University of Southampton

FACULTY OF HUMANITIES

Department of Archaeology

Exploring the spatial structure of pre-Columbian cultural landscapes in the Alto Paraná (Misiones province, Argentina)

by

Philip George Constantine Riris

Thesis for the degree of Doctor of Philosophy

December 2014

This thesis is dedicated to the memory of Eleni and Constantinos Riris

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF HUMANITIES

Archaeology

Doctor of Philosophy

EXPLORING THE SPATIAL STRUCTURE OF PRE-COLUMBIAN CULTURAL LANDSCAPES IN THE ALTO PARANÁ (MISIONES PROVINCE, ARGENTINA)

by Philip George Constantine Riris

This thesis investigates new approaches to analysing and interpreting the spatial structure of pre-Columbian cultural landscapes in the eastern La Plata basin, through two case studies the upper watershed of the Río Paraná, Misiones province, Argentina. Drawing on 'non-site' and 'distributional' archaeological theory to establish a robust spatial framework, the first case study concerns the organization of lithic technology in a sample constructed from survey data recorded during June and July 2013 in Eldorado Department. Point pattern data, combined with a desk-based analysis of stone tools, forms the baseline for the application of a family of spatial statistical analyses of surface archaeology derived from Ripley's K function, and supported by Monte Carlo simulation. These methods succeed in detecting significant technological trends at multiple spatial scales. The results are interpreted as a long-term accumulation of material deposited through different systems of land use, which overlap and blend in a palimpsest of occupational events that are irreducible to their individual episodes. The findings imply that the notion of archaeological 'sites' is unfit for the purpose of studying past cultural processes in the region. The results also show that surface data possess significant potential for generating new insights on pre-Columbian settlement patterns in both Misiones and its broader regional context.

In the second case study, the role of monumental architecture in the later pre-Columbian period of Misiones is investigated with a geospatial model. It tests the emergence of territoriality among southern proto-Jê groups as a function of differential access to mound and enclosure complexes. Through a computational approach that combines archaeological and simulated random data, the model is able to discern different hierarchical modalities of accessibility to a sample of southern proto-Jê funerary earthworks. The results demonstrate that the model succeeds in characterizing hereto unknown patterns of structured mobility that existed in relation to these distinctive elements of the later Holocene built environment. Together with a focused point process model using a larger sample of monuments from Rio Grande do Sul, Brazil, these efforts demonstrate that employing quantitative methods allow archaeologists to move from conceptual models to robust explanatory frameworks in the context of understanding pre-Columbian socio-political complexification.

In sum, it is argued that standard practice of collecting and interpreting surface data in the wider study region fundamentally mischaracterizes the variability, temporality, and spatial scale of this record. Adopting non-site methods and theory offers a solution to this problem. The approaches are evaluated in the Alto Paraná study area in terms of the new interpretative perspectives they enabled. New avenues of enquiry for research aiming to reconstruct past land use are presented based on the findings, including specific improvements concerning survey method and integrating excavated data.

RESUMEN ESPAÑOL

Esta tesis investiga nuevos métodos para el análisis e interpretación de la estructura espacial de los paisajes culturales precolombinos en el este de la cuenca de La Plata, a través de dos estudios de caso ubicados en la cuenca superior del Río Paraná, provincia de Misiones, Argentina. Sobre la base de teoría 'non-site', que constituye un marco espacial de probada robustez, el primer estudio de caso explora la organización de la tecnología lítica en una muestra construida a partir de los datos registrados durante el trabajo de campo desarrollado en el Departamento de Eldorado en los meses de junio y julio de 2013. Los datos espaciales, junto con un análisis basado en la organización de tecnología lítica, constituyen la base para la aplicación de una serie de pruebas estadísticas espaciales derivadas de la función K de Ripley al registro arqueológico superficial, pruebas que son apoyadas por la aplicación de la simulación de Monte Carlo, de forma que la combinación de estos métodos permite detectar importantes patrones tecnológicos a múltiples escalas espaciales. Como primera conclusión, los resultados se interpretan como una acumulación de material depositado a largo plazo a través de diferentes sistemas de usos de suelo, que se superponen y se combinan en un palimpsesto de eventos ocupacionales que son irreducibles a sus episodios individuales. En segundo lugar, los resultados implican que el concepto de 'sitio' arqueológico no es adecuado para el estudio de los procesos culturales pasados en esta región. No obstante, es preciso remarcar que los resultados también muestran que el registro arqueológico en superficie posee un importante potencial para profundizar en el conocimiento sobre los patrones de asentamiento precolombinos no solo en Misiones sino también en un contexto regional más amplio.

El segundo estudio de caso investiga el papel de la arquitectura monumental en el período precolombino tardío de Misiones a través de un modelo geo-espacial. Específicamente, se pone a prueba el desarrollo de la territorialidad entre los grupos proto-Jê del sur entendida como una función de los niveles de acceso diferenciales a los complejos de montículos funerarios de la zona. A través de un enfoque computacional que combina datos arqueológicos y simulados, el modelo es capaz de destacar diferentes modalidades jerárquicas de la accesibilidad a una muestra de montículos funerarios proto-Jê del sur. Los resultados demuestran que el modelo tiene éxito en la caracterización de los patrones de movilidad estructurada (desconocidos hasta ahora) los cuales se relacionan con estos elementos de arquitectura distintivos del Holoceno tardío. Adicionalmente, se han contrastado estos resultados con la una muestra más amplia de monumentos ubicados en Rio Grande do Sul, Brasil, lo que ha demostrado que la utilización de métodos cuantitativos permite a los arqueólogos pasar de modelos conceptuales a marcos explicativos muy robustos en el contexto del estudio de complejidad de las estructuras sociopolíticas pre-colombinas.

En resumen, se argumenta que la práctica estándar del registro e interpretación de los datos arqueológicos en superficie en la región de estudio más amplia caracteriza erróneamente la variabilidad, la temporalidad y la escala espacial de este registro. No obstante, la aplicación de los métodos y de la teoría 'non-site' ofrece una solución a este problema. De este modo, estos enfoques son evaluados en el área de estudio del Alto Paraná en cuanto a las nuevas perspectivas interpretativas que permitieron por un lado explorar nuevas posibilidades para las investigaciones que tienen como objetivo la reconstrucción de los usos del paisaje en el pasado sobre la base de los hallazgos en superficie, y por otro lado, proponer mejoras específicas tanto en el método de prospección superficial como en la integración de los datos arqueológicos excavados.

Contents

List of tables

List of figures

List of equations

DECLARATION OF AUTHORSHIP

I, Philip George Constantine Riris declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

Exploring the spatial structure of pre-Columbian cultural landscapes in the Alto Paraná (Misiones province, Argentina)

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. Parts of this work have been published as:

Riris, P. and I. Romanowska. 2014. "A Reconstructed Reduction Sequence for Curved Bifacial Stone Tools From the Eastern La Plata Basin, Argentina" *Lithics* 35.

Signed: ....

Date:..

Acknowledgements

My family, both old and new, near and (relatively) distant, have always been my ultimate point of reference for most things in life. I thank them for their unswerving love, support, and faith in me while I carried out this research, to which I add the hope that I can continue making them proud. Becoming an archaeologist has brought me intellectual and emotional satisfaction the likes of which I could not have imagined when I embarked on my studies almost a decade ago. It was all made possible through them and the faculties they equipped me with.

First, the research presented in this documented would not have been possible without the amazing team I was blessed to have working with me in Eldorado between June 17 and July 15 2013. I give my thanks to Olivia Martin, Kasia Maynard, Iza Romanowska, and Clara Schonfeld for putting up with the setbacks, bad weather, *mbarigüíes*, and hours of lab work that we faced together. All future teams will be held to the standard you set. I cannot thank you enough.

In Southampton, I would like to thank everyone who I had the pleasure and stress of sharing Room 2241 with for the past three or so years. I believe the spirit of *communitas* that exists in our little slice of Avenue Campus is unrivalled in any department of archaeology, and contributed in no small part to the writing up of this research. The innumerable coffee breaks, lunchtime chats, and Friday pub sessions at the Crown undoubtedly had a profound and lasting impact on this work. I would also like to thank my supervisors, David Wheatley and Fraser Sturt, for the incredible support they gave me for the attainment of my goals, which was above and beyond the call of duty. Without the doors they were able to open, this project may very well never have got off the ground. The support of the Richard Newitt Bursary I was awarded helped me achieve more than I thought possible at the outset, while the Graduate School of the Faculty of Humanities also supported much of my travel to workshops and conferences around the world.

Special mention goes to a select group of people who in large part contributed to the maintenance of my mental and physical health throughout this project. They are: Cleome Dakin, Flávio de Oliveira, and Matthew Harrison, for our regular gaming nights and table-top hijinks; Kieran Rones and Nick Hedger, for keeping me lifting heavier things three times a week, every week; and Anna Stegman, for her constant support and encouragement, and for being so very dear to me. The above individuals definitely bore the brunt of my neuroticism, and are deeply thanked for their patience and good humour.

In Misiones, I received all the support and warm welcome I could have asked for from the city of Eldorado and its citizens. In particular, Marcelo Calier, Margarita Kummerer, and Norberto Hermes Aguirre are thanked for the logistic support that was offered to and gladly accepted by the Piray Mini Exploration project. Mario Lapchuk and Lorenzo Barreiro were excellent and patient guides for us the backwoods of Eldorado department, smoothing our way in the field and allowing us to find the *"piedritas antiguas"* we were looking for. The data in this thesis would have been very different without their help. Hector Leiva and his family are thanked for their kindness and for opening their home to us for a truly memorable asado. The owners of the fields and plantations we surveyed in

Misiones are thanked greatly for their cooperation and patience in allowing us access to their properties. Karin Schlagenaufer, Ernesto Aumer, and Alfredo, Aldo, and Gerardo Gruber are especially thanked for letting a mysterious group of *extranjeros* have free reign of their plantations.

In Buenos Aires, my gratitude goes to the people and organizations that permitted me to carry out my research in Argentina. The Instituto Nacional de Antropología y Pensamiento Latinoamericano issued the research permits which allowed us to study the past and cultural heritage of Misiones, and graciously allowed me access to collections from the province. This research was carried out as a sanctioned sub-project of "Arqueología del Bosque Atlántico Meridional Sudamericano", led by Daniel Loponte (INAPL) and Mirian Carbonera (Unochapecó). Their help is duly acknowledged. Kevin Lane and Jennifer Grant are thanked for their help and hospitality during my two stints in Buenos Aires, and for helping me to make sense of it all. Alejandro Acosta is also thanked for his guide to the city and its sights.

Finally, I would like to thank my many colleagues who greatly influenced me during the execution and writing of this research. In particular, it is worth singling out John "Mac" McNabb for his thorough and helpful critique of the stone tool analysis in Chapter 5; Yvonne Marshall and Jenny Watling for reading portions of this work at various points and offering terrific comments; Rafael Corteletti for our intellectually stimulating fieldwork and discussions in Urubici, as well as his and Tatiana's hospitality in Porto Alegre; Marcos Llobera, Tom Brughmans, and Patricia Murrieta-Flores for their specific comments on the models in Chapter 7; and Manuel Arroyo-Kalin, Marisa Lazzari, Edward Swenson, and Barbara J. Mills for their generous advice on securing fieldwork funding. I also thank Enrico Crema and Andy Bevan for the many interesting conversations we intermittently had on R scripting, simulation, and spatial analysis in archaeology. Without their advice, I doubt I would ever have taken to the R programming language as quickly or with as much gusto. The Bivariate Local K in Chapter 6 was run entirely through a series of scripts given to me freely by Enrico, and enriched the analysis presented therein substantially. Finally, I would like to thank the wider community of South American archaeologists based in the UK, whose research always provided a backdrop to my own, and for the steady exchange of knowledge, perspectives, and "war stories" that continue to emerge from our continent of study.

The music of Mastodon, Clutch, Kvelertak, Nile, Baroness, and Opeth formed the soundtrack to which this thesis was written, and carried my thoughts through many of the more challenging passages and sections. The members of these bands are thanked for their continuing creative output.

The analyses presented in this thesis were performed in R (R Core Development Team 2013) with the spatial statistical package 'spatstat' (Baddeley and Turner 2005).

1. Introduction to research

1.1 Introduction

The goals of this research have been refined many times during the time it has taken to write this thesis. At its core the fundamental focus has always been to provide an answer to the question: "how was the landscape of Misiones province inhabited by its pre-Columbian occupants?" Patterns of settlement and land use at all scales are major components of cultural expression in the past, and recent developments in the field in South America continue to highlight the importance of understanding them (Walker 2012). The simplicity of this question is, however, deceptive without grounding it in the history of

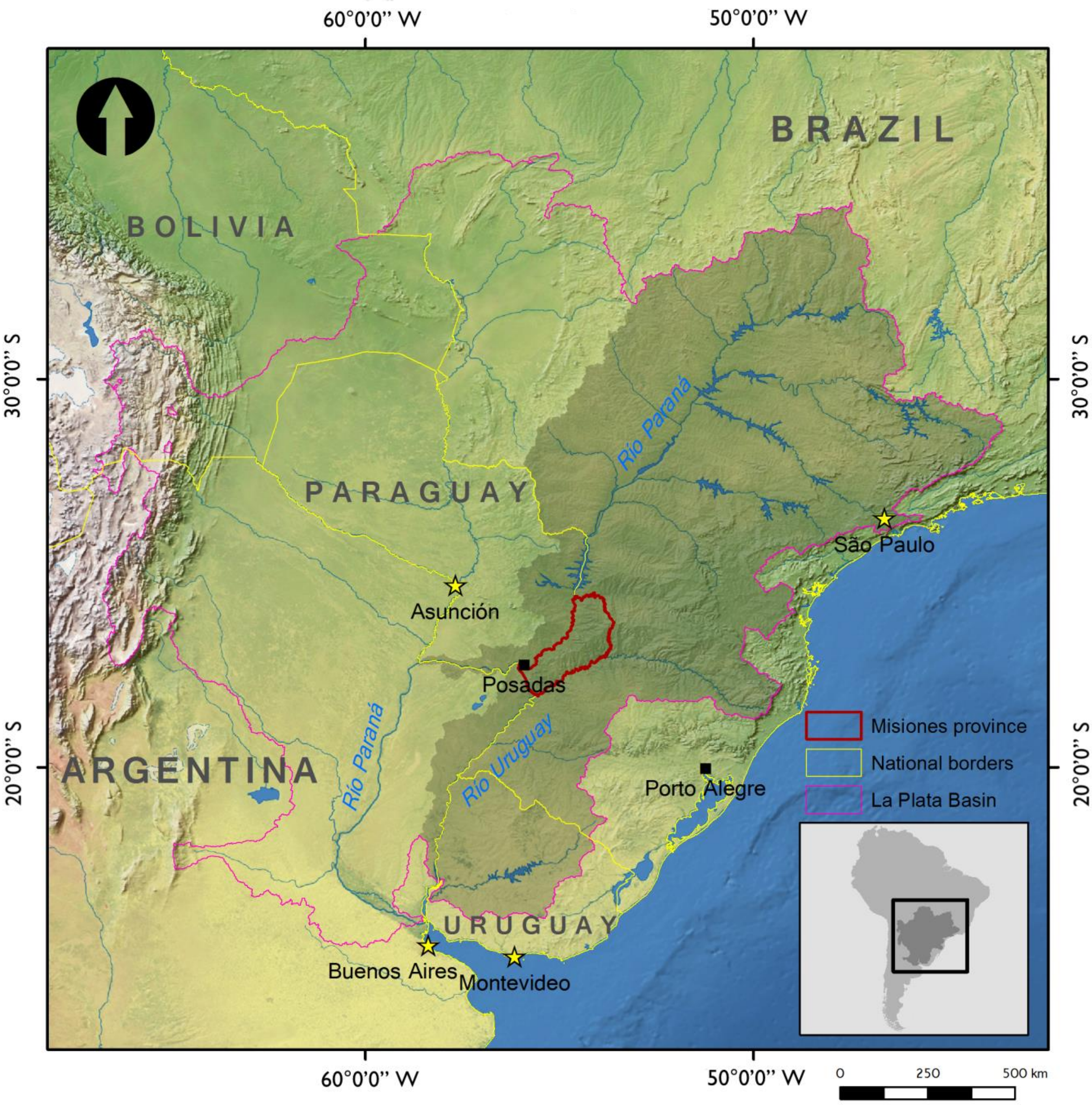


Figure 1.1: Location of Misiones province in the regional macro-context of the eastern La Plata basin (shaded), composed of the Uruguay and Upper Paraná catchments. Source: USGS

archaeological discourse in Argentina and neighbouring states of Brazil. Following from this, the introductory chapters of this thesis will contextualize Misiones province in its wider geographical context: the macro-region of the eastern La Plata basin (Figure 1.1). Also note that in the course of this research, the densely forested subtropical environment of Misiones province itself presented obstacles to the goal of generating landscape-level insights into pre-Columbian land use. Logistical issues to fieldwork in forests aside, accomplishing one of the traditional goals of archaeological surveys – defining sites and their material cultural content – proved from experience to be a challenging endeavour in the study area (Riris 2010b).

In order to solve this problem, and in doing so build an analytical platform for answering the research questions, this thesis diverges from previous exploratory work in the larger study region in two key ways. First, this research will investigate settlement and depositional patterns at multiple spatial scales. To this end, the data collection strategy of this research will use non-site methods (Dunnell and Dancey 1983; Ebert 1992), where individual artefacts function as the unit of analysis in order to assess archaeological remains across the landscape as a continuous distributional pattern of artefacts. Although non-site methods have existed for close to four decades (Thomas 1975), they are to an increasing degree a key tool in the inventory of archaeologists across the globe (e.g. Bevan and Conolly 2002; Holdaway et al. 2004; Caraher et al. 2006; Bradbury et al. 2008; Douglass 2010; Johansen 2010; Harrison 2011; Crema and Bianchi 2013), but to date have seen very limited uptake in the eastern La Plata basin (see Araujo 2001). Allied with the ubiquity of spatial technology in the twenty-first century discipline, it will be argued that they have a significant contribution to make towards generating landscape-level understandings of the material record. Consequently, the methods developed here aim to take in a far larger archaeological sample than what was extant in Misiones prior to this research. The results of the fieldwork are composed of a spatial database linked with an accompanying lithic database, which helps to contextualize the raw spatial point patterns. Second, in terms of method, the variability in this record is addressed using explicitly spatial analytical techniques. Using computational modelling and simulation, a rigorous approach is drawn from wider scholarship in archaeology, point pattern analysis (a subset of general spatial analysis), and landscape ecology. This represents a significant advance on previous correlative and simplistic models of land use in the larger study area.

1.1.1 Location and geography

Misiones is located in the Argentinean northeast, embraced by two main branches of the Río de La Plata fluvial system: the Uruguay and the upper Paraná. The study area within the province is contained by the boundaries of the area of governance of Eldorado department (Figure 1.2) in the north-western sector of the province. The areas investigated

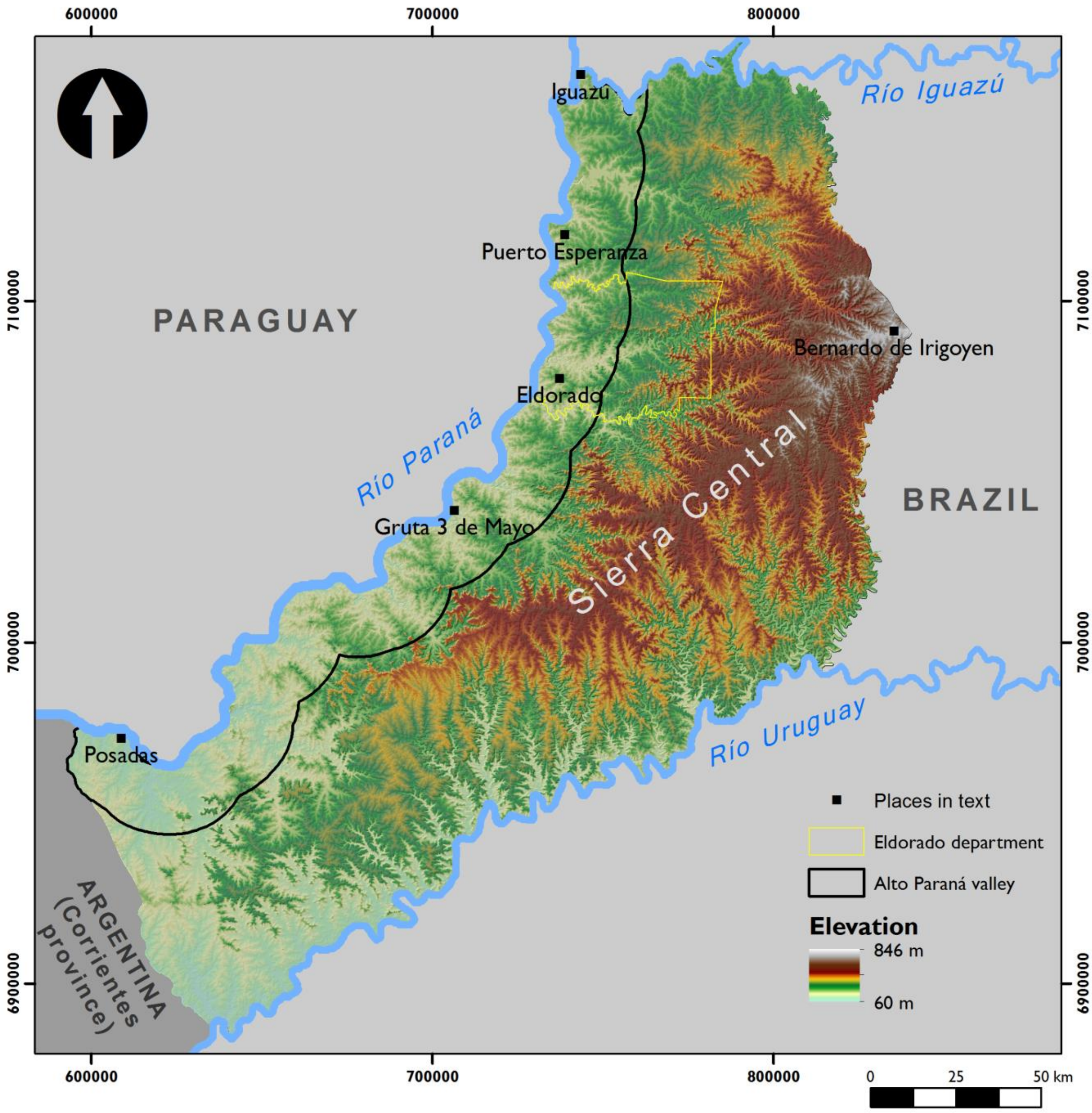


Figure 1.2: Relief and hydrography of Misiones province, with major locations and features mentioned in the text.

by the fieldwork component of this project lie on the margins of the Paraná floodplain and in the transitional zone towards the *Sierra Central*, or central mountain range. The term Alto Paraná will be used throughout to refer to the area that was investigated within the department of Eldorado. In terms of relief and ecology, the low-lying riverine settings of the province stand in contrast to the uplands. The latter represent the south-western extremities of the southern Brazilian highlands or *planalto*, a relatively high-altitude geographical area which has been the subject of more sustained archaeological interest over the past five decades.

