ERT would be useful in this context, so we were glad to be able to experiment with this using the Tar-3 that the project had already acquired for traditional resistivity mapping, rather than needing to first acquire an expensive dedicated system that might not, ultimately, prove useful. As a test to see if ERT would allow this sort of ashmound mapping at Brahmagiri, we surveyed a single transect that spanned 35 m. This resulted in 609 individual resistivity readings, each of which required

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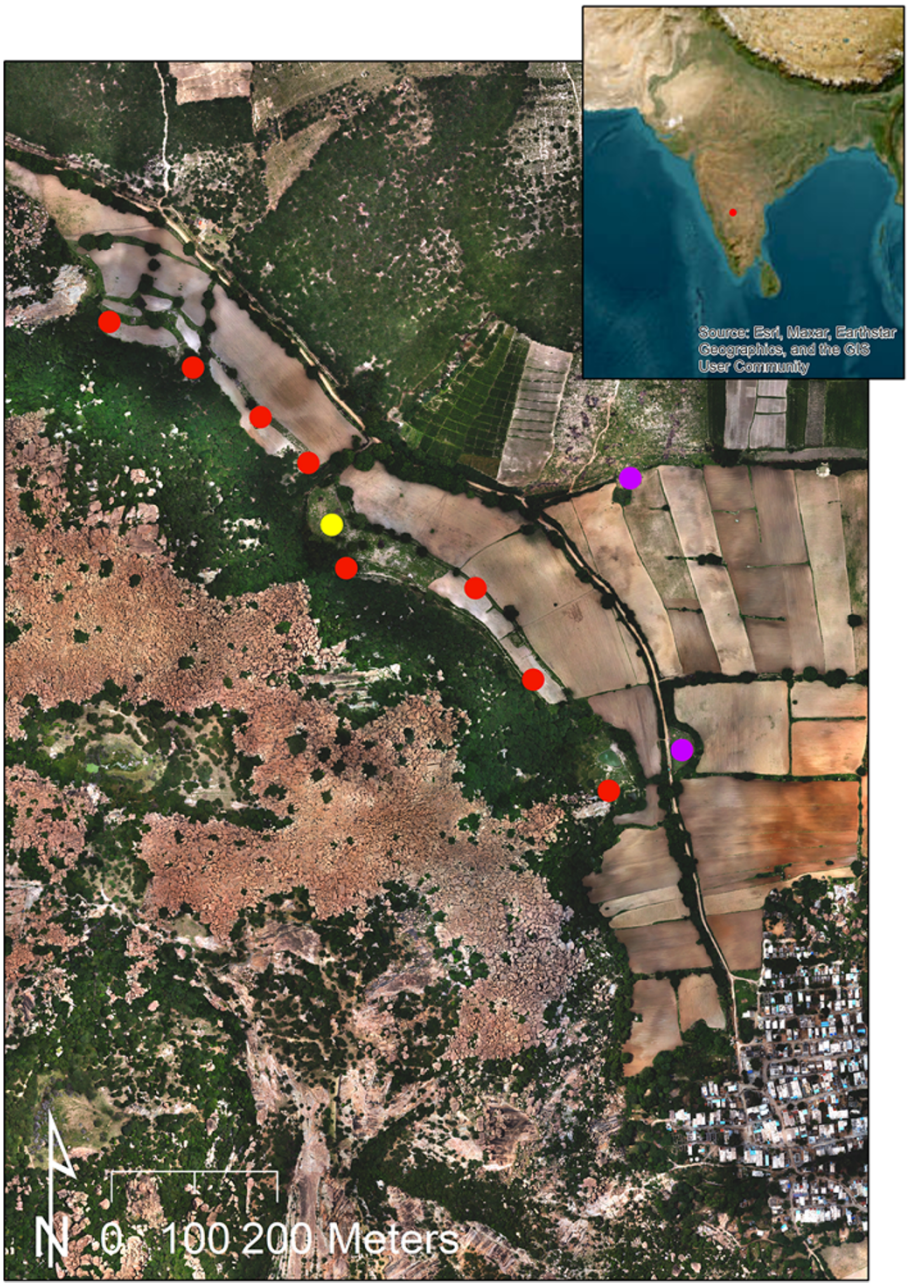