The province, and therefore study area, is connected with the rest of the eastern La Plata basin through its rivers and the terrain they cut across. The geomorphology, ecology and climate of this macro-study region, defined as the catchment of the upper Río Paraná, the Río Uruguay, and their main tributaries (see Figure 1.1), are discussed in more detail below. Although the study of the past possess very different trajectories and epistemologies on either side of the Argentina-Brazil border, the material record of the macro-region itself is broadly comparable (see Chapter Two). While the archaeological nomenclature for the various pre-Columbian cultures differ, the material culture, architecture, ethnolinguistics, chronology and, possibly, history of human-environmental interaction of various groups can be discussed on common terms where needed. Recent projects in Brazil have drawn attention to the range of variability in many archaeological cultures, among both later pre-Columbian societies such as the southern proto-Jê (De Masi 2005; Corteletti 2012; Schmitz et al. 2013b; Iriarte et al. 2008; Iriarte et al. 2013) and earlier pre-ceramic hunter-gatherers (Hoeltz 2005; Dias 2007; Parellada 2008a; Dias and Hoeltz 2010; Schmitz 2010). Establishing a common framework for comparison can help integrate the archaeology of Misiones in broader regional debates.

Misiones province represents almost 30,000 square kilometres of terrain, up to half of which is under the canopy of dense native vegetation termed the Paraná Interior Atlantic Forest (Chebez and Hilgert 2003, 147; Camara and Galindo-Leal 2003), or simply abbreviated to Interior Atlantic Forest. Until the mid-twentieth century these forests would have covered most of the province. *Misioneros,* citizens of the province, refer to the native forests as *monte* or, somewhat more romantically, by the name of *Selva Misionera*. The lushness and vastness of the forest has historically been noted by visitors (e.g. Ambrosetti 2008 [1896]). In the present day it is seen both as a source of wealth and a natural treasure in need of preservation; Misiones is the only province of Argentina with a Ministry of Ecology, whose role includes preserving the largest remaining contiguous area of Atlantic Forest in South America (Galindo-Leal and Câmara 2003; Izquierdo et al. 2008). In short, it is an integral part of the modern identity of Misiones, and is known to have been extant for the past two thousand years at a minimum (Gessert et al. 2011).

South America has been referred to by anthropologists and archaeologists alike as the least known continent (Lyon 1974; Bruhns 1994). Although there have been many significant advances in knowledge with passage of time, against this backdrop the *Selva Misionera* invokes the mystery of an archaeological landscape that remains largely defined by unknowns. Viewing Misiones province in the context of the macro-study region the lacunae can be fully appreciated (see Chapter 2). Tremendous barriers remain in place to developing a comprehensive prehistoric narrative for this enthralling continent (Heckenberger and Neves 2009, 259), extending archaeological knowledge to "the blank spaces on the map" continues provide us with new perspectives on pre-Columbian socio-cultural diversity (Walker 2012, 26). The vast majority of the province remains unexplored in archaeological terms, but this research provides a first genuine attempt at accessing the landscape dimension of pre-Columbian culture in Misiones. In the face of new evidence that will no doubt emerge, however, the findings presented here are certainly open to re-evaluation.

1.2 Overview of archaeological research in Misiones

Half a century of sporadic archaeological research in Misiones province has left the landscape dimension of its pre-Columbian occupation largely unaddressed. The most recent regional synthesis of archaeological knowledge (Rodriguez 2001) was produced largely by inference from the sparsely distributed studies that have been carried out from the 1950s to the present, and from correlations with the far better studied parts of the eastern La Plata basin that lie within Brazil. The chronology of Misiones reproduced in the cited publication should be regarded as highly speculative, as it relies on no formal comparison with Brazilian material or independent sources of information on the past. Nonetheless, it has been adapted here (Figure 1.3) in order to circumscribe the broadest of trends in the material record of Misiones. Chapter 2 addresses this in greater detail.

The history of formal archaeological investigation in the province begins with work of the Austrian archaeologist Oswald Menghin in the mid-1950s, who carried out excavations and surface collection near the city of Eldorado in the north-west sector of the province. His works (Menghin 1955/56; Menghin 1957) defined the archaeological vocabulary that remains in use to this day, dividing the archaeological record into the pre-ceramic *Altoparanaense* culture and subsequent "Neolithic" ceramic-producing cultures represented by the *Eldoradense* and Tupiguarani. Excavations were carried out on monumental earthworks that today are known to relate to the southern proto-Jê archaeological culture (Iriarte et al. 2008). The groups of this affiliation produced ceramics that are identified as the Taquara/Itararé tradition in southern Brazil (see Beber 2005; Araujo 2007). This archaeological tradition is equivalent to Menghin's Eldoradense culture. Surface collections from throughout Misiones and eastern Paraguay, including Eldorado, supplemented this data (Menghin 1955/56, 172). He also recognized the archaeological presence of Tupiguarani groups that were known to live along the major watercourses of the province in colonial times.

Further surface collections were carried out by Schimmel (1967) and Madrazo and Laguzzi Rueda (1967) in San Ignacio, Iguazú and Posadas departments with the guidance of Menghin, demonstrating that material similar to that of the cultures he identified in Eldorado also extended across the wider province. The next major investigations, however, did not come for another decade in Garuhapé, some 60 km south of Eldorado, where Antonia Rizzo (1967; 1968) carried out her doctoral research on cave deposits in the *Gruta 3 de Mayo*. These excavations produced evidence of occupation by the Altoparanaense and Eldoradense cultures in a rock shelter some 4 km inland from the banks of the Paraná. Until renewed excavations in 2013, the material recovered from the

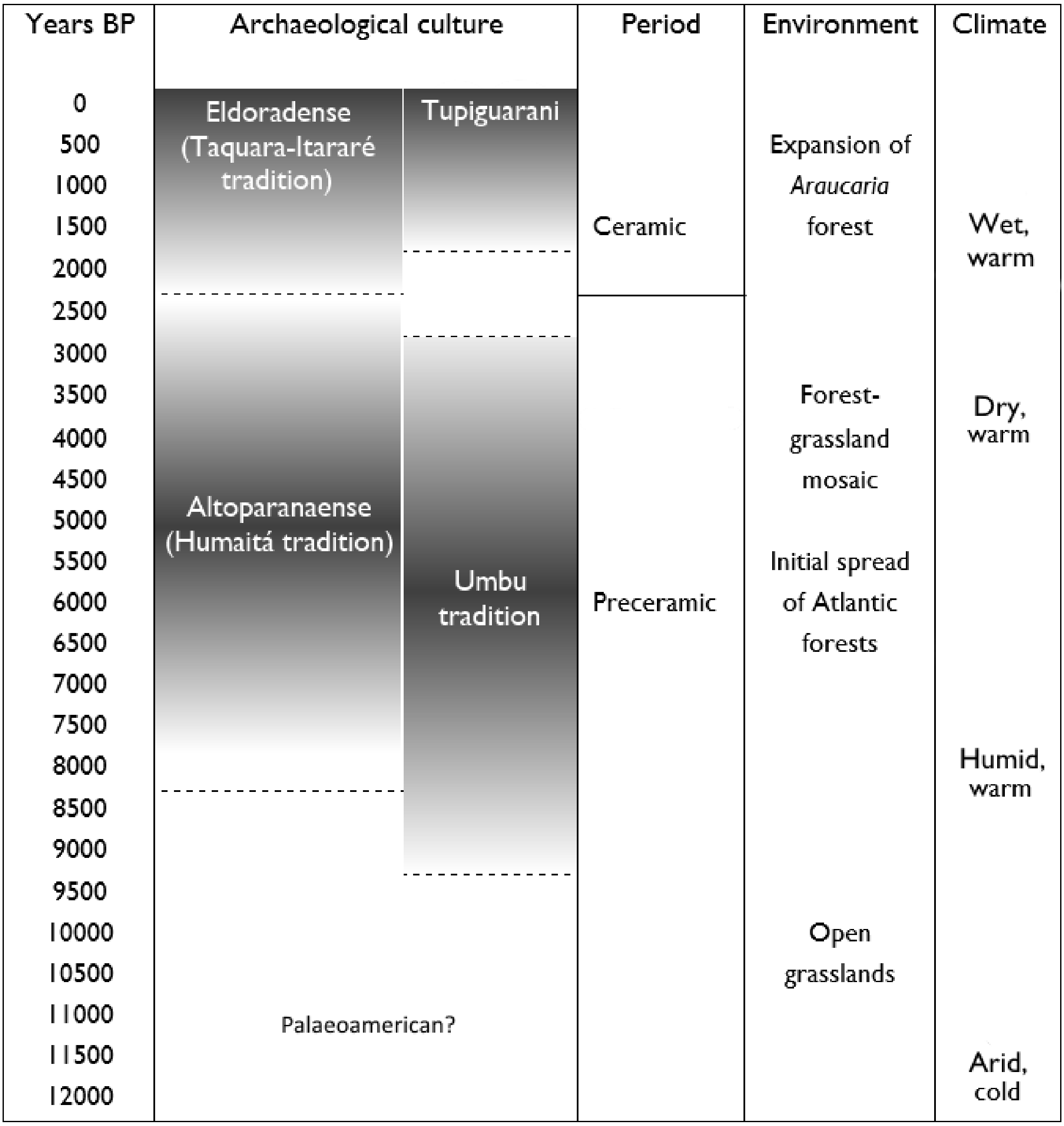


Figure 1.3: Received cultural chronology of Misiones province following Rodriguez (2001), with palaeoenvironmental and climatic data from southern Brazil (Behling 1998; 2002; Ledru et al. 1998; Stevaux 2000; Leonhardt and Lorscheitter 2010) and Misiones (Gessert et al. 2011). Palaeoenvironmental data is discussed in detail in section 1.4. This simplified schema is derived directly from Brazilian data (Loponte 2012, 55) and is subject to several important caveats, explained below.

Shaded gradient indicates the inferred range of dates for archaeological cultures in Misiones province (Poujade 1992; Rodriguez 2001), while dotted lines are the outer chronological boundaries of the cultures in question in southern Brazil, whose names appear in parentheses below the name in Misiones. The Taquara/Itararé and Tupiguarani cultures are the predecessors of historically known Jê and Guarani groups (Noelli 1999/2000; 2005).

Elements of the Humaitá tradition persist into later ceramic-producing cultures, making this existence of this "tradition" a point of contention (Dias 2003; Hoeltz 2007; Dias and Hoeltz 2011). There is, however, no demonstrable direct link between the Altoparanaense/Humaitá tradition and later cultures linked to the appearance of southern proto-Jê groups in the eastern La Plata basin (Eldoradense and Taquara/Itararé) (c.f. Dias 2007).

Finally, a Palaeoamerican occupation of the province is not known, but early sites of this nature are purported to exist along the Brazilian margins of the Uruguay River (Schmitz 1987; Prous and Fogaça 1999) and its presence in the province must be regarded as speculative.

cave included the only pre-Columbian human bone and bone tools recorded in the province, due to the acidity of the soils hindering preservation elsewhere.

In line with archaeological practice at the time (Politis 1995), the works of Menghin, Rizzo and their collaborators are cultural-historical and largely classificatory towards the material record. Despite pioneering the field in Misiones, the works provide a limited impression of pre-Columbian society for the modern archaeologist, which is in part also due to their unsystematic nature. As evidence of Menghin's lasting influence, Hermann Wachnitz, an avocational archaeologist who collaborated with Menghin, later published a monograph on the "pre-Guarani" inhabitants of Misiones, including a distribution map of the southern proto-Jê funerary earthworks, showing the spatial relationships between the eight enclosures (Wachnitz 1984). The proposed chronology from this time was unconfirmed by absolute dating when published, leading later syntheses to rely on data collected across the border in Brazil or in the neighbouring province of Corrientes for comparison (e.g. Poujade 1992; Rodriguez 2001). Rizzo and colleagues (Rizzo et al. 2006) revisited the material from the Gruta 3 de Mayo and dated charcoal associated with ceramic sherds to 2035 – 1628 BCE (LP-1446). This date is earlier than similar Taquara/Itararé tradition ceramics in southern Brazil by a margin of several centuries (Loponte 2012, 62; see also De Masi 2005), and requires additional dates to support it.

Leading up to the turn of the century, researchers mainly focused on Tupiguarani sites along the Paraná (Giesso 1984; Giesso and Rizzo 1985; Giesso and Poujade 1986), as well as the exploration of the Jesuit *reducciones*. These were occupied from AD 1609 until the expulsion of the order in 1767 (Poujade 1992; Giesso 1998). These works represented some of the first archaeological, as opposed to historical, research on the mission settlements that gave the province its name. Further surveys also occurred in Puerto Esperanza and San Vicente, which resulted in the expansion of collections of Altoparanaense, Eldoradense and Tupiguarani material. Stone projectile points, resembling pre-ceramic Umbu Tradition lithics from southern Brazil, also formed part of these assemblages (Mújica 2000; 2007). Rodriguez (2001) considers this type of lithic tool to pre-date the Humaitá Tradition in Brazil and the Altoparanaense in Argentina (Schmitz 1987). Surveys in the Sierra Central purportedly recorded pit house settlements characteristic of the highlands of Brazil (Caggiano 1984; Beber 2005; Loponte 2012, 61). Limited work has thus far taken place in the valley of the Uruguay (Sempé and Caggiano 1995).

It is not coincidental that the works discussed up to this point are predominantly located in the upper Paraná valley, in the western part of the province. This region of Misiones has been the most heavily settled throughout the history of European colonization, in part due to the navigability of the river in comparison to the Uruguay. As a result, the modern provincial infrastructure initially linked these settlements with each other and ultimately the rest of the republic (Eidt 1971). The outcomes of this process are still visible through their impact on Atlantic Forest fragmentation in the modern day, which is strongly associated with roads and major settlements in these areas (Rau 2005; Izquierdo et al. 2008). It may be suggested that the development of these roads provided scholars with a point of entry to Misiones that offered less resistance than the remote forested highlands or the sharper relief of the Uruguay valley. Combined with the land clearances that followed colonization, this factor probably caused a higher rate of detection of pre-Columbian material in the absence of dense forest. In this context, it is worth noting that the last native non-Guarani group recorded in Misiones, the Kaingang, were encountered in San Pedro in the far east of the province (Ambrosetti 2006 [1895]). Finally, it can be conjectured that the origins of the colonists are also likely to have had an effect on the rate of discovery in this area. Countries such as Denmark and Germany possessed developed scholarly traditions in archaeology by the mid-twentieth century, and hence a larger presence in the public consciousness. It can be tentatively suggested that immigrants to Misiones from these countries, such as Ulf Moensted and Hermann Wachnitz (Wachnitz 1984) were able to more easily recognize prehistoric archaeological material in the upper Paraná valley.

In the last decade, archaeological research in Misiones has expanded significantly. Starting in 2006 and ending in 2008, the PM01 mound and enclosure complex (MEC) in Eldorado was re-excavated by a University of Exeter team (Iriarte et al. 2008; 2010a). Renewed excavations of the enclosing bank of the central mound feature provided the site with radiocarbon dates that place its use in the thirteenth to fourteenth centuries AD (Iriarte et al. 2008, Table 1). These earthworks are securely dated to a southern proto-Jê occupation of Misiones and the southern Brazilian highlands. Residue analyses on Taquara/Itararé ceramics deposited in the enclosing banks of the monument implicate the consumption of maize at the site, possibly in commensal activity linked to an ancestor cult. These data suggest that southern proto-Jê groups were building closer ties to their social and physical environments through the elaboration of this monumental complex (Iriarte et al. 2008; 2010a). Subsequent surveys to the east of PM01 in the plateau (Iriarte et al. 2010b) expanded the inventory of known sites significantly over a spatially-extensive area. This data was employed to produce a predictive model of site location for the upper Piray Mini and Piray Guazú catchments (Riris 2010b) and to validate the viability of survey for defining large, heterogeneous areas of deposition and land use.

In 2013, a joint team from the *Instituto Nacional de Antropología y Pensamiento Latinoamericano* (INAPL) of Buenos Aires and the University of Chapecó, Santa Catarina launched the first cross-national archaeological research between Brazil and Argentina in Misiones (see Loponte 2012; Carbonera 2013). Excavations in the Gruta 3 de Mayo were re-opened to investigate the section of the rock shelter floor that Rizzo (1968) did not open in her original excavations (Figure 1.4). An additional rock shelter was identified in the same department as Gruta 3 de Mayo, the *Cueva del Yaguareté*, with evidence of pre-Columbian occupation in the form of lithic and ceramic scatters. Finally, a

Figure 1.4: Excavations underway in the Gruta 3 de Mayo, Garuhape, May 2013.

Tupiguarani site with anthropogenic dark earths (ADE) on the margin of the Paraná was discovered near the former site of the Corpus Christi Jesuit reducción (Loponte and Acosta 2013; Loponte and Carbonera 2014). Excavations are in progress.

To summarize the short and thus far limited history of research in the province, two aspects are especially relevant to this thesis. First, the reliance on surface collected artefacts to furnish primary data in published works (e.g. Menghin 1957; Schimmel 1967; Madrazo and Laguzzi Rueda 1967; Mujica 2007; Riris 2010b). Due to these studies being preliminary and largely methodologically informal, very little can be said for certain about the lives and systems of the societies that deposited the reported archaeological material. The complexities of the surface record in particular, namely its formation through human and biotic interference (Schiffer 1972), are not dealt with systematically if at all. Nonetheless, the range and distribution of material reported in these works highlight the viability of survey for procuring archaeological data on a broader spatial scale than possible through excavation. A poor understanding of the pre-Columbian past of Misiones is therefore due to the approaches that have been adopted rather than the poverty of the record. The second point, related to this, is the lack of a view over the larger spatial scale of pre-Columbian culture in this setting.

In developing a more comprehensive view of pre-Columbian cultural landscapes through this study, the rich record of surface material requires both appropriate context and suitable analytical techniques. Rather than constrain the analysis and interpretation of material, the potential of non-site survey will be used to develop an altogether novel type of perspective on past land use in the larger study region. The archaeological landscape of Misiones is a puzzle that has yet to be deciphered, and this research stands to inform future agendas.

1.3 Research questions

The overarching purpose of this research is to generate new insights into the long-term dynamics of pre-Columbian culture in Misiones province, in order to contribute to our understanding of settlement practices and cultural landscapes in subtropical settings.

Through analysis of surface gathered data, this will proceed as a landscape-level, artefact-centric approach to the surface record. The impact of this, in a more general sense, will be to develop intensive, systematic survey as a principal tool for characterizing the depositional and land use practices of past groups at multiple scales, as well as explore what can these approaches can contribute towards our understanding of pre-Columbian use of space. These tenets inform the formulation of the specific project aims and guide the development of a method for providing an answer.

The *first aim* is to provide new perspectives on the regional prehistory of Misiones by engaging with the patterning of archaeological material at a landscape level. This will seek to build up a landscape-level understanding from the most durable components Misiones province: lithics. The study of flaked stone artefacts under the general heading of "technological organization" (TO) provides a point of departure for getting the most out of this fragmentary record (Andrefsky 2009; Carr and Bradbury 2011). In order to achieve this aim, an interface between the TO approach and the spatial analysis will be created to concentrate on a set of specific questions:

- How may surface data be used to characterize long-term depositional behaviour, land use and the social use of space in the study area?

- How was flaked stone tool technology organized, and how can rigorous spatial analyses be used to enhance the perception of different organizational systems?

- What is the relationship between pre-Columbian settlement and the present distribution of archaeological material on the surface, and to what extent is the latter representative of the former?

It is necessary to bridge the patterning of material 'on the ground' with ancient trajectories of land-use, social dynamics of settlement and how distinctive cultural landscape were produced. To date, little empirical research in the eastern La Plata basin has sought to connect surface remains with practices that have systemic significance. The *second aim* is therefore concerned with evaluating the effect of the adopted approach on our understanding of the past. As non-site surveys are rare in tropical settings (Zeidler 1995) and rigorous spatial analysis is underdeveloped in South American archaeology (Walker 2012), this has important implications for the impact of these methods on the future development of the discipline.

- How does departing from site-centric models of settlement in analytical frameworks change our perception of pre-Columbian cultural landscapes?

- What are the implications of this analysis for understanding the archaeological palimpsest of the study area?

- In areas with significant lacunae in knowledge or conflicting interpretations, can computational modelling provide a means of testing hypotheses in lieu of additional empirical data?

In order to explore the regional archaeology of Misiones province, this research project will draw upon a pre-existing body of research primarily located in Brazil. While this corpus uses a different vocabulary and theoretical tradition to describe the material record than that of Argentina, the archaeological constructs in use in both contexts “map on” to one another well enough for a synthetic discussion. So far, the main weakness of surface collected data in the eastern La Plata basin is the near-absence of any attempt to incorporate it in a spatially explicit framework (see Araujo 2001). Engaging with the surface record beyond the correlative terms used in the extant literature will be fulfilled by developing a multiscalar spatial perspective that makes use of the individual artefact as the unit of discovery, analysis and interpretation. A more comprehensive look at the surface record can reveal statistical trends that single observations cannot, since long-term patterns of land use are unlikely to be fully represented by individual sites. Patterns in the structure of the material record are easiest to access through time-transgressive cultural deposits on a landscape level (Douglass 2010, 79-80). By using intensive survey as the principal data collection strategy, this research will supply answers on the structure and scale of pre-Columbian cultural landscapes in Misiones province. The eastern watershed of the Río de La Plata will be used throughout this research as the principal large-scale geographic frame of reference, and is referred to as the macro-study region (see Figure 1.1).

1.4 Physical environment of the eastern La Plata basin

The La Plata as a whole is the second largest fluvial system in the world by area, only dwarfed by the Amazon. Its purpose is to function as a framing device for a range of different factors that form the backdrop of this research. The eastern La Plata basin is defined as the combined land area drained by the Uruguay, the middle Paraná and the upper Paraná. It encompasses the watersheds of these rivers, and does not include the Paraguay or the lower Paraná and its delta. In terms of phytogeography, Misiones is part of the Atlantic Forest biome of South America, more specifically the Paraná Interior Atlantic Forest (Galindo-Leal and Câmara 2003). Geologically, it is part of the Paraná-Etendeka Igneous Province that today forms the majority of the bedrock of the southern Brazilian highlands. In terms of indigenous culture history, Jê-speaking groups inhabited the forest-covered floodplains and plateaux of the province in the past, while Tupiguarani groups came to dominate the major river valleys by the time of contact (see Figure 2.3). Although the former group was more widespread in an absolute sense, southern proto-Jê groups likely dominated the planalto proper. Both linguistic stocks ultimately stem from Amazonia and hence are found throughout the La Plata system (Prous 1992; Noelli 1998; 2005).

National boundaries are problematic starting points for building a holistic perspective; the coverage of research is patchy and has rarely bridged the border between Argentina and Brazil (Loponte and Carbonera 2013). Published studies from the three southern states of Brazil (from north to south: Paraná, Santa Catarina, and Rio Grande do Sul) and São Paulo form the comparative basis for the archaeology of the macro-region with Misiones. The shared characteristics of many elements of the material record in these states make them useful points of departure for discussing that of Misiones province. Although the archaeology and culture history of adjoining regions, such as Central Brazil and the Atlantic coastal strip are related, significant differences exist compared to the highland record that renders them a less fruitful basis for comparisons (Wüst 1983; Prous 1992;

Robrahn-González 1996; Gaspar 1998; Lima and López-Mazz 1999; DeBlasis et al. 2007; Araujo 2007; Gaspar et al. 2008), however, reference will be made where appropriate. Although defining the eastern La Plata like this is idiosyncratic, it serves the purposes of this research as a shorthand term to be able to discuss a range of topics that do not conform to the borders of modern nations. Emphasizing Misiones province, the following section outlines the physical environment of the larger study region.

1.4.1 *Geology and geomorphology*

Flood basalts of the Paraná Large Igneous Province (LIP) dominate the geology, topography and hydrology of the eastern La Plata basin. This vast geological formation is the result of magmatic activity during the Late Jurassic-Early Cretaceous (137 – 127 million years ago) intruding through older formations (Mena et al. 2006, 1283). In the present day, the LIP forms an interior plateau in eastern South America. Older Pre-Cambrian metamorphic rocks enclose the LIP to the north and south (Stewart et al. 1996, 107; Peate 1997, 218-220; Iriondo and Paira 2007, 2). The eastern edge of the upland zone is represented by the Serra Geral ranges running parallel to the Atlantic coastal strip in Brazil, while the western edges are over 600 kilometres away in Paraguay. It runs north-south from approximately 17°S to 35°S, across central and southern Brazil and towards northern Uruguay (Figure 1.5). The mountain ranges formed in part by the LIP rise sharply from the coastal zone and reach their highest point in Paraná state, Brazil at nearly 1900 meters above sea level. The plateau gradually slopes downwards until it meets the Río Paraná and the northern edges of the Pampa in the west.

While the elevation gradient of the LIP from east to west is slight on a continental scale, relief can be sharp on a local scale, including Misiones. The portion within Misiones, the *Sierra Central,* peaks at roughly 850 meters above sea level, close to the border with Brazil (Iriondo and Paira 2007, 13). The basalts local to Misiones are generally red to brown in hue, possessing a fine grain with occasional quartz inclusions (Morrás et al. 2009, 144). Steep relief, consisting of deeply incised river valleys with narrow bottoms, characterizes the Sierra. In contrast, hills and ridges located in the lower valleys have a relatively gently undulating relief with only occasional peaks and outcrops of the

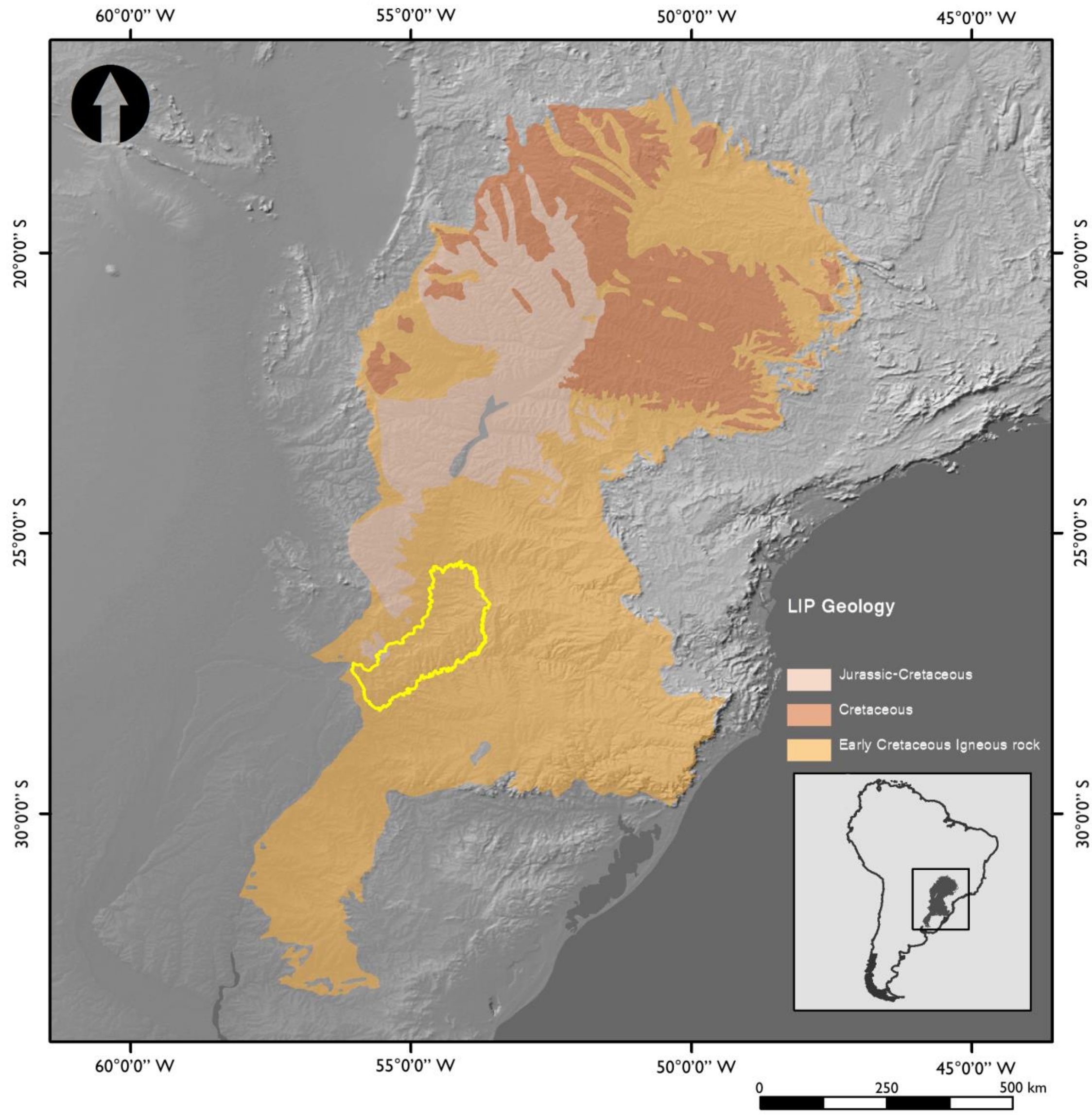


Figure 1.5: The location of Misiones in the Paraná Large Igneous Province. This formation is bordered by Quaternary deposits to the west and older (Permian and Triassic) formations to the south, east and north. Source: USGS.

underlying basaltic rocks. Weathered and acidic ultisols of Pleistocene date cap the geology, and is locally termed the Oberá formation (Figure 1.6). These are composed of silts or clayey silts and vary in depth between three and eight metres (Morrás et al. 2006, 316; Zech et al. 2009, 123). The origins of the formation are a contested area of research. One model suggests that aeolian processes introduced "tropical loess" from equatorial latitudes in central Brazil. The alternative model is that decomposed basalts were weathered *in situ* to form the bright red soils that characterize the province today (Iriondo and Kröhling 2004; Morrás et al. 2009).

Figure 1.6: Although usually thick, the red-brown Misiones soils can be thin in places, as seen here in a plantation.

A significant proportion of the precipitation that falls in the southern Brazilian highlands is gathered by the Paraná and Uruguay and moved via Misiones (Iriondo and Paira 2007, 12; García and Pedraza 2008, 304). The Sierra Central running down the middle of the province separates the catchments of the Paraná and Uruguay Rivers, whose sources lie in central and southern Brazil, respectively. As a result of the perennial wet climate, smaller rivers crisscross Misiones, forming a dense hydrological network. Their channels are meandering but give way to short rapids and waterfalls in places, especially in the catchment of the Uruguay (Chebez and Hilgert 2003, 161; Rau 2005, 25-26). Rivers empty into the Paraná if their flows generally move westwards or into the Uruguay if their flows are generally southward. The Arroyos Piray Mini and Piray Guazú in the study area of this project are two of the longest tributaries to the Paraná in the province, since their headwaters are very close to the highest point of the Sierra Central.

1.4.2 Climatic regime

Climate in the eastern La Plata basin is heavily influenced by the South Atlantic Convergence Zone. In this area, warm, humid air from the South Atlantic meets with cold, dry Antarctic air (Iriondo and Garcia 1993, 210; Iriondo and Paira 2007, 9). Due to this feature, a high annual level of precipitation is experienced relative to the semi-arid climate of Chaco and central highlands, as well as the temperate Pampa. Annual precipitation varies between 1300 mm and up to as much as 3500 mm, with the mean at around 1700 mm (Rau 2005, 20; García and Pedraza 2008, 308; Ríos et al. 2008, 745; Gessert et al. 2011, 3). Although the southern winter is the least wet time of the year by a small margin, high levels of precipitation are perennial (see Behling 2002, 20; Behling et al. 2005, 237; Iriarte and Behling 2007, 114). The subtropical climatic regime of Misiones therefore does not display any dry season, supporting the lush subtropical semi-deciduous vegetation. This makes the province one of the wettest within Argentina, exceeded only by certain parts of the Andean Cordillera (Zech et al. 2009, 123). Mean annual temperatures vary with altitude in Misiones, being colder on average in the higher parts of the Sierra Central (19°C) and warmer in low parts (22°C). The maximum mean monthly temperature of 26°C is not often exceeded. Frosts are a rare occurrence during winter (Rau 2005, 21; Ríos 2006, 23). Freezing temperatures are, however, experienced far more frequently in Brazil as the elevation of the Serra Geral increases (Behling 1998, 144; Behling 2002, 20-21). Temperature increases in the southern Brazilian plateau along an east-to-west gradient. Precipitation, on the other hand, has a north-to-south gradient (Iriondo and Paira 2007, 10). Fossil pollen data suggests that during the Pleistocene and early-to-mid Holocene epochs (before circa 5000 BP), eastern South America experienced longer annual dry periods than today. The constant high humidity today is a recent phenomenon, dating to the onset of the later Holocene (Behling 1997, 120; Behling and Pillar 2007, 247-249; Iriarte and Behling 2007, 117).

1.4.3 The Atlantic Forests, past and present

The term Atlantic Forest denotes a variety of biomes located on or adjacent to the Atlantic coast of South America, from Rio Grande do Sul to Rio Grande do Norte states in Brazil

Figure 1.7: Lowland semi-deciduous Atlantic Forest, Garuhapé municipality.

and as far inland as Misiones province and eastern Paraguay (Galindo-Leal and Câmara 2003). Rather than an exhaustive discussion of the full range of Atlantic Forest communities located in the larger region, this section provides a palaeoenvironmental context for the three biomes that are of greatest relevance to the archaeology of the region: Campos-type grasslands (in Misiones, only extant in the extreme south), moist highland forest and Paraná Interior Atlantic forest (see Giraudo et al. 2003, 165). The geographical scope is therefore more focused than the above sections. The term Atlantic Forest will be used as a shorthand to collectively indicate the admixture of highland forest and semi-deciduous forest in the province (Figure 1.7), and distinctions will be made as appropriate. The province hosts the largest contiguous remnant of the Atlantic Forests, due to intensive exploitation and clearances in Brazil and Paraguay during the twentieth century (Giraudo et al. 2003, 160) and concerted efforts at conservation within Misiones itself.

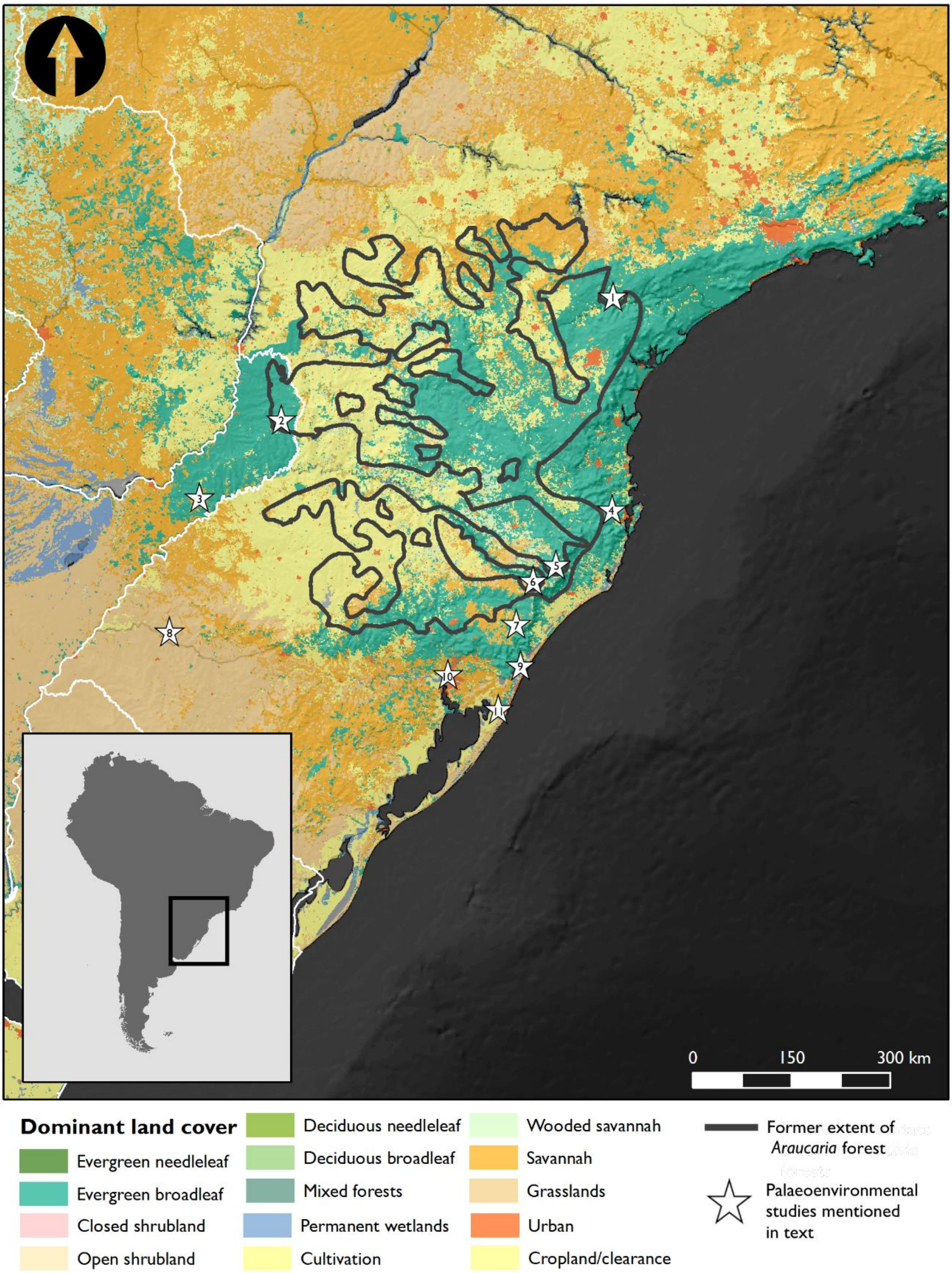


Figure 1.8: Map of dominant land cover in Misiones province and bordering regions (After: Broxton et al. 2014). Black outline represents inferred former extent of Araucaria forest in the plateau (After: Gessert et al. 2011). Note westernmost extent of formation in the eastern Sierra Central. Cropland in the present would formerly have been a mosaic of Atlantic Forest and *Campos* grasslands. Sediment cores discussed in text indicated: 1. Serra Campos Gerais (Behling 1997), 2. Parque Provincial Cruce Caballero (Gessert et al. 2011), 3. Oberá (Zech et al. 2009), 4. Serra da Boa Vista (Ledru et al. 1998), 5. Morro da Igreja and 6. Serra do Rio Rastro (Behling 1995), 7. Cambará do Sul (Behling and Pillar 2007), 8. São Francisco de Assis (Behling et al. 2005), 9. Terra de Areia (Ledru et al. 1998), 10. Morro de Santana (Behling et al. 2007), 11. Lagoa dos Patos (Ledru et al. 1998).

Important families in the forests of Misiones include bamboos (e.g. tacuara, *Guadua angustifolia, Merosthachys claussenii,* and *Chusquea* sp.), hollies, including non-cultivated yerba mate (*Ilex paraguariensis*), various kinds of ferns (*Alsophila* sp., *Blechnum* sp., *Dicksonia* sp., *Osmunda* sp.) and sedges (*Cyperaceae* and *Marantaceae*), to name a few examples (see Rau 2005, 29; Gessert et al. 2011, 31). The upper canopy is dominated by tall deciduous trees and, where extant under favourable upland conditions, the coniferous *Araucaria angustifolia*. On the other hand, the lower canopy is more closed and provides shade to the forest floor. Shade-tolerant species constitute the ground layers of vegetation, which can be thick but is relatively sparse in comparison to the low-to-mid levels of forest cover (Rau 2005; Ríos et al. 2008).

Through the study of multiple pollen sequences collected across the southern states of Brazil (see Figure 1.8), it has been possible to trace the evolution of the Atlantic Forests over a large part of the plateau, although these studies cluster in its eastern sector. In some exceptional cases the environmental history can be viewed back to before the Last Glacial Maximum (see Iriarte and Behling 2007 for a representative list of publications). To date, only a few other regions of South America have enjoyed a similar amount of concentrated palynological study (Iriarte and Behling 2007, 117). This allows a synthesis of the late Quaternary palaeoenvironment to be presented, once again with an emphasis on the Holocene. Due to the lack of reliable evidence for the presence of humans pre-dating the Terminal Pleistocene in this part of South America (Prous and Fogaça 1999; Scheinsohn 2003, 344; Politis et al. 2004; Araujo and Pugliese 2009, 170), this time is less relevant for present purposes. A similarly extensive, high-resolution record is lacking in Misiones, although records from sediment cores are beginning to emerge (Gessert et al. 2011).

During the glacial period, through the LGM, the southern highlands were characterized by a cold and semi-arid climate (Ab'Saber 2000 [1977]; Behling et al. 2004, 294; Ruiz Pessenda et al. 2009, 446), with no archaeological evidence of human presence until the very end of the Pleistocene (Scheinsohn 2003, 344; Araujo and Pugliese 2009, 170). The transition from this epoch to the early Holocene marks the peopling of the eastern La Plata basin (Politis et al. 2004, 210), with the appearance of the first palaeoindian tool industries between 13000 and 11000 cal BP in this part of South America (Rodriguez 2005; Araujo et al. 2012). Up to the Pleistocene-Holocene transition, communities of Atlantic Forest in southern Brazil were likely restricted to refugia in deep river valleys and wetter coastal mountain regions (Behling 1997, 112; Ab'Saber 2000 [1977], 72; Behling et al. 2002, 241; Behling and Pillar 2007, 245; Leonhardt and Lorscheitter 2010, 462). The Campos grasslands of the high plateau remained the dominant floral community, as in the glacial period, as *Araucaria* possesses a preference for cool environments with high humidity and were not able to penetrate this zone (Behling 1998, 150; Behling et al. 2004; de Oliveira et al. 2005). In Misiones, multi-proxy geochemistry of soil organic matter has supported the reconstruction of the Late Quaternary palaeoenvironment across the LGM-Holocene cline, indicating that a phase of forest expansion took place during the Late Glacial period, while the Holocene conversely saw an expansion of grasses contributing to the soil, possibly with human intervention (Zech et al. 2009).

A key finding of Holocene palaeoenvironmental studies is that the perennially humid climatic regime that is felt today only commenced after circa 3500 BP. While the post-glacial period as a whole was more humid than the last glacial age, a mid-Holocene high saw a peak in temperatures and corresponding reduction in precipitation which is likely to have limited the spread of Atlantic Forest. As the forests depend on stable humidity and temperature, the end of these comparatively dry conditions as the Holocene progressed had a major impact on the viability of the highlands for colonization by these ecosystems (Behling 2002, 26; Behling et al. 2004; Leonhardt and Lorscheitter 2010, 462). Hence, there are two marked increases in *Araucaria* pollen in several palynological sequences which occur as the warmer and wetter Holocene took hold. The first is likely due to the initial expansion of pioneering gallery forests along major watercourses, and the second of possible anthropogenic origin around 1000 BP (Iriarte and Behling 2007; Gessert et al. 2011). This second expansion of Atlantic Forest is evident in the severe reduction of Campos-related pollen (*Poaceae*) in relation to that of *Araucaria* and other arboreal species during the later Holocene. This implies the transition of the vegetation to historically known patterns: subtropical mixed forest as far as 24°S in the interior and moist *Araucaria* forests forming a mosaic with grasslands in the highlands. *Araucaria* is noteworthy for producing large yields of starchy and edible seed clusters annually, for which there is direct evidence for exploitation by pre-Columbian groups (Bitencourt and Krauspenhar 2006; Iriarte and Behling 2007).

The particulate charcoal record indicates that fires were rare until the end of the Pleistocene. Despite the increased precipitation throughout the Holocene, charcoal content in cores continues to increase in frequency after 7400 BP (Behling et al. 2005, 247). A link between this trend and human activity has been Rio Grande do Sul. This is reinforced by the sudden drop seen in certain sequences after circa 500 cal year BP, which may correspond to the beginning of European contact and the subsequent impact of colonization on indigenous cultures (Bitencourt and Krauspenhar 2006; Behling and Pillar 2007, 250; Bissa et al. 2009). The implications of the charcoal record would indicate that anthropogenic fires had a measurable impact on the pre-Columbian ecology of the eastern La Plata basin, at least at a local scale (Jeske-Pieruschka et al. 2010; Gessert et al. 2011, 35).

This synthesis is made possible due to the many studies undertaken over a sizeable geographical region. Only a single sequence exists for Misiones, taken from the Cruce Caballero provincial park in the plateau of the north-eastern sector of the province, which is very close to the inferred former extent of *Araucaria* forest across the plateau. The findings of Gessert et al. (2011) therefore stand out, as they have produced an insight into the vegetation and fire history in the Sierra Central that covers the past two millennia. Their findings indicate that mixed *Araucaria* forest was never the predominant community in the immediate environs of Cruce Caballero, despite the upland setting, and that this zone likely formed the westernmost extent of this formation (Gessert et al. 2011). The deposition of regional and local charcoal particulates peak between 896 – 1148 CE (Erl-12104), suggesting that more intensive pre-Columbian activity was occurring around this time. *Poaceae* (grass) pollen is underrepresented, reflecting the lack of Campos-type grasslands in the catchment of the sampling site (Gessert et al. 2011, 36). Finally, a single grain of *Zea mays* (maize) pollen was encountered in the lower levels of the core (Gessert et al. 2011, 32). As relatively heavy grains of maize pollen rarely travel far from the parent plant (Pearsall 2000, 258), this discovery may show signs of cultivation in the vicinity of Cruce Caballero, possibly by southern proto-Jê groups. Nonetheless, the scale, intensity, and time of arrival of horticultural activity remain open questions (see Miller 1971; Behling et al. 2005; Iriarte et al. 2008, 954). Although a variety of other cultigens, including squashes (*Cucurbita* sp.), manioc (*Manihot* sp.), yams (*Dioscorea* sp.), and beans (*Phaseolus* sp.) have been documented in direct association with southern proto-Jê archaeological material in Urubici, Santa Catarina state (Corteletti 2012), these are to date not attested in the record of Misiones. The dietary importance of maize to related pre-Columbian groups in a locality as far removed as Misiones should not be overstated at this stage.

Although geochemical studies have pursued similar questions on the evolution of climate and geology (Iriondo and Kröhling 2004; Morrás et al. 2009; Zech et al. 2009), the details of fire history and ecological dynamics at a local scale are not represented. The isotopic research of Zech et al. (2009) has indicated that wetter climatic conditions after circa 3000 BP encouraged a proliferation of C3 (non-grass) plants, plausibly signifying the emergence of a more forested environment. Following Gessert et al. (2011), it can be inferred that the transitional nature of Misiones between the plateau and lowlands is reflected in the history of its vegetation; mainly subtropical forests interspersed with mixed *Araucaria* forest and a late Holocene fire regime of plausible (but not proven) anthropogenic origin. Detailed information of conditions in the early-to-mid Holocene is, unfortunately, not available at present, requiring further investigation.

1.5 Scope of research

1.5.1 Study area: the Alto Paraná

Primary data collection for this research was carried out in June-July 2013 as a joint project with INAPL, dubbed the Piray Mini Exploration project (hereafter the PME project), which focused specifically on the river of the same name as well as some neighbouring valleys. The study area comprises the Department of Eldorado, particularly the lower catchments of a group of rivers that drain into the upper course of the Río Paraná (Figure 1.9). This study area is one of the most heavily cultivated and impacted by human activity in the province. The municipality of Eldorado itself is the third most populous settlement, after the provincial capital Posadas and the town of Oberá, and functioned as the base of operations for the PME project. The two principal watercourses in the study area are the Piray Mini the Piray Guazú, which constitute two of the main westward-flowing drainages of the northern Sierra Central. A number of sites were also surveyed in the much smaller catchment of the Arroyo Pareha (see Chapter 4). Provincial highway 17 branches off the national motorway running through Eldorado, and runs from west to east until it meets the border with Brazil. The many dirt tracks running off this main transportation artery permitted access to the cultivated hinterland and forests away from small settlements located closer to the principal road network.