Figure 1. Drone-derived base map of Brahmagiri with locations of identified ashmounds (red), megalith areas fenced by ASI (purple), and the ERT survey location (yellow). Inset: site location. (Color online)

the four probe wires to be manually switched to connect to the appropriate stakes. The Tar-3 works well for collecting this sort of data, but it is slow. We worked as a team of four, with three people moving the clips between each reading, and one person operating the instrument (see Figure 2). At the end of the survey, an elevation was recorded for each point along the transect so that topography could be incorporated into the analysis. Elevation data was recorded with an Emlid Reach RS3 and with an Emlid Reach RS2+ acting as a base station on a known point.

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Figure 2. View looking west of the set-up for pseudosection recording in the field. The author (Hill) stands with the Tar-3 instrument while two crew members prepare to start moving the probes between sets of pins placed at regular intervals along the pseudosection to be recorded (marked with pin flags and a yellow measuring tape). The drainage ditch with an exposed profile of Ashmound 1 can be seen in the background. Photo courtesy of Moriah McKenna. (Color online)

The transect selected for this survey was chosen in a field where our surface survey suggested buried ashmound deposits might be close enough to the surface to be visible in a pseudosection, and where we hoped to be able to detect the edge of the deposits. During the terrestrial survey of the northeast side of the outcrop, we identified nine locations where ashmound deposits were visible, either on the surface or exposed by cuts (see Figure 1), either old excavation units or recent agricultural drainage cuts. Ashmound 1 is a large feature, exposed on its west and part of its north side and visible in a recent drainage ditch. Its eastern edge is not visible on the surface. We placed the ERT transect adjacent to the exposed west side of Ashmound 1, where it was visible approximately 2 m below the surface. The transect was oriented east–west away from the outcrop in the hopes of finding the eastern edge of Ashmound 1.

ERT data must be postprocessed for interpretation, and the inversion algorithm for this is nontrivial (Morelli and LaBrecque 1996; Tsourlos et al. 2014; Zhang et al. 2015). For these data, we used the free and open source ResIPy inversion software package (Blanchy et al. 2020) based on the R family of code written by Andrew Binley (http://www.es.lancs.ac.uk/people/amb/Freeware/Freeware.htm). When the data were modeled and inverted in ResIPy, and elevation data were added to account for elevation change, it produced the visualization shown in Figure 3.

The processed pseudosection appears to show a low-resistance band (shown in red in the visualization) that starts on the west side of the transect about 2 m below the surface. This places the red band at the same elevation as the ashmound deposit visible in the drainage channel profile approximately 3 m to the west. This band of lower resistance is likely the ashmound deposit. It runs horizontally for 30 m before it intersects the surface, which slopes from west to east. It is reasonable to expect that ashmound deposits would be visible in the pseudosection. Resistivity variability is most sensitive to moisture content in the soil (Schmidt 2013), and the ash deposits are very likely to retain moisture at different rates from the surrounding soil. ERT studies of naturally occurring volcanic ash deposits were similarly able

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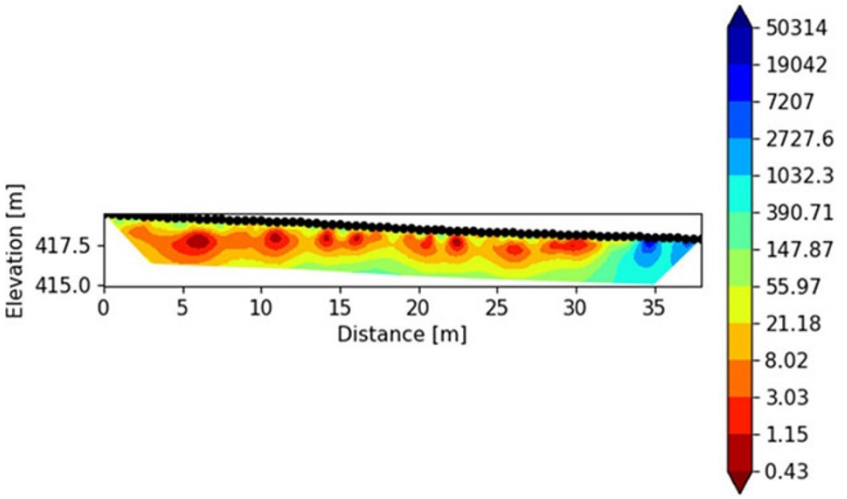