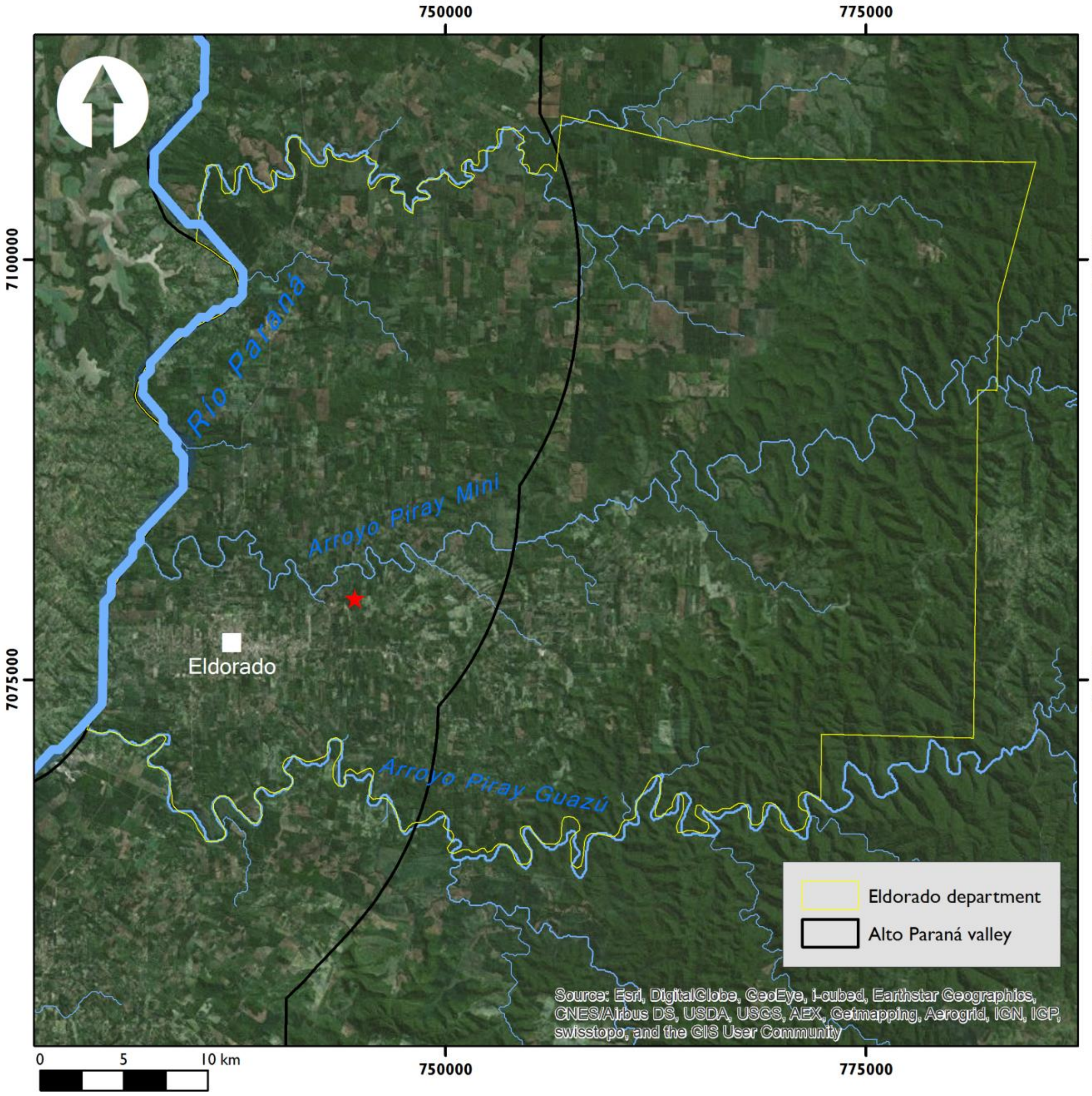


Figure 1.9: Eldorado department, study area of the PME project. Location of PM01 earthworks indicated by red star. See Figure 1.2 for location within Misiones province.

All of the surveyed locations during the PME project fieldwork lie within Eldorado department, and all are under some form of cultivation. Also located near Eldorado is the complex of eight southern proto-Jê funerary earthworks excavated by Menghin (1955/56) and later Iriarte and colleagues (Iriarte et al. 2008; 2010a). Beyond an unsystematic collection of archaeological material in 2006 to supplement the latter investigation (J.C. Gillam, personal communication), the excavations at the PM01 earthwork represented the sum of archaeological knowledge in the study area up to the PME project surveys. Although the *Casa del Fundador de Eldorado y Museo Municipal* holds a large quantity of material gathered by collectors in the department and further afield. The precise provenance and representativity of these collections is impossible to establish to a sufficiently useful degree. A cursory examination of the collections indicated that, of the material recognizable as archaeological artefacts, large stone tools exhibiting bifacial reduction (Altoparanaense/Humaitá) and large cores predominated.

Local informants and landowners that were visited prior to the PME project fieldwork indicated that similar remains were consistently encountered on their properties. Due to the patchy history of research and the circumscribed spatial scale of preceding investigations, it is difficult to say anything for certain about the landscape dimension of the pre-Columbian societies that inhabited Misiones. The extent of collections, however, combined with the high rate of positive responses from informants suggests that the overall distribution of archaeological material in the study area is extensive but ephemeral. Fundamentally, this is an issue of sampling that has been compounded by the difficulty of access and low visibility within areas of Interior Atlantic Forest. By explicitly targeting extensive clearances where this is not the case, the core aim of this thesis is to begin to reveal the structure of pre-Columbian cultural landscapes in Misiones. In summary, this deploys a non-site framework that diverges from the practice of archaeology in the larger study region in several significant ways that will be explored below.

1.5.2 Spatial data and presentation

All of the spatial data presented in this thesis that is focused on Misiones has been projected to UTM zone 21 J (southern hemisphere), with the exception of the computational modelling datasets in chapter seven that are located in southern Brazil. These are projected to UTM zone 22 J. Furthermore, continental-scale maps (e.g. Figure 1.1 and Figure 1.5) are projected to the South American Lambers Equal Area projection for purposes of presentation. The survey carried out in Misiones (chapters three and four) collected spatial information in decimal degrees using a handheld GPS, which was later projected to the relevant coordinate system. The topographic information shown in maps is derived from the Global DEM (version 2) dataset generated from the ASTER sensor on-board the Terra satellite mission. The ASTER GDEM is a product of METI and NASA made available free of charge. Hydrographical data was obtained from the USGS HydroSHEDS portal, and is based on SRTM version 4.0 DEM data. All radiocarbon dates are presented as calibrated age ranges (95.4% confidence) in calendar years, using the Southern Hemisphere SHCal13 calibration curve (Hogg et al. 2013) in OxCal 4.2.

1.5.3 Structure of the thesis

Chapters two and three are focused on setting out the methodological and theoretical means of examining the questions that were outlined in this introduction. Chapter two outlines the research context in detail by carrying out a critical analysis of archaeological discourses in Argentina and Brazil, specifically as they relate to Misiones province. This is essential to understanding the genesis of archaeological research of the study region, as well as the way the practice of archaeology has developed and impacted our perception of the past in the broadest sense. A review of the treatment of surface collected data in southern Brazil is also carried out. Building upon this, the chapter details the theoretical engine that drives this research, meaning non-site, distributional archaeology, and its interface with the notion of the site and spatial analytical approaches. The study of long-term patterns of deposition as it relates to the temporal dimension of the surface material record is also considered. Separately, the issue of scale is considered with respect to the types of societies that are theorized to be under examination as part of this research. The implications of scalar patterning for understanding pre-Columbian cultural landscapes form part of this theoretical discussion.

Chapter three builds upon the perspective established in the preceding chapter and develops the data collection strategy employed in the field and in the laboratory. This includes a non-site survey design where the individual artefact functions as the unit of discovery. The strategy is developed by building upon the results of a separate survey carried out by the University of Exeter in 2010 (Iriarte et al. 2010b; Riris 2010b). The flaked stone artefacts collected in the field by this project were subjected to a metric analysis of their technological attributes, following an approach that draws upon the school of thought under the general heading of "organization of technology". A more fine-grained analysis was undertaken on a sub-sample of the survey assemblage to assess core exploitation strategies and is explained separately from the metric analysis. The management strategy for the spatial datasets produced by the fieldwork is given and the how it is integrated with the artefact database for the purposes of analysis. An outline of the spatial analytical techniques used on the marked point pattern data completes the chapter with a rationale for their application to the research problems.

In order, chapters four, five and six present the results of the fieldwork in the Department of Eldorado, Misiones province, the results of the lithic analysis and the results of the spatial analysis. The survey results are presented as a fieldwork report, with a general description of all the material recorded and its spatial distribution broken down by survey quadrat. The effects of modern land use on the formation of the material record are considered following field observation and comparison with the survey data. The fifth chapter bridges the field results and the sixth chapter, supplying flesh to the bones of the spatial data with a technological analysis of the lithic assemblages. Summaries of artefact attributes on a quadrat-by-quadrat basis are presented and evaluated in light of preceding studies on pre-Columbian technological strategies in the larger study region. The chapter concludes with a summary of the key exploitation strategies of lithic resources that were identified in the laboratory analysis. Using the information from the preceding chapters, the intent of chapter six is to deal with the analysis of spatial point patterns in depth. This proceeds hierarchically. Global patterns in the survey data are assessed before other indicators of spatial association are deployed to assess the behaviour of the survey assemblages in space at multiple scales, between archaeologically meaningful subsets of the data (following Chapter 5), and finally at local scales.

Chapter seven details the construction and implementation of a geospatial mobility model (see Llobera et al. 2011), using a sample of southern proto-Jê monumental mound and enclosure complexes (MECs) from Argentina and Brazil. Computational modelling and simulation-based approaches are used to engender more holistic and spatially-explicit considerations of how pre-Columbian cultural landscapes may have been structured. The adopted method contrasts with previous attempts at spatial analysis in the larger study region by extending the range of the analysed phenomena to multiple scales. Second, the spatial behaviour of a well-studied subset of MECs in southern Brazil is examined through a point process model using both environmental and "social" covariates. The roles that MECs are interpreted as having played in southern proto-Jê society are reviewed with reference to the results of the modelling efforts.

The penultimate chapter evaluates impact of this research project in light of previous approaches to spatial patterning in the archaeology of the eastern La Plata basin. The results are summarized and interpreted following the theoretical guidelines established in advance. The results are then placed in the wider context of landscape-level investigations in lowland South American archaeology and the implications of pushing non-site methods in tropical and sub-tropical settings. The picture that emerges is used to suggest additional methods for studying surface collected data in the future, and re-emphasizing the importance of rigorous and statistically-robust data analysis when dealing with archaeological information. The final chapter will conclude by reflecting on the findings as they relate to the pre-Columbian inhabitants of Misiones specifically and chart a course for future investigations to take. The research questions are re-visited in light of the knowledge gained throughout this endeavour and the key research outcomes are listed in detail.

2.Research context and framework

"Culture is physically embedded and inscribed in the landscape as nonrandom patterning, often a palimpsest of continuous and discontinuous inhabitation by past and present peoples." Balée and Erickson 2006, 2

2.1 Introduction

This chapter introduces and discusses an extensive background to three topics relevant to the pursuit of the research questions and the development of non-site methods in the study area. The first seeks to establish the place of the Misiones province in relation to the research agendas that historically developed in both Argentina and Brazil. This is a historiographical narrative of the dominant paradigms and their impact on the perception of the past in the modern era. An appreciation of these theoretical trajectories is crucial for properly understanding the context to which this research aims to contribute. In this vein, the second part of the chapter provides a detailed outline of the cultural-historical framework for the areas of interest within the eastern La Plata basin (following the introduction in Chapter 1). Although the time depth of the archaeological record of the region is well-known after more than a century of research (Schmitz 1987; Prous and Fogaça 1999), relying on generalist models of "lowland" cultural trajectories (often a synonym for Amazonia and circum-Amazonian regions) downplays the complexities of the sequence. The use of the eastern La Plata basin as a frame of reference will seek to avoid some of these pitfalls. The final part aims to expand upon the theoretical underpinnings of non-site archaeology and surface prospection in order to inform the method for studying long-term spatial patterning of archaeological material in Misiones province.

The concept of the wider eastern La Plata basin will bring the relevance of Misiones to the whole (and vice versa) into focus, as recent research programs have sought to do (see Loponte and Carbonera 2013). Due to the archaeological landscape of the study area being defined largely by unknowns (notable exceptions are Menghin 1955/56; 1957 and Iriarte et al. 2008; 2010a), chapter emphasizes models established from data gathered elsewhere. The aim is not to give a complete overview of the state of research or an exhaustive regional introduction, however, but to invoke the notion that non-site archaeology studies phenomena on a significantly different scale from "traditional" archaeological research. There is therefore no reason to expect that the perspective put forward here will map on to pre-existing constructs. In doing this, an alternative and complementary perspective on the spatial dimensions of the pre-Columbian past may be established. Unless otherwise stated, years are uncalibrated years before present.

2.2 The epistemology of archaeological research in the macro-study area

2.2.1 Early history of research (1877 – 1964)

The earliest research on the human past in both Brazil and Argentina began in the late nineteenth century, and was centred almost wholly on programs run by national museums. In the former country, this was the Museo de La Plata (Buenos Aires) and in the latter the Museu Paulista (São Paulo) and the Museu do Pará (Belém, Para state), now the Museu Paraense Emílio Goeldi (Funari 1999, 20; Podgorny et al. 2005, 63). Drawing inspiration from institutions in North America and Europe, the scholars at these museums promoted an evolutionary doctrine during a period of post-colonial national consolidation, which included the desire for progress in both public and academic life. Evolution used in this sense represented the replacement of indigenous lifeways by people of European descent. In this socio-political context, the role of archaeology as the study of past societies was not seen as an end unto itself in the incipient days of the discipline in Brazil and Argentina (Politis 1995, 195). Rather, the discipline formed a practical means for museums to display knowledge about the savage pre-colonial order in newly-independent nations. The works of Ameghino (1880) epitomized these nascent agendas in Argentinean archaeological research, while the same can be said of von Ihering (1904) in Brazil, who directed the Paulista Museum until 1916. By extension, fieldwork was only prioritized as an activity to expand collections, and several expeditions were mounted to accumulate items of ethnological interest in both countries (Politis 1995, 196; Funari 1995, 234).

The early twentieth was more critical to the formation of the discipline, however, in that it would define agendas for several decades in Argentina, and to a somewhat lesser extent in Brazil. Through the influence of the Italian anthropologist José Imbelloni during the 1920s and 1930s at the University of Buenos Aires, the *kulturhistoriche methode* would become influential in Argentinean archaeology (Imbelloni 1936; Gonzalez 1985, 509). This made him a central figure in the formation of the Vienna School offshoot *Escuela de*

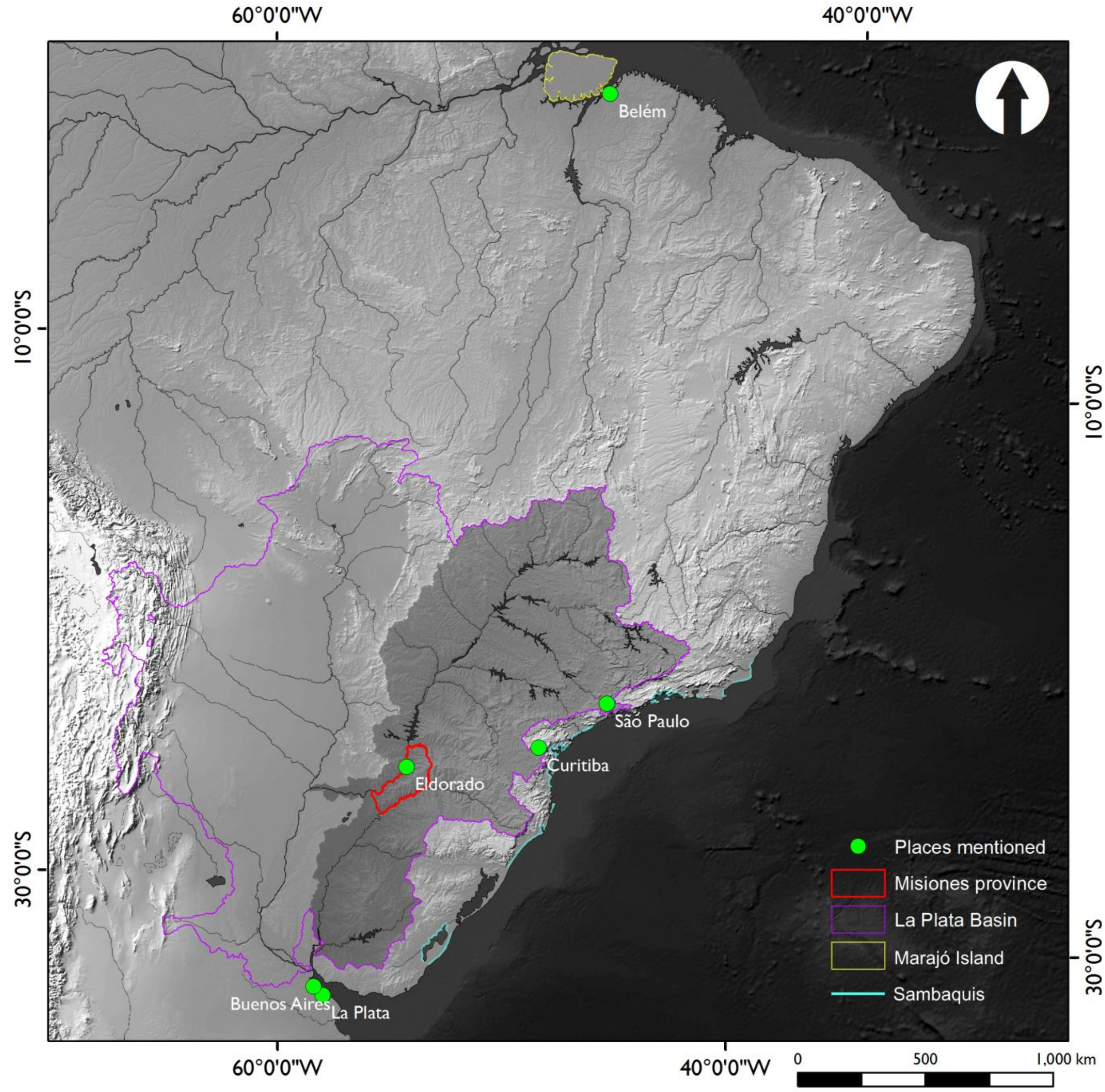


Figure 2.1: Map of cities and locations discussed in the chapter, including the distribution of coastal shell mounds in south- and south-eastern Brazil, which fall outside the macro-study region (shaded area) and are not discussed in section 2.3. After: Gaspar et al. 2008; Wagner et al. 2011.

Buenos Aires, which enjoyed a great following in both Argentina and Uruguay (López Mazz 1999, 41). Cultural diffusion was pushed to the fore as the main determinant of change in the past. Culture-areas were defined by the perceived association of diagnostic traits confined to a particular territory and through a period of time. This mirrored contemporary trends across Latin America (Politis 1995, 199-200). By applying his training as a physical anthropologist, Imbelloni also explicitly correlated the distributions of present-day indigenous groups as the descendants of ancient cultures (Curtoni and Politis 2006, 98). The conflation of modern indigenous groups with archaeological cultures is historically a persistent and influential undercurrent of thinking in the archaeology of the La Plata basin.

In a highly critical overview of archaeology in Brazil prior to the 1960s, Betty Meggers described the research of this period as that of part-time amateurs (Meggers 1985, 366). This neglects to show that first half of the twentieth century was crucial to the formation of the discipline in Brazil, since many of the first works on pre-Columbian art and material culture were published during this period (Funari 1999, 21). Nonetheless, the lack of research programs outside of the pursuits of national museums perpetuated the absence of a dominant research paradigm in Brazil, much in contrast to what Imbelloni had achieved in Argentina (Funari 1995, 234). The vast geography of the country also likely had a limiting effect on the spread of ideas. Latin American archaeologists tended to work exclusively within their own national territories at this time. Conversely, North American or European archaeologists often conducted research in several South American countries at once (Politis 2003; Da Silva 2010, 329). The work of the Argentinean Antonio Serrano (see Serrano 1937; 1940) was a notable exception to this trend. He was responsible for the first systematic excavations of coastal shell middens (*sambaquis*) in Rio Grande do Sul. From this work he was able to define a "non-Guaraní" class of ceramics and in the process introduce cultural-historical archaeology in southern Brazil (Meggers 1985, 364; Noelli 2005, 171). Very similar ceramics would later be discussed by the Austrian archaeologist Oswald Menghin in his work in Misiones as part of the Eldoradense culture, after the nearby settlement of Eldorado (Menghin 1957).

If the decades leading up to World War II saw the emergence of the Escuela de Buenos Aires, the post-war period firmly cemented it in archaeological practice. Leaving Europe due to his political association with National Socialism, Menghin arrived in Argentina in 1948 (Kohl and Pérez Gollán 2002; Podgorny et al. 2005, 63; Trigger 2006, 219). He was instrumental in the early development of Vienna school archaeology, which Imbelloni drew heavily upon and naturally set the scene for Menghin's arrival in Argentina (Kohl and Pérez Gollán 2002). Menghin found sympathy in the Perón government, almost immediately gaining positions at the Universities of Buenos Aires and La Plata, as well as the Museo Etnográfico (Politis 1995, 204-205). His work in Patagonia and that of his students are still influential (Gonzalez 1985, 511). Within a hyperdiffusionist framework, he separated the lithic industries of these areas into categories inspired by European nomenclature, such as "epiprotolithic" and "mio-epiprotolithic" (Kohl and Pérez Gollán 2002). Through alleged correlations of these with the Stone Age of the Old World he traced the "degeneration" of cultural traits as they spread across South America from a presumed Asiatic origin (Orquera 1987).

Menghin saw "cultural simplicity" in the Patagonian and Pampean industries he studied, relative to the more advanced societies of Amazonia and the Andes (Orquera 1987, 345). In light of this, it is interesting to note that he was the first archaeologist to conduct fieldwork and suggest a cultural chronology for Misiones province. He carried out excavations of pre-Columbian earthworks near the city of Eldorado and analyzed surface collections held by locals. From this, he identified three cultures in the province: the "Mesolithic" *Altoparanaense*, the "early Neolithic" *Eldoradense*, and a "recent Neolithic" Guarani culture (Menghin 1955/56; 1957; 1961). He estimated that the Altoparanaense dated as far back as 11000 BP, while the Eldoradense developed from this preceramic culture via "neolithization" during the Christian era (Menghin 1955/56, 179; Menghin 1957, 34). Although he was aware of Serrano's work on "non-Guarani pottery" in Rio Grande do Sul, Eldoradense became the accepted term for the producers of these fine, dark ceramics in the larger study region (see also Becker and Schmitz 1969). Menghin's attempted use of the ethnographic record linked this "pre-Guaraní" material to "Proto-Gê" groups entering the region from Amazonia (Menghin 1957, 34). The arrival of Guarani groups in the region around 1000 BP were thought to displace the Eldoradense culture (Lafón 1971, 144; Rodriguez 2001, 718; Noelli 2005, 171; Araujo 2007, 12).

While these developments took place in Argentina, two important series of events took place in newly-Republican Brazil. The first academic program of archaeology was established under Paulo Duarte at the University of São Paulo in 1952 (Funari 1995, 234; Funari 1999, 21). Using his influence as an aristocrat and the Prehistory Commission as a vehicle, Duarte trained and specialized educated people as archaeologists. He also succeeded in introducing legislation that protected Brazilian cultural heritage, which included pre-Columbian art and artefacts (Funari 2000, 76; Funari 2002, 212; I. Chmyz in: Delle 2003, 225). Through his links with Paul Rivet, director of the Musée de l'Homme, Duarte invited Joseph Emperaire and Annette Laming-Emperaire to southern

Brazil. In the state of Paraná, the three would excavate sambaquis using French techniques and provide the first radiocarbon chronology, occupation floor reconstructions and lithic typologies for sambaquis in the south of Brazil (Schmitz 1987, 54; Barreto 1998, 575; López Mazz 1999, 44). As a result, the Emperaires had a lasting impression on Brazilian archaeology, particularly in the field of lithic and rock art studies, which drew inspiration from the Palaeolithic research of Bordes and Leroi-Gourhan (Laming-Emperaire 1967; López Mazz 1999, 46; Politis 2003, 249).

The second major development was the arrival of the American archaeologists Betty Meggers and Clifford Evans in 1948 in the city of Belém (Pará state), on an expedition to collect data for their doctoral dissertations (see Evans 1950; Meggers 1952). Excavating earthworks at the mouth of the Amazon on Marajó Island, they produced a ceramic chronology and proposed a sequence of settlement for the monumental mounds. Their cultural-ecological outlook worked with the fundamental assumption that a tropical environment by its nature imposed insurmountable obstacles to the development of culture (Meggers 1954). This formed the backbone of subsequent investigations in Ecuador, Venezuela and then-British Guyana in order to create a comprehensive spatio-temporal chronology for Amazonia on the basis of ceramic seriation (Meggers and Evans 1957; Evans and Meggers 1961; Meggers et al. 1965; Heckenberger and Neves 2009; Denevan 2012). The ultimate goal of this research was to prove that advanced cultural traits brought by migrants from the Andes, such as art, social hierarchy and agricultural technologies, were the subject of decay in unsustainable climatic conditions. The Marajó sequence was used to demonstrate that the rainforests curtailed the ability of pre-Columbian people to produce food surpluses and thus sustain large, sedentary populations (Neves 1998, 629; Funari 1999, 26; Roosevelt 2009, 159).

Two key theoretical themes emerged in Brazil from Meggers' and Evans' works: *a)* the importance accorded to the physical environment as a determinant of the development of pre-Columbian society (see Steward 1946a; Steward 1946b) and, *b)* the use of ceramic seriation to derive relative cultural chronologies and site occupation phases (Politis 1995, 207; DeBoer et al. 1996; Barreto 1998, 576). While there was no innovation over Ford's (1962) system, they were among the first to apply a North American culture-ecological perspective to the archaeological record of Amazonia (Popson 2003), albeit one couched in heavily deterministic terms (Roosevelt 1991a; Neves 1995; Noelli 2005; Roosevelt 2009). This eventually led them to manage the Brazilian national program of archaeological research, or PRONAPA. This endeavour had a lasting effect on the practice of archaeological research in Brazil into the present day.

2.2.2 PRONAPA and its legacy (1964 – 1985)

The Programa Nacional de Pesquisas Arqueológicas was an ambitious program of research which ran from 1965 to 1970. This is a brief summary of its inception, outcomes and considerable influence. Naturally, this was anything but a period of stasis for archaeology in Argentina as a whole (see Politis 1995; 2003; Podgorny et al. 2005). With the exception of a handful of investigations (Schimmel 1967; Madrazo and Rueda 1967; Wachnitz 1984; Giesso and Poujade 1985), research in Misiones lay for the most part dormant. Contemporary archaeologists working in the neighbouring provinces of Corrientes, Santa Fe and Entre Rios did not generally turn their attentions upstream to Misiones (see Lafón 1971; Serrano 1972; Caggiano 1984). A notable exception is the partial excavation of the 3 de Mayo cave (Rizzo 1967; 1968), which tentatively located Altoparanaense material in deposits dating to 6000 BP. This contrasted with Menghin's (1955/56, 179) original estimate of circa 11000 years BP, which later PRONAPA radiocarbon dating helped to put to rest decisively (Schmitz 1987).

PRONAPA involved the collaboration of eleven Brazilian universities and two scientific bodies with the Smithsonian Institution. During its period of activity, nine states of Brazil were subjected to extensive prospection in order to document and catalogue their archaeology (Brochado et al. 1969, 3; PRONAPA 1970, 1-2; Da Silva 2010, 332). A year before its official formation in 1965, Betty Meggers and Cliff Evans led workshops and training seminars in Curitiba (Paraná state) on their methodology, which was attended by archaeologists from the 11 participating institutions (Funari 1995, 235; Barreto 1998, 576; I. Chmyz in: Delle 2003, 225). Annette Laming-Emperaire also produced a guide to lithics in 1966, which provided Brazilian archaeologists with a common point of departure for the study of stone artefacts (Hoeltz 2005, 20). A new generation of Brazilian archaeologists was created, possessing the same analytical techniques, terminologies and theoretical outlook on the material record.

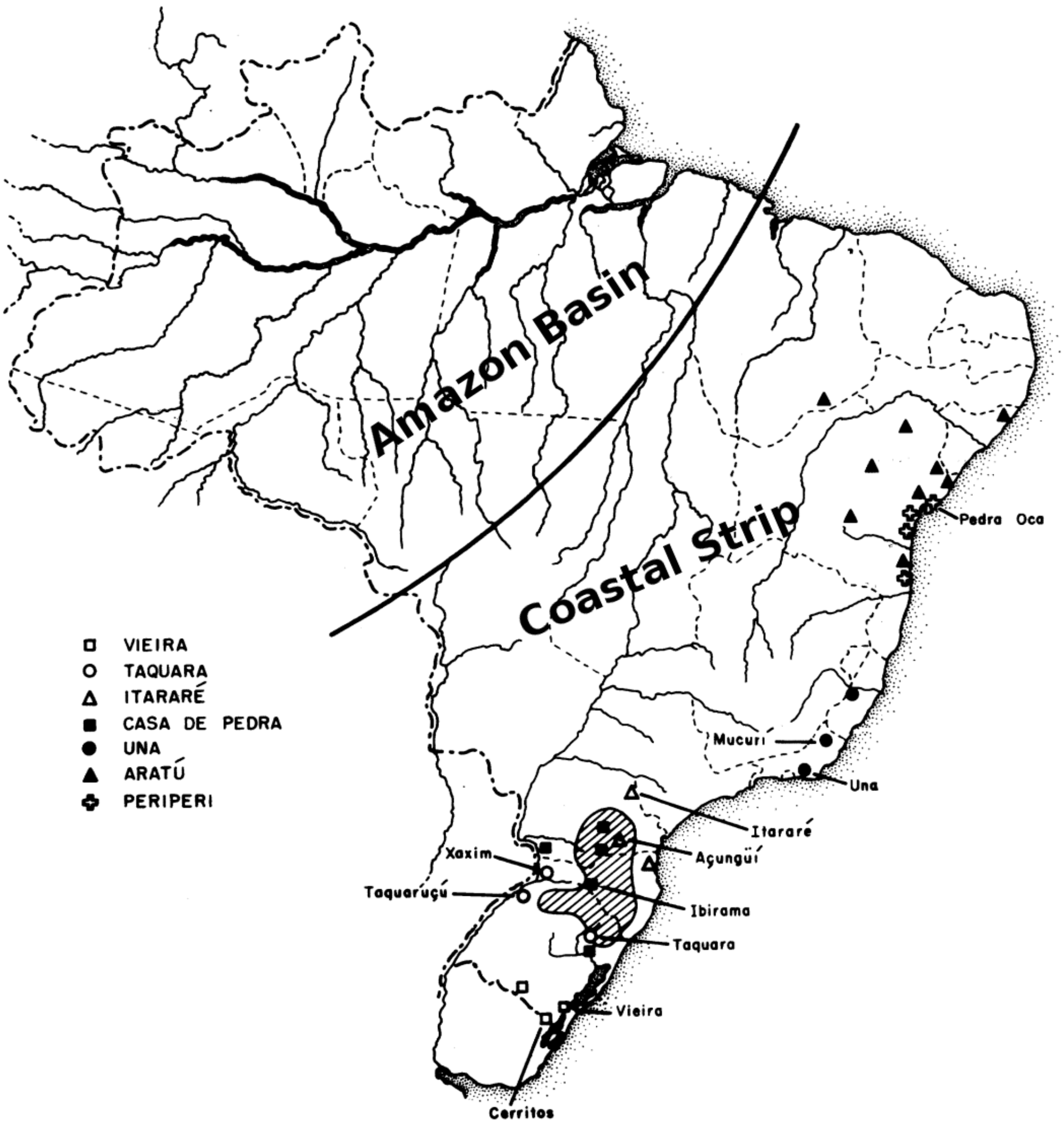


Figure 2.2: Principal environmental zones identified in Brazil by PRONAPA (1970, 5), with distribution of major ceramic "traditions".

The PRONAPA methodology was to classify pottery by attributes, such as temper, colour, surface treatment, decoration, vessel shape or even find location in relation to the environment (see Meggers and Evans 1970 for a full description). This information defined a *phase*, the minimal spatio-temporal unit of PRONAPA. Phases from multiple sites were controlled against one another using stratigraphic depth, supplemented with radiocarbon dating. Those with the greatest similarities were grouped to define a *tradition*. Type morphology was employed for defining stone industries, using the same terminology of phases and traditions (Brochado et al. 1969; Barreto 1998; 577; Noelli 2005, 171). Primary emphasis was always on the seriation of ceramic traits to derive chronology and phase/tradition distributions where possible (Meggers 1985, 367). While conceptually similar to Ford's (1962) method employed by Meggers and Evans in Amazonia, its mode of implementation was less consistent in its choice of diagnostic traits. As a result, many phases were ambiguously defined or had an unclear relationship to broader patterns in the material record (Barreto 1998, 577).

The demands placed on the researchers by the vast area to be surveyed meant that it took place rapidly and with only a little time spent at any given site (Noelli 2005, 168). Nonetheless, a series of regional syntheses resulted from these efforts by the end of the decade (Brochado et al. 1969; PRONAPA 1970; Simões 1972; Meggers 1985, 369). The division of Brazilian archaeology by PRONAPA into the Amazon Basin and the Coastal Strip (see Figure 2.2) descends directly from Steward's (1946a; 1946b) ethnographic division of lowland South America into Tropical Forest and Marginal cultures (Curet 2003, 5). As Meggers' objective was to "deal with [material] culture artificially separated from human beings" (Meggers 1955, 129 quoted in: Noelli 2005, 168), archaeological data was not used to modify Steward's model in any significant way but sought to confirm it through environmental correlation to material culture.

From an early date in southern Brazil, the Itararé, Casa de Pedra (Chmyz 1967) and Taquara (Miller 1967) traditions were recognized as related to Eldoradense pottery in Misiones (Becker and Schmitz 1969). Typical ceramic vessels shared between them included shallow bowls, small wide-mouthed pots and narrow cylindrical jars. Decorations by incision or impression were occasionally present. Fabrics were dark, fine-grained and smooth, with thin vessel walls and thicker bases. Stone tools reported for the Taquara tradition included unifacial and bifacially flaked pieces, worked flakes and large polished pestles, as well as projectile points reportedly in bone (Brochado et al. 1969, 10-14; PRONAPA 1970, 5-9). Pit-houses or "*casas subterrâneas*" defined the domestic architecture, which were observed in clusters or linear arrangements. Some could be substantial in size (>10 m in diameter), but were rarely more than 3 m in diameter and 2 m deep (Chmyz 1968, 44; Mentz Ribeiro 1980). Finally, earthen mounds enclosed by low earthen banks similar to the complex discovered by Menghin in Misiones were encountered in several localities (Miller 1967; La Salvia 1968; Miller 1971; Chmyz and Sauner 1971; Schmitz and Becker 1991, 293; Prous 1992; Araujo 2007, 14). Using the highlands as a point of departure, it was proposed that the economy of the ceramic traditions included gathering *Araucaria* nuts and hunting, possibly supplemented by maize horticulture (Miller 1971). As pit houses were very rarely encountered below 500 meters above sea level, this was developed to suggest adaptation to the cold and wet climate of the plateau (La Salvia 1983). Both Menghin's (1957) neolithization model for hunter-gatherers in Misiones and Meggers and Evans' diffusionist outlook agreed that the highland ceramic traditions emerged due to preceramic hunter-gatherers adopting the technology of the Amazonian Tupiguarani culture expanding into the La Plata basin (see Schmitz 1991; 2006a).

In summary, the two and a half decades before the fall of the military dictatorship in Brazil was a period of explosive growth. The view of the past remained, however, strongly normative and typological in its approaches. Classification and description were the ultimate goals of fieldwork, and changes were introduced into cultures by diffusion. In this respect, PRONAPA did little to challenge perspectives on the past which had begun prior to its inception. Rough correlations with modern flora and fauna were sufficient to draw conclusions about pre-Columbian environmental adaptation in most cases (Roosevelt 1991a; Funari 1995, 237-238). This aspect was roundly criticized in later years for producing datasets with questionable integrity and interpretative value, compounded by an inconsistent methodology for deriving relative chronologies (Barreto 1998, 576; Noelli 1998, 655).

PRONAPA was able to impose a measure of order on the pre-Columbian archaeological record of a remarkably large portion of Brazil, despite the logistical limitations it faced. As a result, the PRONAPA terminology has become recognized in the international literature, while in Argentina the Altoparanaense and Eldoradense are now considered a local subset of the Brazilian scheme (Poujade 1992; 1995; Rodriguez 2001; Nami 2006;

Loponte 2012). Links relied on visual comparison of the evidence, without systematic studies taking place. Attributing large-scale variations in the material record to environmental factors, however, had clear limitations to its ability to explain dynamic processes in the past. Simply describing and synthesizing the results of fieldwork into cross-referenced chronologies did not permit insight into issues such as settlement patterns, site formation processes or land use (Funari 1995, 236-237). Instead, PRONAPA succeeded in providing a post-hoc explanation for the modern distributions of indigenous groups in terms diffused cultural traits (Neves 1998, 625). In practical terms, phases and traditions had no ethnographic value and functioned only as abstractions that was unable to draw links between the archaeological record and actions in the past (Funari 1995, 236; Politis 2003, 247). A gradual change in this state of affairs would begin to take shape in the latter half of the 1980s.

2.2.3 Post-PRONAPA developments and into the present (1985 –)

A change in archaeology as a profession in Brazil occurred during the late 1980s and early 1990s, which led to breaks with past practices. This section provides a general overview of these shifts in theory and method in the context of the past three decades of research. A cultural chronology of the macro-study area is summarized separately in section 2.3. Misiones province itself continued to lack concerted programs of archaeological investigation (Loponte 2012, 55), with the exception of Guarani and Colonial sites (Giesso and Rizzo 1985; Giesso 1998) and environmental impact studies (Giesso and Poujade 1986). In Brazil, however, major works such as Prous' *Arqueologia Brasileira* (1992) synthesized the regional overviews that dominated the preceding two decades (Barreto 1998, 578). A greater number of Brazilian archaeologists working in southern Brazil also began to receive doctorates in countries such as the USA (De Masi 1999; Neves 2000) and France (Kern 1981; Copé 2006a).

From a theoretical point of view, archaeologists in Brazil were able to incorporate the works of American and European scholars to an increasing degree (Funari 1995; Politis 2003). New critiques were able to emerge, including those influenced by post-processual and anthropological thought (Funari 1995, 241). From a landscape perspective, the work of Kern et al. (1989) in Rio Grande do Sul serves as an early example, while De Masi (1999; 2005) makes explicit use of Binfordian models of hunter-gatherer mobility and settlement (see Binford 1980; 1982). A movement beyond the exclusively ceramic-based approaches of PRONAPA is evident in works such as these, along with an interest in new methods. This has included stable isotope analysis for dietary reconstruction of individuals interred within caves (De Masi 2007) and sambaquis (De Masi 1999). Geoarchaeological studies have emerged in both inland and coastal settings (Araujo 2001; Parellada 2008a; Klokler et al. 2010), as well as experimental studies of taphonomic processes tailored to the geological specificities of southern Brazil (Araujo and Marcelino 2003). Integrated approaches to palaeoecology by archaeologists are giving a deeper and more nuanced understanding of Holocene human-environmental interaction (Scheel-Ybert 2001; Iriarte and Behling 2007; Gessert et al. 2011), paralleling trends in Amazonia (see Heckenberger and Neves 2009; Arroyo-Kalin 2010; Mayle and Iriarte 2014). Additionally, international projects are making an impact on the region through cross-border collaboration (Iriarte et al. 2008; 2010a; Loponte 2012; Iriarte et al. 2013; Carbonera 2013). Finally, deeper understandings of landscape-level patterns and chronologies have emerged from recent research programs, especially in Rio Grande do Sul (Schmitz and Rogge 2004; Saldanha 2005; De Masi 2005; Rogge 2006; Schmitz 2010; De Souza and Copé 2010; Corteletti 2012), resulting in a greater degree of methodological and interpretative pluralism.

Indeed, a break with the standard model of pre-Columbian culture history in the eastern La Plata basin is emerging much as in Amazonia (see Viveiros de Castro 1996; Neves 1998; Denevan 2012). Decade-old nomenclature was rehabilitated into composites that are both more manageable and meaningful, such as the Taquara and Itararé ceramic traditions becoming simply the Taquara/Itararé or Itararé-Taquara (Beber 2005; Araujo 2007). This echoed earlier mentions of consolidating the three "non-Tupiguaraní subtraditions" into a single umbrella term (Becker and Schmitz 1969; Miller 1971; Mentz Ribeiro 1980). The validity of other terminology is being questioned separately, such as the case of the preceramic Humaitá industry, with proposals to abandon the term altogether due to the lack of specificity and rigour in their original definitions (Hilbert 1994; Dias 2005; Hoeltz 2007; Dias and Hoeltz 2010). By extension, this would apply the Altoparanaense in Misiones. An anthropological critique of how the ethnographic record has been deployed to interpret archaeological data (e.g. Noelli 1999/2000; Noelli 2005) is resulting in the exploration of more considered ways to strengthen models of the pre-Columbian cultures of the wider study region (Iriarte et al. 2008; 2013; De Souza and Copé 2011; Corteletti 2012). More explicit connections were made between living groups of Jê stock such as the Kaingang or Xokleng and the inhabitants of the region during the pre-Columbian period, particularly in the fields of rock art (Da Silva 2001), social organisation (Da Silva 2002; Iriarte et al. 2008; De Souza and Copé 2010) and material culture studies (Silva 1999; Dias 2007a).

2.2.4 Summary

A range of research paradigms have guided the study of the past in the eastern La Plata basin, mirroring broader theoretical developments that took place in the archaeological discipline as a whole. It is clear that PRONAPA was by far the most influential single program of research. Its members were responsible for defining terminology and chronology across areas and time periods which could never be equalled by lone archaeologists such as Oswald Menghin. Moreover, to a greater degree than the sporadic investigations in Misiones, archaeologists in the southern states of Brazil sustained a continuous tradition of research into the pre-Columbian past. Bearing in mind the changes in focus, scope, and outlook that have accompanied the passage of time, a cultural-historical overview of the eastern La Plata basin can be put to serve as a general framework for the type and provenance of the material that fieldwork might encounter in the Alto Paraná

2.3 Cultural-historical overview of the eastern La Plata basin

As discussed in brief above, regional cultural chronologies within the eastern La Plata basin were traditionally defined with reference to diagnostic traits on stone and ceramic artefacts. The dearth of research in Misiones province means that the pre-Columbian culture history of Misiones province is built on many assumptions and comparatively few data (see Figure 3.1; Poujade 1992; Lafón 1971; Rodriguez 2001; Loponte 2012). In

Brazil, diagnostics were cross-referenced with radiocarbon dates in order to build up the basic PRONAPA *phases*, which on a larger scale were organized into umbrella terms called *traditions* (Brochado et al. 1969; Simões 1972). Later, phases and traditions were thought to correspond with ethnographic constructs such as "tribes" and "indigenous nations" (Meggers 1987; Schmitz and Becker 2006, 69), likely related to the growing appreciation of anthropological and linguistic information by archaeologists (Araujo 2001, 10). Brochado (1984) identified the principal issues with the methods of PRONAPA in his doctoral thesis, stating that purported phases and traditions rarely form complete regional chronologies. This historically limited the ability of archaeologists to precisely

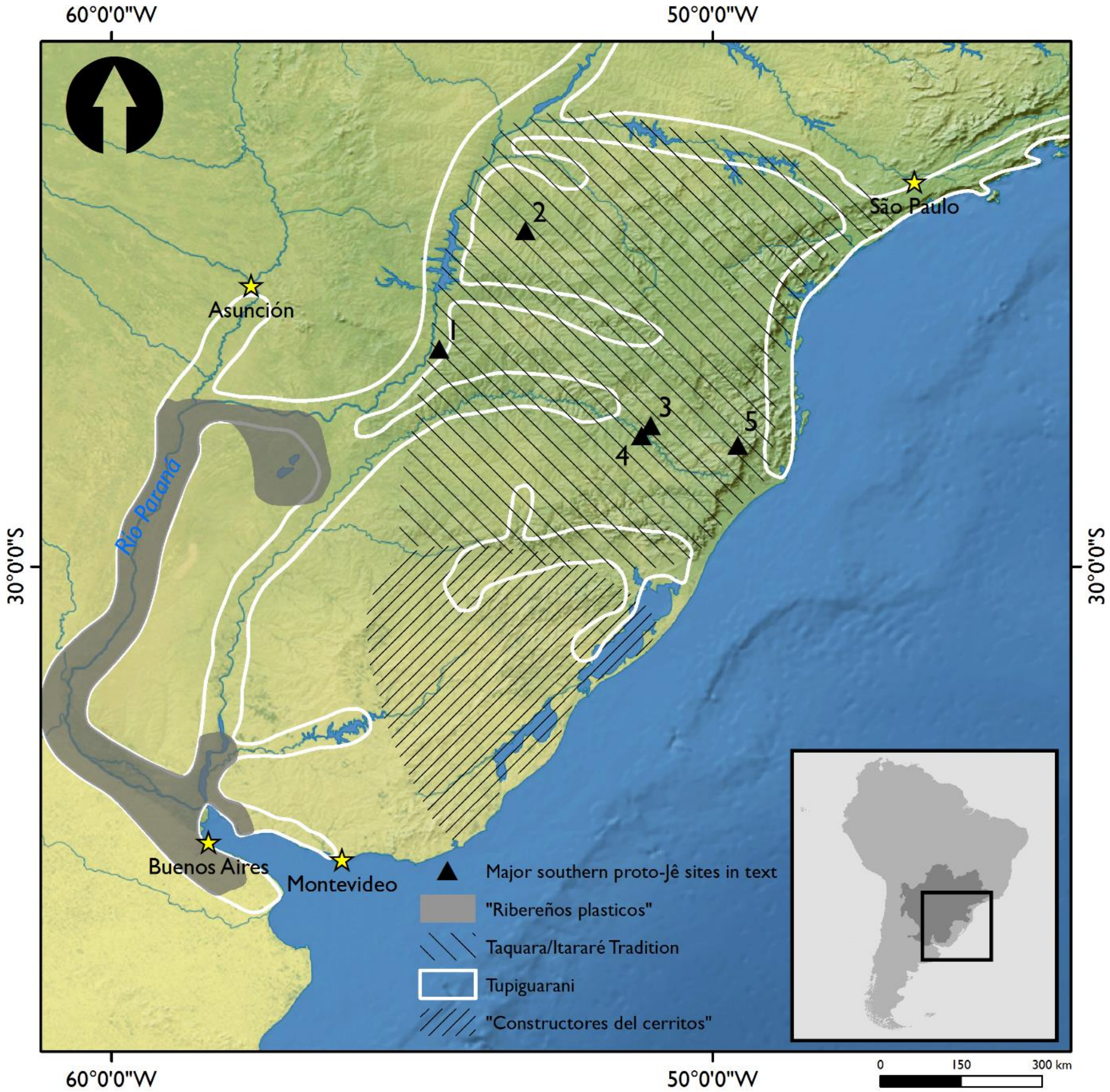


Figure 2.3: Principal late Holocene archaeological cultures in Misiones province and surrounding regions (after: Iriarte et al. 2008). Numbered points are areas with major Jê mound and enclosure complexes discussed in Chapter 6: 1. Eldorado (Iriarte et al. 2008), 2. Piquiri (Chmyz and Sauner 1971), 3. Campos Novos (De Masi 2005), 4. Pinhal da Serra (Iriarte et al. 2013), 5. Urubici (Corteletti et al. 2015).

describe spatio-temporal patterns beyond models describing general trends.