Figure 3. Pseudosection resistance profile (in ohm/m) of the survey transect (facing north). (Color online)

to discriminate ashy deposits from the surrounding matrix (Xia et al. 2010). Although the Brahmagiri ashmounds are not naturally occurring, like volcanic ash deposits, their high silica content is similar, so it should not be surprising to see the ashmound deposits show up in the pseudosection.

The ability to discern the ashmound layer in the pseudosection data is encouraging, establishing the viability of this method for subsurface depth estimation of ashmounds. Given surface evidence for multiple ashmounds along the base of the Brahmagiri hill and the proximity of these features to one another, establishing the locations, depths, and sequencing of these features is critical. The large size of the ashmound zone (around 11 ha) means that excavation can only be a partial solution, with ERT providing critical subsurface evidence. The ability to remotely sense these features gives us the ability to begin to explore a larger variety of ashmound forms and to dissect their specific histories of construction. Consequently, we may be able to better understand the "life histories" of a set of Neolithic ashmounds, linking them to habitation deposits and to the wider depositional history of the site and region.

Being able to discern the frequency and extent of ashmound deposits is critical for understanding the depositional history at the site. Until now we could identify ashmound deposits only where they happened to be exposed naturally by erosion or accidentally by modern agricultural practices. Therefore, we do not know how many individual ashmounds there are, if there are *continuous* deposits over a wide area, or what the extent of those deposits are. But the ability to potentially visualize these features via ERT can help us better understand this. It has already helped us identify other relevant data as well. For instance, the resistivity data appears to show the eastern side of Ashmound 1 coinciding with the surface at around the 30 m mark. On the ground, in person, when the earth had been recently turned for planting, there was no obvious hint that this area might be the eroding edge of the deposit, even though ashmound deposits are significantly lighter in color than other cultural deposits or the natural soil. However, once we identified this as the spot where the ashmound might be on the surface, we looked at historic aerial imagery of the same field at different times of year, and it is sometimes possible to see a distinct boundary between darker soil to the west and lighter soil to the east that lines up directly with this same location. Using the Google Earth time slider, this boundary is visible in February 2017 and March 2012 (Figure 4). This seems to help confirm that the eastern edge of Ashmound 1 is indeed eroding in the field here. The curve of the feature is visible as it bends around to the north, suggesting the limit of this ashmound deposit. The area defined by this visible color change is approximately 1,600 m^2, suggesting a minimum size for this ashmound deposit. Further soil-color variation in the adjacent fields also suggests the extent of additional deposits at the site.

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Figure 4. Apparent soil color change line visible in the same field as the ERT survey. This shows a comparison of 2023 drone imagery (*top*) and Google Earth imagery from 2012 (*middle*) and 2017 (*bottom*). The apparent round shape of the light soil edge visible in the earlier imagery (*middle* and *lower*) is marked in red (*top*) on the more recent imagery where it is not visible. Satellite imagery has had contrast enhanced slightly to exaggerate the color change. Note the white color of the fields to the southeast of Ashmound 1 where another ashmound is located. (Color online)

Chipped stone tools were used in both the Neolithic and earlier Iron Age (Morrison et al. 2022) in this region. Our surface artifact mapping consisted of counts along transects spaced 250 m apart across both the east and west sides of the outcrop. We found a significant clustering of lithic artifacts—many likely to be Neolithic in date and contemporary with the ashmound deposits—at the base of the outcrop in the same location as the ashmound deposits discussed here, further supporting our feature mapping (Figure 5).