A crucial outcome of these developments in scholarship is that definitive cultural historical accounts, such as cultures evolving in linear stages (Menghin 1957; Prous 1992), appearing through a diffusion process (Brochado 1984; De Souza 2011) or resulting from successive external migrations (Noelli 1999/2000; Araujo 2007) are problematic to establish with absolute certainty. Potential causes of this quandary include the great increase in the amount of archaeological data made available in recent years and the absence of an updated and concise synthesis such as *Arqueologia Brasileria* (Prous 1992). For lack of such a periodization in the relevant areas of the eastern La Plata basin, this section addresses the diachronic cultural history in terms of the most important processes as they appear in the material record: the initial colonization by humans during the end of the last Ice Age, the diversification into regional cultures, transitions in settlement, economy and social organization at the beginning of the Common Era, with intensifications and transformations in the later Holocene. This is not a new chronology for Misiones province or the macro-study region, but rather an attempt to clarify the elements which may compose the surface record and how its complexities may be encountered in the modern era. It is intended to be a reflection of current scholarship, rather than an attempt to untangle the historical development of interpretations and nomenclature in the macro-study region. Its temporal scope is intended to be pre-Columbian; the catastrophic impact of European contact on Amerindian lifeways is not covered. Finally, its geographical focus follows that defined in Chapter 1 (the continental interior and highlands), leaving out the Atlantic coast for the most part unless specifically mentioned, although many of the cultures occupying the interior continent (e.g. the Taquara/Itararé tradition and the Tupiguarani) are also encountered on the Atlantic coast (see Figure 2.3).

2.3.1 Initial peopling

The Palaeoamerican record for the eastern La Plata basin is distributed sparsely over this vast geographical area, with a particular lack of evidence for its initial peopling along the principal course of the Paraná (see Araujo et al. 2005a, Figure 1). Indeed, in Paraguay and the Argentinean north-east a complete lack of sites pre-dating 7000 BP persists

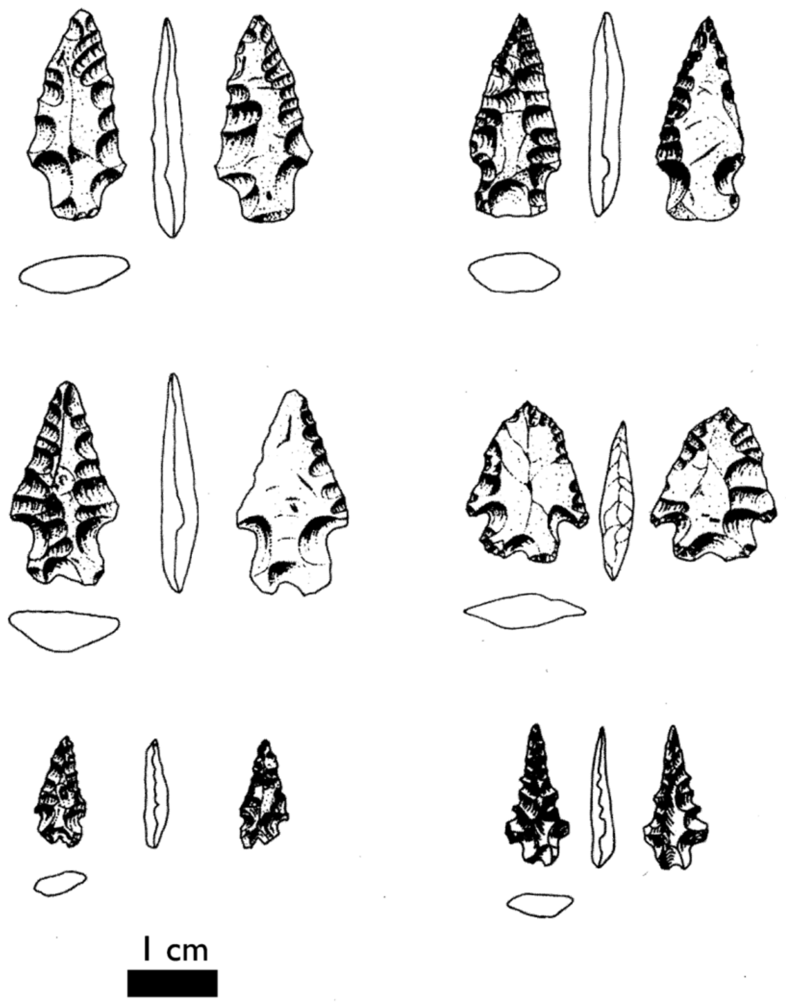


Figure 2.4: Projectile points from Rio Grande do Sul attributed to the Umbu tradition. Adapted from Dias (2007, 49).

despite recent advances in southern Brazil and Argentina in general (Prates et al. 2013). Some of the best-studied sites on the Late Pleistocene/Holocene boundary in central Brazil are, however, located relatively close to the borders of the study region with that of the São Francisco basin in the Lagoa Santa region, Minas Gerais state (Prous and Fogaça 1999; Neves et al. 2004; Araujo et al. 2012). Due to the remarkable number of Palaeoamerican sites and the early and sustained archaeological interest in Lagoa Santa (see Neves and Piló 2008), current evidence suggests that the first people to inhabit the wider study region were certainly present by 11000 BP, but possibly up to two millennia before this time (Feathers et al. 2010; Araujo et al. 2012, 537). Furthermore, occupations of similar ages stem from rockshelter sites within the Paraná watershed located in Goiás, which are dated to 10,500 BP (Schmitz et al. 1989), as well as in the central Amazon (Roosevelt 1996).

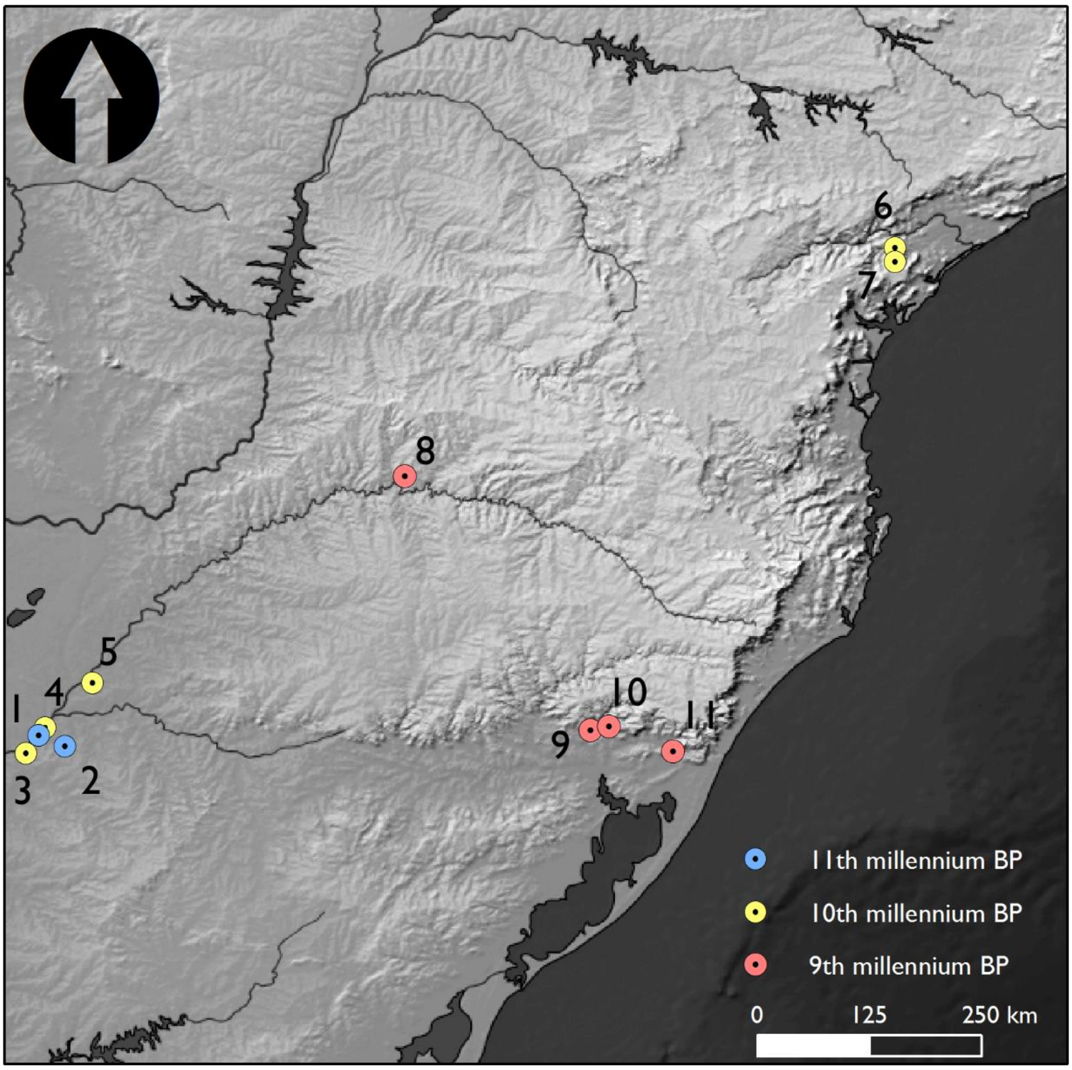


Figure 2.5: Important early Holocene sites in southern Brazil with radiometric dates reliably associated with archaeological evidence (After: Bueno et al. 2013). 1. Laranjito 2. Milton Almeida 3. Touro Passo 1 4. Palmito 2 5. Pessegueiro 6. Batatal 1 7. Capelinha 8. Itapiranga 9. Garivaldino 10. Sangão 11. Adelar Pilger.

Despite significant differences between the lithic industries of central and southern Brazil (Pugliese 2007; Bueno 2010b; Dias 2012; Okamura and Araujo 2011), it seems likely that the earliest people to occupy the eastern La Plata basin and the Atlantic littoral came from the general direction of the Central Brazilian plateau. The pioneering groups in the southern states produced a lithic industry characterized by bifacial reduction, composed chiefly of projectile points (Miller 1967; Dias and Jacobus 2001). Defined in large part by remarkable conservatism in reduction strategy over a period of millennia, common archaeological practice in Brazil became to group all projectile points into the so-called "Umbu Tradition" (Figure 2.4; Okamura and Araujo 2014, 59). Despite this umbrella term as serving to incorporate all bifacially-flaked projectile points in southern Brazil until contact (Kern 1981; Dias 2007b; Lourdeau et al. 2014, 198), the oldest examples dated to between 11000 and 8000 BP certainly represent some of the first reliable evidence of human occupation in the eastern La Plata basin and the adjacent coastal plain (Figure 2.5; Noelli 1999/2000, 231; Araujo et al. 2005a; Araujo and Pugliese 2009, 171). This form of material culture is not recorded in the interior of Paraná or São Paulo until circa 7000 BP (Chmyz 1983; Vialou 1984). This may be an issue of preservation or research bias, given the probability of riverine environments facilitating dispersals and the pre-existing occupation documented in the Central plateau (Prates et al. 2013, 117; Bueno et al. 2013, 87).

During this long phase of colonization, population density could be expected to be low, while group mobility was relatively high (Dias 2007), although coastal resources probably made this area especially attractive for settlement (Araujo et al. 2005a, 303). Indeed, by the mid-Holocene (from at least 6000 BP onwards), the large *sambaqui* shell middens are ubiquitous landscape features along the south eastern coast of Brazil, indicating precocious and intensive exploitation of coastal resources (DeBlasis et al. 2007; Barreto 2014, 8). The Capelinha site (see Figure 2.5) has one of the earliest dates associated with riverine shell midden construction, at 9757 – 8740 BCE (Plens 2007, Beta 189330). Hunting-based subsistence strategies in southern Brazil by Palaeoamericans appear to differ very little from those of Lagoa Santa in the central plateau, and display very similar faunal (Araujo et al. 2012, 547) and vegetal (Jacobus 1991) inventories. The overarching interpretation is that the Umbu toolkit was adapted to broad-scale subsistence in several very different environments (coast, pampa, riparian forest, highland plateau) across southern Brazil (Prous and Fogaça 1999). Specific raw materials were sought out and used preferentially for stone tool production by early groups as well (Dias 2012). In a continental perspective, the early occupation of southern Brazil is clearly related to the patterns seen in more tropical latitudes. They are also distinctive to such an extent, that it is feasible to state that Palaeoamericans in the region were clearly able to identify the distinctive challenges of the environment and rapidly adapted to its affordances as a result (Dias 2004; Bueno et al. 2013, 87). The diversification seen more strongly in the archaeology of subsequent early Holocene hunter-gatherers clearly stems from deep-rooted cultural processes established during the first peopling.

2.3.2 *Diversification*

Unlike the "Archaic gap" seen in parts of central Brazil, a period of landscape abandonment purportedly caused by extreme climatic dryness (Araujo et al. 2005a; Araujo et al. 2005b), the early- to mid-Holocene occupation of southern Brazil continuous uninterrupted from the Late Pleistocene colonization. The lithic toolkits produced by these societies are traditionally separated into two "traditions", representing different industries. Both persist in the material record for a very long period of time with what appears to be an extraordinary degree of conservatism and stability in technological organization and adaptive behaviour (Dias 2012).

The first is the continuation of the Umbu Tradition (Dias and Hoeltz 2010, 45) which, as noted above, became commonly accepted nomenclature for any industry containing bifacial projectile points in southern Brazil regardless of age. Perhaps due to its catch-all nature, elements of this putative tradition were produced as late as the age of European contact (Okamura and Araujo 2014). Burins, bolas, scrapers, and blades were also produced in a variety of materials (Rodriguez 2005, 26). Surface sites with relatively deep deposits (possibly >80 cm) on the margins of the Iguazú and Paraná rivers have yielded Umbu points (Mujica 2007; Loponte 2012). Although no dated Umbu sites exist within Misiones itself, deposits in nearby western Santa Catarina are dated to 7526 – 7186 and 5990 – 5711 BCE (Hoeltz and Brüggeman 2011). The second is termed the Humaitá Tradition, effectively synonymous with the Altoparanaense in Misiones (Menghin 1955/56; Dias and Hoeltz 2010, 55), which is defined on the basis of bifacial reduction without the presence of projectile points (Miller 1969; Schmitz 1987; Prous 1992). Characteristically, these take the shape of large handaxe-like tools and "curved cleavers" (Menghin 1957; Hoeltz 2005; Riris and Romanowska 2014). Tools fashioned from bone, including needles and fish hooks, are also associated with both (Rizzo 1968, 145-147; Schmitz 2006b, 23). Some of the earliest dates available for Humaitá Tradition sites are in the upper Uruguay River valley in Rio Grande do Sul (7953 – 7483 BCE, SI 995) (Schmitz and Brochado 1972) and the Paranapanema valley in São Paulo (5997 – 5828 BCE, GSY 6250) (Vialou 1984). Early sites are also dated to 5968 – 5630 BCE in the interior, on the Brazilian side of the Iguazú drainage (Chmyz 1983, SI 4994).

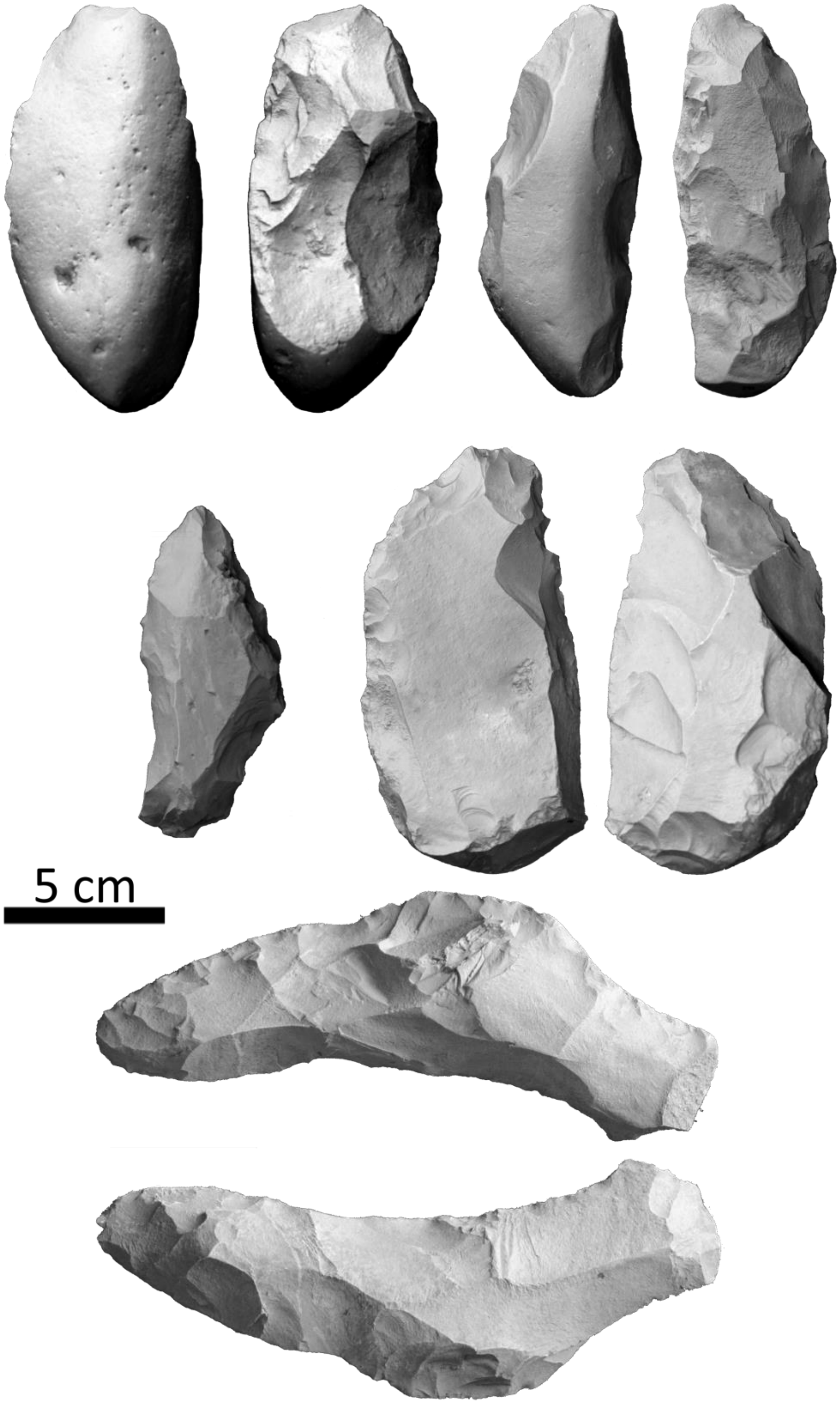


Figure 2.6: Bifacial lithic pre-forms and tools collected in Misiones typologically attributed to the Altoparanaense culture/Humaita tradition. Adapted from Riris and Romanowska (2014) and photos courtesy of D. Loponte (bottom).

These dates notwithstanding, the temporal distribution of Humaitá sites is extremely broad (up to nine millennia), a similar timespan in absolute terms to the Umbu Tradition. The youngest sites in the case of the former are dated to the 17th and 18th centuries (Noelli 1999-2000, Table 3). Indeed, components of both the Humaitá and Umbu industries continued to be produced well into the period after the appearance of cultigens and ceramic technology in the eastern La Plata basin (Barreto 1998, 579). This type of late sites associated with Tupiguarani and Taquara/Itararé material are few in number, with the majority of Humaitá sites falling in the 6000 to 2000 BP interval (Dias and Hoeltz 2010) and the Umbu between 9000-2500 BP (Noelli 1999-2000, Table 1). Traditionally, these different traditions of stone tools are assumed to be adaptations to the different environments that developed with the Holocene climatic amelioration (Kern 1991). Specifically, projectile points reflected the distribution of groups adapted to hunting in open grasslands, while bifacial tools belonged to foraging groups occupying more closed forest environments (Schmitz 1991; Hoeltz 2007, 211). On the whole, the occupation of southern Brazil by "Archaic" groups appears to be substantially more intense than the comparatively ephemeral Palaeoamerican period, as reflected in the numbers of sites encountered (Schmitz 1987). Finally, the majority of sambaquis date to the mid-Holocene (4000 – 2000 BP), which could indicate an increasingly intensive and diversified exploitation of the coastal biome (DeBlasis et al. 2007; Gaspar et al. 2008, 322; Villagran et al. 2010, 196), but could also be an artefact of sea level changes obscuring earlier sites (Barreto 2014, 8).

No residential structures have been associated with either Umbu or Humaitá sites in southern Brazil, limiting the ability to infer settlement patterns of either putative tradition. Low-density surface scatters are interpreted as part of a low intensity and shifting occupation of the landscape (Dias 2003; Hoeltz 2005). High mobility and seasonal patterns of environmental exploitation are inferred to have taken place, due to the large variety of faunal remains encountered in environments that favour their preservation (Schmitz 2010, 99; Dias 2012, 15). Rockshelters and caves were occupied by groups of both traditions, including Altoparanaense/Humaitá layers in the Gruta 3 de Mayo of Misiones province (Rizzo 1968). Burials dating to the preceramic period are also documented in similar contexts in Brazil (Neves and Okamura 2005; Rodgriuez 2005, 28; Parellada 2008a).

Despite uncertainty emerging over the past two decades around the true differences between the Umbu and Humaitá Traditions as definitive cultural groups (see Hilbert 1994; Dias 2003; Hoeltz 2005; 2007; De Masi 2005; Dias and Hoeltz 2010), it is apparent that patterns in the material record reflect the responses of populations to the variety of environments that became available over the course of the mid-Holocene (Kern 1981; Schmitz 1987; Noelli 1999-2000). Taking into account the intensive exploitation of coastal resources occurring over the same period (Gaspar et al. 2008; Wagner et al. 2011) in parallel to the new biomes in the interior, cultural diversification is interpreted as being linked to the degree of environmental differentiation seen in a post-Pleistocene context. Even if the lithic technologies of the "Traditions" cannot be securely attributed to strictly different cultural groups, there is little reason to doubt that the opportunities afforded by new environments would have been explored in various ways. The stable patterns observed during this long period of time have to be considered alongside the transition to more sedentary lifeways observed in the later Holocene.

2.3.3 Transition

The end of the preceramic period is marked by the appearance of Taquara/Itararé Tradition pottery in the material record of the eastern La Plata basin. In very general terms, it is defined by production of tall, thin-walled ceramics with a dark paste, domestic architecture in the form of excavated "pit houses", and, towards the peak of the sequence, elaborate funerary monuments termed "mound and enclosure complexes" (Noelli 1999-2000; 2005; Beber 2005; Araujo 2007; Copé 2006a; Iriarte et al. 2008; 2010a). The current research paradigm links the genesis of this archaeological culture to the entrance of migratory Jê-speaking groups into the eastern La Plata basin and Atlantic littoral around circa 2200 BP, assuming that that the spread of these languages co-varies more or less with the spread of Taquara/Itararé material culture. The diversity of languages in the Macro-Jê linguistic stock (in southern Brazil represented by Kaingang and Xokleng) is highest in central Brazil, indicating the likely location of the ultimate origins of the languages that are today group into the southern Jê (Rodrigues 1999; Ribeiro 2006). Glottochronology suggests that the divergence likely occurred around 3000 yr BP (Urban 1998). The route of expansion taken by pre-Columbian southern Jê groups, or "southern proto-Jê" (Da Silva 2001; Iriarte et al. 2013) was likely through the modern states of São Paulo and Paraná (Araujo 2001; 2007).

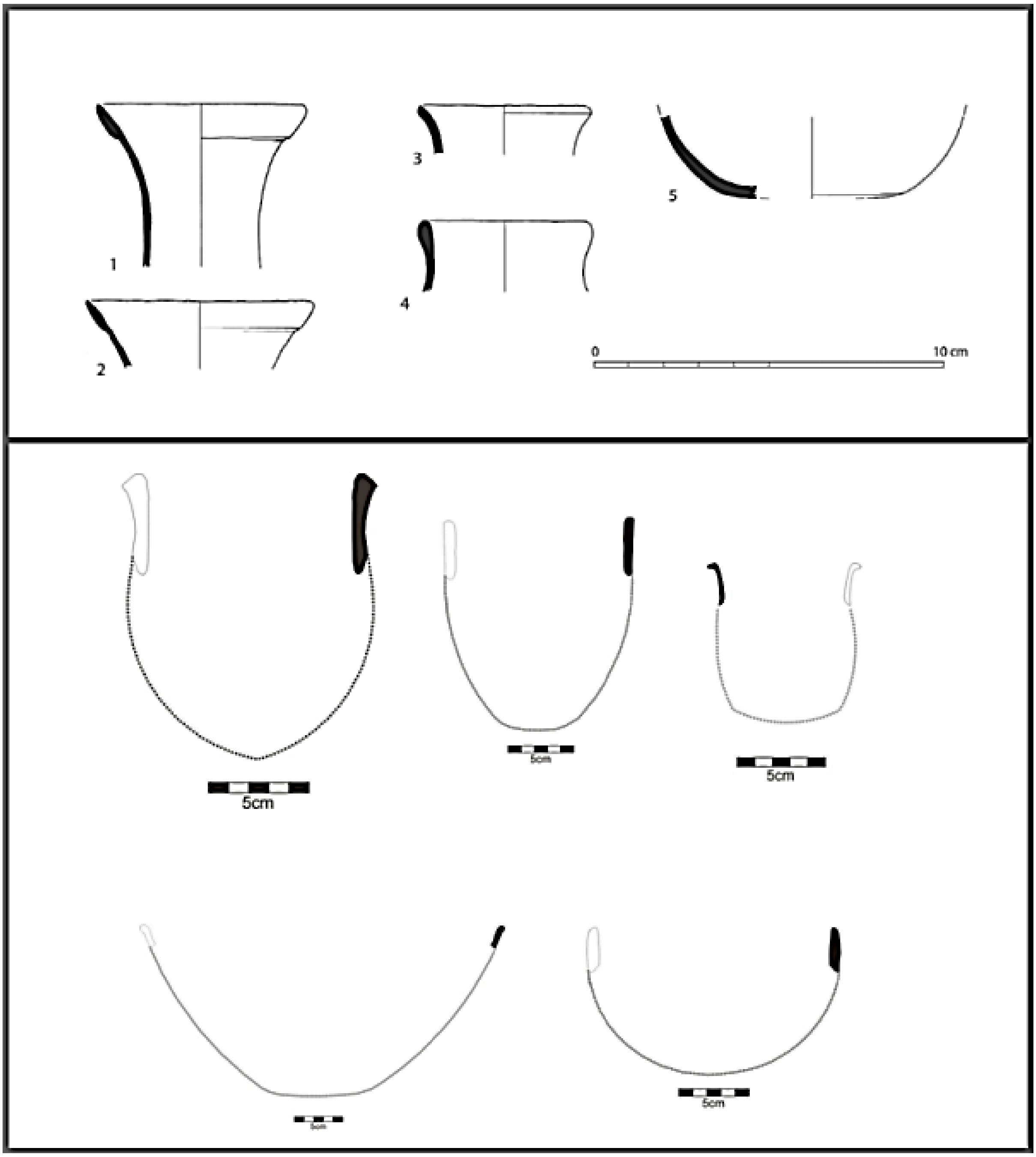


Figure 2.7: Reconstructed profiles of Taquara/Itarare tradition ceramics recorded in Misiones province. Top: adapted from Iriarte et al. (2008, 955). Bottom: drawings by R. Corteletti (Iriarte et al. 2010b).

It should be noted that in Misiones radiometric dates from charcoal assicated with Taquara/Itararé tradition ceramics have returned very early dates (Rizzo et al. 2006), as well as in Santa Catarina state at 2860 BCE (De Masi 2005), respectively. Without further contextualization in their respective settings, however, it is difficult to know how they relate to the majority of the sequence, given the long period of time that separates them from other early dates in the north of the macro-study region. The only other available dates for the southern proto-Jê in Misiones fall between the mid-thirteenth to late fourteenth centuries CE (Iriarte et al. 2008, 952). The majority of early dates cluster around the centuries immediately before and after the beginning of the Common Era (see Noelli 1999-2000, Table 4; Beber 2005; Iriarte and Behling 2007, Table 1; Araujo 2007), with a significant proportion of these located in Rio Grande do Sul (Araujo 2007, 28).

A growing body of evidence indicates that southern proto-Jê groups consumed cultigens, including maize (*Zea mays*), manioc (*Manihot sp.*), squash (*Cucurbita sp.*), yams (*Dioscorea* sp.) and beans (*Phaseolus sp.*) (Miller 1971, 45; Iriarte et al. 2008; De Masi 2009; Gessert et al. 2011; Corteletti et al. 2015) in a mixed economy of hunting, collecting, and horticulture. This interpretation is supported by multiple lines of evidence in the cited works, including fossil pollen, phytolith studies, carbon isotope analysis on skeletal remains and ceramics, and starch grain analysis. In this regard, the most diverse evidence stems from domestic contexts in the southern Brazilian plateau (the Bonin site in Corteletti et al. 2015). Furthermore, carbonized seeds of the Paraná pine (*Araucaria angustifolia*) are frequently encountered in association with pit house hearths (Beber 2005; Schmitz and Becker 2006). The distribution of pit houses is thought to coincide with that of

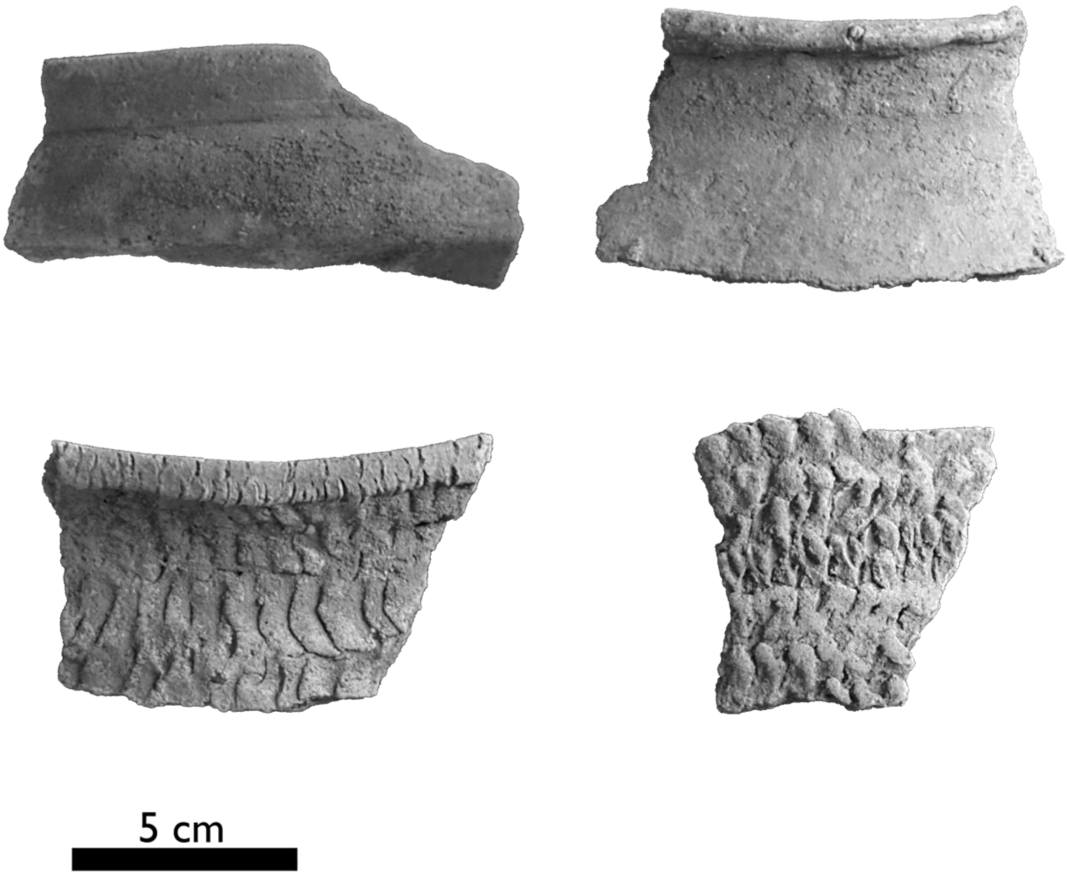


Figure 2.8: Examples of Tupiguarani ceramics collected in Misiones province, with corrugated decoration (bottom). Photographs courtesty of D. Loponte.

the *Araucaria* highland forest containing this resource, possibly indicating some degree of forest management practices related to the occupation of this zone (Bitencourt and Krauspenhar 2006; Iriarte and Behling 2007). They are almost totally unreported for Misiones province (Caggiano 1984), but are common in the highlands of southern Brazil and the interior of Paraná state. Iriarte et al. (2013, 77) note that in Rio Grande do Sul state, anthropogenic dark earths associated with Taquara/Itararé ceramics are reported in the absence of pit house villages, which rarely occur below 500 meters above sea level (see Miller 1967; Miller 1971).

At a point in time only slightly after the southern proto-Jê dispersal, Guarani groups spread into the La Plata fluvial system via the Paraná, the Paraguay, and the Uruguay, as well as along the Atlantic seaboard of south-eastern and southern Brazil from an Amazonian origin (Brochado 1984; Noelli 1998; Noelli 2004a; Noelli 2004b; Bonomo et al. 2014). By 1500 BP, Guarani groups were well-distributed along these major watercourses, including those of Misiones province (Menghin 1957; Giesso 1984; Giesso and Rizzo 1985; Sempé and Caggiano 1984; Noelli 1998, 656; Noelli 1999-2000). Guarani lifeways in the La Plata basin were highly prescriptive, and were connected to a cultural ideology which encouraged the incorporation of neighbouring groups into the Guarani sphere by assimilation or warfare. Additionally, the accompanying cultural "package" of managed and domesticated plants, material culture (including distinctive corrugated, thick-walled ceramics and polished axe heads), and prestige objects was conserved across vast distances (Loponte and Acosta 2013). Villages are frequently associated with extensive patches of anthropogenic dark earths (Noelli 2004b, 8), indicating long-term, intensive occupation of circumscribed territories in riverine environments (Noelli 2004a, 24). Secondary burials in urnfields near settlements characterize their mortuary practices.

Together, the appearance of the southern proto-Jê and Guarani in the eastern La Plata basin (as well neighbouring areas) led to the establishment of increasingly sedentary lifeways linked to more intensive systems of land use and territoriality (Schmitz 2006b, 14; Copé 2006a; Corteletti 2008; Rogge and Beber 2013; Schmitz et al. 2013b; Iriarte et al. 2013). In many cases, the arrival of these cultures coincides with terminal episodes of sambaqui construction, often represented by dark layers of soil containing Taquara/Itararé or Tupiguarani ceramics (Gaspar et al. 2008, 321; Barreto 2014, 8) The various types of cultigens, ceramic technology, and domestic architecture constitute a significant impact on the material record. Although they represent a transition to novel lifeways in the centuries before the Common Era, a degree of carry-over from previous cultures can be inferred from the continued production of Umbu- and Humaitá-affiliated lithics while these new groups established themselves.

2.3.4 *Intensification*

By the middle of the first millennium of the Common Era, a gradual intensification of southern proto-Jê land use is witnessed, during which larger quantities of domestic sites begin to accumulate in the southern Brazilian highlands (Copé 2006a; Corteletti 2008; Rogge and Beber 2013; Schmitz et al. 2013b). Villages of up to 107 individual dwellings are known which developed over potentially long trajectories of location re-use (Schmitz et al. 2013a). The majority of pit houses, however, occur alone, in pairs, or in clusters of up to ten (Beber 2005, 201). The rapid expansion of highland forests during the late Holocene might be linked to anthropogenic influences on the environment, favouring the spread of economic species such as *Araucaria* trees in places where pit houses are extant (Bitencourt and Krauspenhar 2006; Iriarte and Behling 2007; Iriarte et al. 2013, 80). Taquara/Itararé pottery and lithic tools are often abundant and in association with pit house settlements throughout the zones occupied by pit houses. This intensification of highland settlement occurs in parallel to other important processes that took place in the centuries leading up to 1000 BP and until contact (Iriarte and Behling 2007, 125). Perhaps most notable is the emergence of monumental mound and enclosure complexes, hereafter MECs, which are held as significant examples of communal monumental facilities in the eastern La Plata basin.

The development of MECs, earthen funerary tumuli enclosed by low circular or occasionally quadrangular banks of soil, began to complement communal cave burials. The basic configuration of a central mound with one or more enclosures has many names in the archaeological literature of southern Brazil, variously, *aterros, estruturas anelares,* *danceiros, areas entaipadas* and combinations thereof (Rohr 1971; Chmyz and Sauner 1971; Mentz Ribeiro and Ribeiro 1985; Schmitz 1991; Schmitz and Rogge 2004; De Masi 2005; De Masi 2006; Copé 2006a; Müller 2008; De Souza and Copé 2010). The majority were erected in the three centuries before European contact, but the activity lasted well into the colonial era (Baldus 1937; Métraux 1946; Iriarte et al. 2013). Some of the best-known examples in the macro-study region have been investigated in Misiones and the upper Canoas and Pelotas rivers in the Brazilian states of Santa Catarina and Rio Grande do Sul (De Masi 2005; Saldanha 2005; De Masi 2006; Copé 2006; Copé 2007; Iriarte et al. 2008; 2010a; Iriarte et al. 2013), although they are found throughout the southern Brazilian highlands.

MECs likely functioned as centers for the enactment of post-mortuary rites to solidify inter-group ties (Iriarte et al. 2008, 2010a; Riris 2010a), with MECs of different sizes serving the ritual needs of local or regional groups (De Souza and Copé 2010; Iriarte et al. 2013). Microbotanical evidence from ceramics recorded in excavations on the PM01 monument in Misiones suggests that valued foodstuffs, such as maize (*Zea mays*), were consumed in these locations to promote commensal relationships. Ethnohistorical data would suggest that this crop was used to prepare alcoholic beverages during special ritual gatherings for collective consumption (Baldus 1937; Métraux 1946; Maybury-Lewis 1974). Furthermore, two examples of excavated enclosures provided evidence of rock-lined cooking hearths, implicating meat consumption in feasts at MECs. Radiocarbon dates of multiple hearths at the PM01 monument in Misiones province indicate that it was repeatedly visited, potentially for centuries (Iriarte et al. 2008), suggesting that this activity may have occurred periodically at MECs (Métraux 1946; Maybury-Lewis 1974). The use of funerary mound and enclosure complexes continued past the period of European contact and into the twentieth century, where it is recorded in Kaingang groups that survived the devastation wrought by the colonizing powers of South America (Baldus 1937; Métraux 1946). Furthermore, among Central Jê groups the space occupied by a village functions as a nexus of landscape cosmology (Fabian 1992; Wüst 1998). This is particularly interesting given that among the Kaingang burial rites are concerned with the transfer of the deceased to the *numbê* or “village of the dead” (Crépeau 1994; Veiga

2000). In pre-Columbian times, it is argued that this place corresponds to the MECs (Iriarte et al. 2013).

As well as the important intra-societal socio-political dynamics which spurred the emergence of MECs, the expansion of southern proto-Jê mound-building in the last millennium before present ought to be viewed in context with extra-societal processes, (Iriarte et al. 2008, 958). By the peak in mound-building registered after 1000 BP, Guarani groups were widespread throughout the La Plata basin, probably reaching the upper delta of the Paraná by about 700 BP (Loponte and Acosta 2007; Bonomo et al. 2011a; Bonomo et al. 2011b, 316; Politis and Bonomo 2013). As outlined above, general models exist to account for this rapid spread of Tupi-Guarani stock across lowland South America (Brochado 1984; Noelli 1998), however, the exact routes and timing of these passages from the Upper Paraná to its delta are still poorly known. Nonetheless, after their initial entrance along the watercourses of the macro-study region, Guarani groups probably increased in density and numbers. The period after circa 800-1000 BP in the eastern La Plata basin is therefore likely to have seen greater inter-cultural contact between southern proto-Jê and Guarani groups, both peaceful and bellicose (Rogge 2004). On some level, therefore, the MECs likely represent the demarcation of territory and the signalling of cultural ties to particular ancestral landscapes (Copé and Saldanha 2002; Saldanha 2005; Iriarte et al. 2008, 2010a; Iriarte et al. 2013). There are significant unresolved questions in the study of the late pre-Columbian period, especially regarding the scale and intensity of inter- and intra-societal relations, food production, polity size, and the interplay of different systems of land use.

2.3.5 *Summary*

Pre-Columbian groups in the eastern La Plata basin co-existed with their environments and each other in a variety of ways over the long period of time presented in the above sections. Depending on the perspective, the material record shows evidence of long term patterns of stability, as well as change. Although "classic" instigators of change are evident, meaning migrations of people and diffusions of cultural practices, the extent of present knowledge indicates that there is a tremendous degree of regional heterogeneity in the material record that has yet to be fully characterized.

One aspect of research this section has neglected to mention thus far is the great extent to which surface archaeology formed part of archaeological models in southern Brazil. Open-air sites – *sitios céu aberto* – feature extensively (Dias 2003; Beber 2005; Cabral 2005; Parellada 2008a; Carbonera 2009; Schmitz 2010; Galhardo 2010), and are otherwise reported as *sitios superficiais* (Da Silva 2001; Schmitz and Rogge 2004; Rogge 2004; Hoeltz 2005; Saldanha 2005; Copé 2006b; Schmitz et al. 2007; Dias and Hoeltz 2010; Corteletti 2012). This tradition goes at least as far back as PRONAPA; some of the earliest studies of the pre-Columbian period of southern Brazil employed surface collected data. Schmitz' (1957, 122) pioneering work in Rio Grande do Sul mentions collecting pre-Columbian stone and ceramic artefacts brought to the surface by farming. E.T. Miller also began his career in archaeology through an interest in surface collection around his home town (Meggers 1985, 368). In the recent archaeological literature, the preferred term for unstratified contexts representing putative hunter-gatherer occupations is "lithic site" while "litho-ceramic sites" are thought to pertain to specialized activity areas related to but distinct from principal pit house settlement sites of ceramic groups. Reporting sites in this manner is presented as unproblematic, but close examination of their reported characteristics reveals practices of questionable archaeological value. For example, a recent review of southern proto-Jê sites in two areas of Paraná (De Souza and Merencio 2013) establishes that these "sites" cover areas of between 6 m^2 and 90,000 m^2, with no reference to artefacts in terms of absolute numbers, distribution, density, or proportions.

Furthermore, there was rarely a distinction between surface and excavated data when defining archaeological phases and traditions in the earliest years of research (Noelli 2005, 168). Surface data can be considered as filling more than a superficial role since the incipience of the discipline, in some cases acting as the primary source of information on the past (e.g. Piazza 1969). Based on weak geochronological controls (see Zvelebil et al. 1992), surface data have therefore been accorded interpretative value in temporal terms. It is remarkable that only a single study which treats surface collected data as qualitatively different from excavation exists for the southern Brazilian highlands (see

Araujo 2001). As tradition typologies and fossil indices have been critiqued (Hilbert 2000; Dias 2003; 2007; Dias and Hoeltz 2010), the practice of employing diagnostic artefacts for dating pre-Columbian surface sites is increasingly difficult to sustain. Surface sites patently exist in a tremendous size range in a variety of environmental settings with diverse material culture content. Translating an indiscriminate mix of atemporal material from unstratified contexts into units that correlate to phenomenological scales implies a degree of behavioural significance which is uncritical towards record formation, data sampling, and spatial variation. These topics form the focus of the remainder of this chapter, which seeks to establish an alternative framework for surface data in the eastern La Plata basin.

2.4 Surface archaeological investigations in southern Brazil

An important dimension of regional scholarship is the great extent to which surface archaeology has historically informed research in southern Brazil. Surface sites feature extensively and prominently in the literature of this region (see Dias 2003; Beber 2005; Cabral 2005; Parellada 2008a; Carbonera 2009; Schmitz 2010; Galhardo 2010; Da Silva 2001; Schmitz and Rogge 2004; Rogge 2004; Hoeltz 2005; Saldanha 2005; Copé 2006b; Schmitz et al. 2007; Dias and Hoeltz 2010; Corteletti 2012). The use of surface collected data has deep roots in this context, as some of the very first studies of the pre-Columbian period of southern Brazil employed it to a large extent. For example, P.I. Schmitz' (1957, 122) pioneering work in Rio Grande do Sul mentions collecting pre-Columbian stone and ceramic artefacts brought to the surface by farming. E.T. Miller also began his career in archaeology through an interest in surface collection around his home town (Meggers 1985, 368).

Against the broad cultural-historical backdrop given above, it is worth reviewing the treatment of surface collected data in southern Brazilian contexts in a sample of cases to contextualize later discussion. In doing so, this brief appraisal will seek to highlight the effect that certain dominant trends have had on the act of interpretation of cultural remains stemming from surface contexts. It will also serve to bring the advantages of non-site archaeology for dealing with surface scatters to the forefront. As noted above, surface collection historically enjoyed a prominent role in the exploration and definition of the pre-

Columbian archaeology of Misiones province in a range of different settings (Menghin 1955/56; Madrazo and Laguzzi Rueda 1967; Schimmel 1967; Giesso and Rizzo 1985; Mújica 2000; 2007). The cited studies are all largely informal in their methods. They all share the same basic cultural-historical terminology, unmodified from Menghin (1955/56), with some input from Brazilian researchers emerging in the later examples (see PRONAPA 1970). Furthermore, they lack a reason for research beyond that of locating archaeological remains and recording the types of artefacts encountered in broad terms. Based on the sample size and informality of these cases, it is problematic to draw more than superficial conclusions about the nature of surface archaeology in Misiones province specifically. Later discussion covers the results of much more recent systematic surveys, and the informative potential of such research in the province (Iriarte et al. 2010b; Riris 2010b; section 3.3.2). Across the border, however, the time span over which Brazilian studies have accumulated has resulted in a corpus whose breadth allows for a more extensive discussion of how surface archaeology is conceptualized and handled in the study region. There also exists a greater diversity of approaches within these cases, allowing for a comparatively detailed overview of different programs of research and their effects on the construction of archaeological inferences from surface data.