Discussion

Ashmounds may have first drawn attention because of their monumental aspect. The most well-known ashmounds are prominent landscape features, rising up to 10 m above the surface, representing large-

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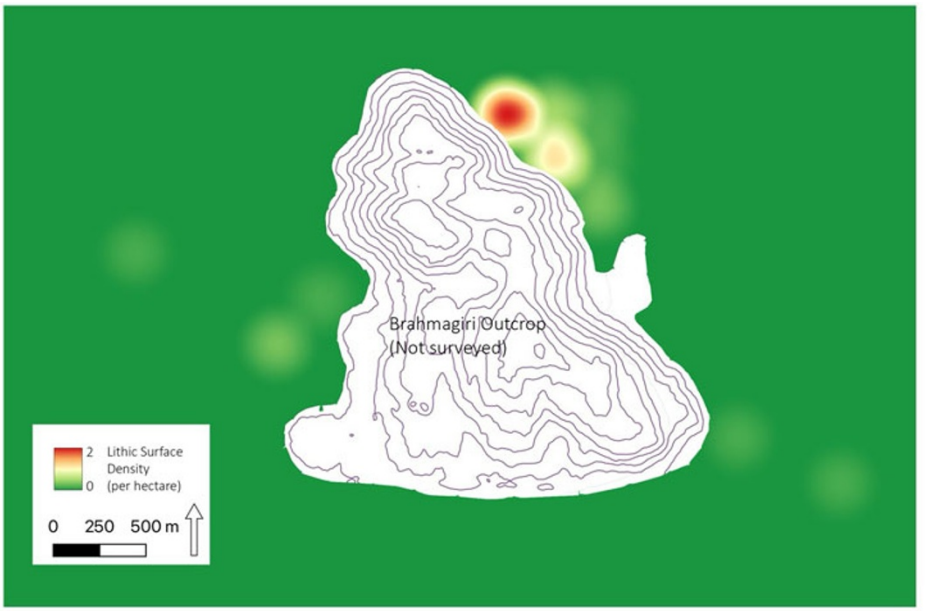


Figure 5. Density distribution map for lithics counted during the surface artifact survey. Note the heavy concentration northeast of the outcrop, in the vicinity of the ashmounds. (Color online)

scale communal enterprise. Much discussion of the ritual and social meaning of ashmounds has centered on the scale of the largest deposits, the long-term utilization of the features, and the relationship to sedentary villages (Allchin 1963; Fuller et al. 2007; Paddayya 2019a, 2019b). Although the scale of deposits at sites such as Wandalli, Kupgal, Palavoy, Kudatini Utnur, and Budihal suggests that the construction of ashmounds functioned as a symbolic communal activity (Allchin 1963; Boivin et al. 2008; Johansen 2004; Morrison 2009), as yet we have little understanding of how this worked or how ashmound building and burning were linked to livestock herding, farming, or patterns of mobility (Rajala et al. 2010). It is critical to document the variability of ashmounds, including smaller ones (Arjun 2017, 2022) and ones with more truncated sequences.

Although the number of sites with identified ashmound deposits is high (at least 150; Paddayya 2019b; Venkatasubbaiah 2012), relatively few excavations of buried ashmound deposits have occurred to date. Where ashmound deposits are more dispersed as more ephemeral buried features—as they are at Brahmagiri—understanding the formation processes, extent of deposits, and evidence for reuse, damage, and modern disturbance is crucial for understanding their wider variability. Documentation of more ephemeral or buried ashmound deposits will also provide novel insight into the variability of ashmound deposits and may even find undisturbed "vallum" deposits such as those that have been described by Allchin (1963) and Foote (1916).

Conclusion

By demonstrating that we can remotely sense the stratigraphic location of ashmound deposits, this research enables a whole new potential avenue for investigating ashmounds at sites such as Brahmagiri and Watgal (Arjun 2017), where, until now, buried deposits have only been visible in excavation trenches or by the fortuitous agency of modern agricultural processes. This relatively small demonstration that we can track ashmounds with ERT will act as a pilot study for a more complete survey at Brahmagiri, which will allow 3D reconstructions of the shape and distribution of buried deposits, volumes estimates, and potentially, reconstructions of the impact of deposits on soil flow and local hydrology. Although there are many remote-sensing technologies available to archaeologists that have the potential to reveal buried features, ERT provides a great and relatively low-cost tool for mapping

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larger homogeneous subsurface anthropogenic geomorphic features that might be difficult to study otherwise.

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Data Availability Statement. The ERT data presented here is available at https://doi.org/10.6084/m9.figshare.31902280.

Competing Interests. The authors declare none.

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