The prominence of surface archaeology in the early history of the discipline in southern Brazil is well known (Barreto 1998, 577; Noelli 2005, 168; Dias 2006, 178). Likely due to its heterogeneity, the material record of surface contexts has led sites of this nature to be reported and discussed under a variety of names: open-air, superficial, lithic, litho-ceramic, and multi-component sites, among others across the literature (see section 2.2). Many of the phases that composed the overarching archaeological traditions of PRONAPA, both pre-ceramic and ceramic, were defined solely on the basis of surface collected data (e.g. Piazza 1969). This practice can be attributed, at least in part, to the rapid pace of fieldwork (Noelli 2005, 168). Surface material was later cross-referenced with stylistically similar objects with associated absolute dates to locate them within the national cultural-historical scheme (see PRONAPA 1970; Simões 1972), ultimately according archaeological remains on the modern land surface a role that was much more than incidental or supplementary to the narrative that was produced. The way in which this process unfolded for pre-ceramic cultures owes a certain intellectual debt to Menghin's original work (Menghin 1955/56), in that formal stone tool morphology was the dominant criterion for defining pre-ceramic cultural units (see Laming-Emperaire 1967; Dias 2006, 179). This quickly led to bifacial artefacts in western Santa Catarina (Rohr 1966; 1968) being identified as part of the "Alto-paranaense Complex" previously documented in Misiones (Carbonera 2013).

Rohr's original fieldwork in western Santa Catarina was able to obtain a radiometric date of 7953 – 7483 BCE (SI 995) from layers containing large bifacially-reduced artefacts. This finding went not only some way towards supporting Menghin's original proposal on their antiquity, but was also used to argue that all instances of relatively large, bifacially-reduced stone tools belonged to the Altoparanaense culture. Many such sites were dated by correlation on the basis of tool morphology (Noelli 1999/2000; Dias 2006, 179), and were later incorporated together as the Humaitá Tradition at the conclusion of PRONAPA. The Umbu Tradition was defined along similar lines by the predominance of projectile points over large bifacial artefacts in assemblages (Schmitz 1987; Prous 1992; Okamura and Araujo 2014, 59). It was also recognized as having a date of inception in the early Holocene (Miller 1987; Noelli 1999/2000, Table 1), with one of the earliest dates at 11,875 – 10,892 BCE (SI 3750) in Rio Grande do Sul (Miller 1987).

This division of archaeological cultures was constructed on the basis of fossil typologies and a relatively small number of radiocarbon dates to scaffold an absolute chronological framework (Kern 1991, 147; Hilbert 2000; Dias 2003; 2007; Dias and Hoeltz 2010). Within it lies the roots of a major problematic within the regional epistemology of archaeological knowledge. Generalizing, surface sites with pre-ceramic material (meaning only stone artefacts) tend to be grouped under the general heading of "lithic sites" with a note to the cultural provenance of the assemblage, and are consequently assumed to represent the remains of relatively old occupations. By the same token, surface distributions that contained both lithics and ceramic material of either Taquara/Itararé or Tupiguarani affiliation were termed "litho-ceramic sites" and usually associated wholesale with younger periods (Copé 2006a, 67). Scholars have, however, pointed out that the distinction between the two classes of surface site is rarely clear-cut (Dias 2006). The aforementioned pre-ceramic/ceramic dichotomy in combination with the tendency to render interpretations in functional terms for the cultures in question (see Robrahn 1989; Kern et al. 1989, 120; Kern 1991, 137; Heberts 2006, 164; Copé 2006; Müller 2008; Vialou 2009; De Souza and Merencio 2013) will serve to highlight some limitations with current approaches to surface collected data. In order to address broader issues surrounding the interpretative use of surface data, as well as the expectations archaeologists have of it, the remainder of this section will draw on specific studies from southern Brazil to illustrate points relevant to the theoretical framework that will be established in sections 2.5 and 2.6.

While diagnostic stone tools are often found in surface contexts, debitage is frequently the most abundant class of artefact in "lithic" and "litho-ceramic" sites alike (see for example Saldanha 2005; Copé 2006a, 309). In-depth treatments of such locations are rare, possibly due to the lack of any stratigraphy to distinguish abutting or overlapping deposits, as well as the perception that surface contexts (and the plough zone in particular) are irreversibly damaged (Araujo 2001, 125-127). Consequently, such interpretations tend to centre on a limited number of spatially circumscribed activities or site types: temporary domestic sites (Schmitz and Rogge 2004; Beber 2005; Saldanha 2005), horticultural fields (Kern et al. 1989), "satellite sites" to principal settlements (Robrahn 1989, 126-131; Heberts 2006, 164), resource extraction camps (Copé 2006a, 171), quarries or workshops (Müller 2008, 40), and villages in the case of larger scatters (Schmitz et al. 2007). As can be seen, the practice of directly "reading back" functional occupations and activities from scatters of ceramic and lithic artefacts (e.g. food preparation, knapping areas) on the surface is commonplace. Although various attempts at integrating these sites into a settlement system perspective exist (Mentz Ribeiro and Ribeiro 1985; Kern et al. 1989; Robrahn 1989), the case of Copé et al. (2002) differ in that the study of the surface archaeology proceeds from the explicit hypothesis that they all formed part of a relatively late settlement system in the Pinhal da Serra region of Rio Grande do Sul that was contemporaneous with southern proto-Jê pit house structures.

Copé (2006a) also employs this hypothesis in Bom Jesus municipality (Rio Grande do Sul) to directly relate two surface sites to nearby southern proto-Jê pit houses in a single settlement system. On the basis that reconstructed ceramic vessels recovered from beneath surface contexts were found to be larger than those recovered from excavations in pit houses, she suggests that they were special activity areas for food processing and preparation away from the principal areas of inhabitation (Copé 2006a, 172). A calibrated radiocarbon age range of 1181 – 1390 CE (Beta 178136) from a subsurface context in a litho-ceramic site (20 cm depth) is used to cement the suggestion that there was interaction between these two different classes of site due to their contemporaneity, and moreover, that a marked differentiation in the use of space existed between domestic and exterior settings (Copé 2006a, 338). Building towards a landscape-level model for late pre-Columbian settlement systems in the highlands, Copé (2006a, 367) suggests that the differences between such sites in part reflects the dynamic variability of land use in the Bom Jesus area over time and across environmental clines. All the surface sites in the study area are included in this model on the basis of the single radiocarbon date.

Other researchers have made similar attempts at relating archaeology encountered on the modern land surface to other site types by employing extensive subsurface testing. Saldanha (2005) presents a series of investigations that includes abundant surface sites in the Barra Grande area. This region was previously studied by Mentz Ribeiro and Ribeiro (1985), who recorded surface material in spatial proximity to pit houses. The four litho-ceramic sites discussed in the text range considerably in size from 64 m^2 to 1020 m^2 (Saldanha 2005, 93). Similarly, the 39 lithic surface sites in the study area have a tremendous reported size range in classes from <2500 m^2 up to 40,000 m^2. The modern vegetation cover also varies from site to site; the Pedreira site was encountered in a ploughed field while PE-22 was found after shovel testing in an area covered by forest. Consequently, the formation processes in operation likely vary significantly on a case-by-case basis. Nonetheless, in addition to the litho-ceramic (Taquara/Itararé Tradition) and lithic (pre-ceramic) site types, the subsurface investigations discussed by Saldanha (2005) permits him to distinguish two surface site sub-types: lithic sites with subsurface "micro-structures" (e.g. hearths or knapping zones) and lithic sites without detectable features. He also includes rockshelters or caves with surface material as a third category, but this class is not discussed here. In addition to the absence of ceramics, these site types are noted for the "constant presence" of large bifacially flaked stone artefacts (Saldanha 2005, 103).

An area of 20 m^2 of the PE-22 sub-canopy site was excavated to a depth of 20 cm, which revealed in situ deposits of entire Taquara/Itararé vessels in conjunction with lithic artefacts. The spatial distribution of the uncovered material was used to suggest that it represented the remains of a pre-Columbian straw hut interior and an exterior discard zone (Saldanha 2005, 97-99). The interpretations of this material broadly agree with earlier work (see Schmitz et al. 2002; Beber 2005, 227) that asserted the contemporaneity of surface sites with the inhabitation of pit house structures. A similar excavation of an area of 13 m^2 in the AG-47 lithic site (an example with "micro-structures") also to the depth of 20 cm revealed a hearth surrounded by a concentration of debitage approximately 4 m in diameter. This is hypothesised to be the remains of a small pre-ceramic (Humaitá Tradition?) hut constructed with perishable material (Saldanha 2005, 107). In both of these cases, the majority of the archaeological material was recorded in the first 10 cm of topsoil, and artefacts located on the surface or by means of small shovel test pits served as a yardstick to guide subsequent excavations. Finally, one of the largest lithic surface sites (Area 93, approximately 4 hectares in surface area) lacks any features. It was systematically surveyed to recover debitage and stone tools widely distributed across within its limits. The site was not, however, subjected to test excavations to the same extent as the aforementioned sites and was interpreted simply as a "specific activity area" (Saldanha 2005, 104-105). The difference between sites with features and sites without features appears therefore to be wholly defined on whether subsurface investigation has taken place.

To close this overview of the treatment of surface archaeology in southern Brazil, it is worth noting the tremendous variability in the reported surface areas of deposits of archaeological material. This issue has already been raised by researchers working in the region. For instance, Kern (1991, 138) notes that pre-ceramic (lithic) surface sites in Rio Grande do Sul of the Humaitá and Umbu traditions range in size from 400 m^2 to 10,000 m^2. Furthermore, when excavated, subsurface material is typically found only in the topsoil or plough zone (first 10 cm), if at all (Kern 1991, 138; Heberts 2006, 159). Similar accounts are evident in Paraná. Syntheses of past work note that the reported sizes of surface sites range from 6 m^2 to 90,000 m^2 (De Souza and Merencio 2013, 101-102). The surface sites PR-AS-03 (3571 m^2) and PR-BS-02 (752 m^2) were also partially excavated and contained shallow subsurface archaeological deposits in a layer of approximately 10 cm. The latter case notably included four burials (see Chmyz 1981; Chmyz et al. 1999). The authors also show that "open air sites" are the most numerous reported site type by a very wide margin in Paraná state (De Souza and Merencio 2013, 105). Together, the above examples can help illustrate some important problematics and prospects for systematic investigations of spatial structure in surface archaeology in Misiones.

The abundance of sites reported on the modern land surface of southern Brazil serves to demonstrate the high likelihood of encountering an analogous archaeological record in Misiones province. Surface sites are large and significant deposits of material, and clearly possess a high degree of variability in several important regards: spatial distribution, size, and the classes and diversity of artefacts recorded. Furthermore, they are repeatedly reported as the most numerous type of archaeological site across the regional literature. The study of such locations with formal spatial methods can help address long-standing questions surrounding their role and significance in the landscape dimension of the pre-Columbian cultures. This requires a rigorous theoretical framework to guide the analysis, as there are several outstanding characteristics of surface archaeological deposits which have remained all but unaddressed to date (see Araujo 2001). These fall within the realms of both theory and methods of study.

Taking into account the results and interpretations of surface collected data within the sketched in outline above, a number of additions to survey and data collection methods ought to be implemented as well. Only a single study exists for the southern Brazilian highlands which treats surface collected data as qualitatively different from excavation, with methods to match (see Araujo 2001). First, a rigorous non-site archaeology of subtropical Misiones requires more detailed controls on post-depositional formation processes and their effect on the structure and integrity of the surface record. This information can be used to discern whether the shallowness of surface archaeological deposits reflects a preserved pattern of transient activity or is an artefact caused by the deflation of topsoil in the targeted areas of Misiones (through modern human intervention). Based on very weak geochronological controls, uncontrolled surface deposits have been accorded interpretative value in phenomenological terms (see examples above; Zvelebil et al. 1992).

It is clear that surface sites exist in a tremendous size range in a variety of environmental settings with diverse material culture content. Translating material from surface contexts into events that correlate to phenomenological scales implies a degree of behavioural significance which is uncritical towards long-standing disciplinary questions surrounding record formation, data sampling, and spatial variation (Dunnell and Dancey 1983; Ebert 1992; Holdaway and Wandsnider 2006; Holdaway et al. 2010). To this end, consistent recording and reporting the spatial extent of the terrain surveyed is necessary, as scale has a direct impact on the results of most spatial analytical methods (Bevan and Conolly 2006). Finally, the practice mentioned above of employing diagnostic artefacts to pigeonhole pre-Columbian surface archaeology wholesale into appropriate cultural affiliations through fossil typologies is increasingly difficult to sustain, as suggested by the critiques mentioned above. Although ceramics can be reliably associated with specific cultural periods, their presence alone does not serve to date a deposit in anything but the broadest terms, and any spatially associated artefacts cannot be assumed to have contemporaneity on proximity or "visual clustering" alone. These four intertwined topics of temporality, record formation, site definition, and the significance of spatial structure form the focus of the remainder of this chapter. This will seek to explain and justify the adoption of non-site archaeology as a group of principles to inform data collection, analysis, and interpretation, and in doing so it will establish an alternative framework for surface collected data in the eastern La Plata basin.

2.5 Principles of non-site archaeology

The surface record is the product of an unknown number of depositional events, instigated by an indefinite number of actors over an uncertain period of time (Holdaway and Wandsnider 2006, 192). This section will examine the role of surface archaeology as a mode of archaeological knowledge production that is on par with, but also qualitatively different from, excavation for reconstructing past land use (Lewarch and O'Brien 1981; Harrison 2011, 10). Primarily, this seeks to define a framework for the implementation of a data collection strategy, as well as the theoretical outline of an analytical approach towards surface collected data that can take into account the limitations above. In historical perspective, surface remains have served two main functions for archaeologists. First, locating surface deposits is probably the most common initial step towards identifying zones where sub-surface deposits may subsequently be excavated. Second, on a broader scale, surface survey is used to determine where an ancient occupation "lenses out" into a presumed random background scatter of artefacts (e.g. Steinberg 1996). As shall be discussed, both of these approaches privilege high-density concentrations of archaeological material, presumed to be more behaviourally or socially meaningful, to the detriment of a more integrated perspective at practices that unfolded at a variety of spatial scales.

Nonetheless, treating the surface record as the exclusive source of primary information has traditionally been viewed by most archaeologists as a problematic prospect. The practice and epistemology of the archaeological discipline instils a sense that surfaces cannot offer insight into the past to the same degree as excavation-focused data collection (Dunnell 1992; Ebert 1992; Harrison 2011). Conversely, it is argued here that using surface collected data effectively is not a question of data quality or representativity, but rather of theoretical orientation and ontological perspective. This involves appreciating how surface collected data are different from stratified deposits of archaeological material, and consequently, what insights they can offer. This section develops the value of spatial analysis of distributional data as a method for characterizing depositional behaviour and reconstructing land use in the study area. Where accessibility, limited pre-existing knowledge, and other environmental constraints hamstring traditional fieldwork methods, common experiences in tropical South America (Zeidler 1995), the nature of this collection of approaches is as an alternative strategy for understanding the past (Dunnell and Dancey 1983, 270; Sullivan 1998; Tainter 1998).

These themes are addressed in detail below in order to establish that using surface archaeological methods will serve to usefully advance our knowledge of pre-Columbian cultural landscapes from an alternative and complementary perspective. Although closely related, approaches that employ surface material as a means to assess the subsurface material record (e.g. Redman and Watson 1970; Steinberg 1996) are not the focus of the forthcoming discussion.

2.5.1 What is in a site?

Non-site archaeology rejects the use of archaeological sites as interpretative units. Further, it is critical of several central concepts within the discipline, including the primacy of absolute chronology and the direct correlation of entities observed in the ethnographic record with the structure of the material record (Tainter 1998, 176). From an epistemological perspective, the core function of sites is as devices to partition the material record into simplified and manageable space-time packages. This enables provenance to be attached to cultural and environmental data. Ultimately, patterns can be sifted from the complexity of the material record and further onwards to the reconstruction of some aspect of human behaviour by comparing information across multiple contexts (Dunnell 1992, 21-23). Over the past century, the site has as a result been developed into one of the most central concepts of archaeological thought, a pre-eminent unit of cataloguing, analysis and preservation within the discipline. It is so basic to the practice of archaeology that the simple fact of observation makes its existence is self-evident (Tainter and Lucas 1983; Orton 2000, 67). In other words, it is a "primitive" of archaeological thought.

Seen in historiographical perspective, however, what constitutes an archaeological site is anything but absolute, and has been the subject of many attempts at formal definition. This has included more or less precise parameters for definition according to the needs of the discipline at the time (see Dunnell 1992; Orton 2000). In New Archaeology, the site as a unit of observation was required to be both culturally meaningful and contextually transferrable, in order to facilitate the construction of general theories and laws about human culture or behaviour (Fritz and Plog 1970; Schiffer 1988; Ebert 1992, 17). For example, Binford (1964, 431, in: Dunnell 1992) provides a programmatic, if obtuse, definition:

> "The site is a spatial cluster of cultural features or items, or both. The formal characteristics of a site are defined by its formal content and the spatial and associational structure of the population's cultural items and features present."

It can be drawn from this definition that the generally-agreed upon characteristics of sites are spatial dimensions, associated articles of material culture and temporal integrity (subject to any formation processes) which allows them to be distinguished from the rest of the world in which they exist. The delineation of sites follows from the specific kinds of spatial and material relationships that they ought to encapsulate. In most contexts, this broadly functional tack remains largely unchallenged (Stern 1993; Holdaway and Wandsnider 2006, 186-187). The default, uncritical position towards this fundamental unit of archaeological knowledge production is that their empirical reality exists independently of observation. Like landscapes as external phenomena, they are "out there" in the world waiting to be discovered (Dunnell 1992, 25; Ingold 1993, 154; Bender 2002, 103).

By establishing that a particular parcel of space is an archaeological site, in opposition to "off-site" areas, a knock-on effect is created by which weakly-patterned remains are deemed to be non-significant and unable to convey information according to essentially arbitrary criteria of significance. The limited ontological status of these areas in site-centric investigations becomes due to the disciplinary-wide expectations of what constitutes a valid source of archaeological data (Plog et al. 1978, 389; Dunnell 1992). The analysis and interpretation of the material record is guided in this manner by an embedded selection process of sites from the total archaeological population (Cherry et al. 1988), rather than rigorous observation of the whole (Dunnell and Dancey 1983, 271). Furthermore, representing sites as such can lead to direct correlations with events or processes which take place on a phenomenological, as opposed to archaeological, scale (for example a camp, village or workshop) (Holdaway and Wandsnider 2006, 185). Facilitating the incorporation of as much of the material record as possible within a single framework appears to be an attractive strategy with regard to these problems (Dunnell and Dancey 1983; Wandsnider 1996, 320; Kantner 2008, 45). Sampling issues are the bane of constructing defensible hypotheses in archaeological research in general (Clarke 1973, 17; Nance 1983; Orton 2000, 81), and so it appears self-defeating from a statistical perspective to discard viable data that does not fit within a site-centric approach to the past.

The activities of any society rarely take place in neatly bounded units of space, and are still less frequently preserved in this way (Foley 1981b, 158; Lucas 2002, 160), which undermines the practice of separating the material record into sites and off-site errata (Gallant 1986). On a practical level in spatial analysis, there are no rigorous or repeatable methods exist for distinguishing what makes a certain density or distribution more socially or systemically significant in comparison to a second (Ebert 1992, 176; Holdaway and Wandsnider 2006, 184). Furthermore, delineating *a priori* units of analysis presumes how events and processes unfolded in the past places, and imposes a scale on the patterning of the material record within and between sites (Carr 1984, 108; Ebert 1992, 174-175). Ultimately, this constrains the perceived structure of the material record and further reinforces a dichotomy between sites and non-sites (Sullivan 1995, 51; Peterson and Drennan 2005, 28). As a result, the most obtrusive elements of the material record – high-density clusters – form the exclusive focus of investigations to the detriment of the archaeological narrative on a landscape level (Nance 1983, 292; Wandsnider and Camilli 1992; Yarrow 2006, 77; Bailey 2007, 204). It also raises further questions about how sufficiently clear a boundary must be to enforce a separation between "closed" and "open" contexts, when it is perhaps more useful to think of data stemming from a continuum of context types (Lucas 2002, 160).

Engaging with the complexity of the surface record and avoiding the exclusion of potentially informative data requires alternative strategies for archaeological data analysis (Ebert 1992, 188-189). From a distributional point of view, what do dense scatters represent if they are not 'sites'? If provenance cannot be attributed to sites, what frame of reference is appropriate? Instead of focusing solely on groups of artefacts in "significant" association, this research seeks to emphasize all the archaeology encountered in association with a landscape. This leads towards apprehending the material record with a different set of expectations, and of prioritizing spatial structure over site structure (see Wandsnider 1996). Distributions are considered continuous, rather than discrete. The spatial behaviour of archaeological remains reflects multiscalar spectrum of overlapping processes, rather than a set of functionally-bounded entities (Camilli and Ebert 1992, 114). The role of temporality in surface data therefore also needs due consideration in order to investigate and dissect these processes in terms that reflect long-term patterns in land use in the pre-Columbian Alto Paraná (Foley 1981a; Bailey 2007, 203).

2.5.2 (A)temporality and the structure of surface data

The lack of temporal information is in surface data the foremost limitation imposed on using surface data (Dunnell 1992, 35; Ebert 1992, 12; Zvelebil et al. 1992; Ramenofsky et al. 2009), since inferring social and environment processes in the discipline largely falls upon the ability to establish a temporal framework. Chronological control (together with spatial and stratigraphic context) is the preeminent tool used for organizing excavated archaeological data into logical sequences of events in the past (Lewarch and O'Brien 1981, 361; Odell and Cowan 1987; Bailey 2007). Many of the spatial critiques of traditional archaeological data collection practices (see section 2.1) also apply in the temporal dimension, linking back to the conflation of archaeological timescales with phenomenological ones (Wandsnider 1998b; Bailey 2007, 206). Outside of exceptional cases, dating a single artefact does not date its layer or closely associated artefacts in terms which correlate to a human scale, and presumes that subsurface material is somehow less disturbed than surface remains (Ebert 1992, 12) Following from this, it is problematic to establish precise temporal overlap between prehistoric sites. The appearance of sites forming a network of contemporaneous, interacting spaces in the material record could easily be an artefact of analysis (Ebert 1992; Anscheutz et al. 2001, 172). Landscape-level investigations with chronological controls for multiple cultural locations deal with broad envelopes of time to an even greater extent (Wandsnider 1998b, 94-95). Contemporaneity, and by extension the study of "settlement systems", is entirely determined by the resolution of dating techniques and the nature of the items or context being dated.

The surface record is the result of the cumulative engagement of human societies with space at different scales, and hence reflects the remains of activities which took place over long periods of time (Ebert 1992, 12). Various strategies exist in the literature to adjust for this perceived shortcoming. Geomorphological controls can estimate the time of surface formation, providing an envelope for artefact deposition (Foley 1981b; Fanning et al. 2007; Holdaway and Fanning 2008). Subsurface features can be dated and spatially associated with surface material, under the assumption that proximity co-varies with time of deposition and that post-depositional disturbances have affected the material minimally (Schlanger 1991; Shiner 2004; Douglass 2010). Finally, temporally sensitive artefacts have been used to broadly date distributions (Bevan and Conolly 2002; Wells et al. 2004; Caraher et al. 2006; Ramenofsky et al. 2009), but this raises the issue of which artefacts should be analytically prioritized in multi-period material. Making use of surface collected data encourages an emphasis on "flattened" horizontal relationships (Harrison 2011, 10) as opposed to time depth. Non-site archaeology therefore capitalizes on the useful qualities of surface data instead of forcing an interpretative conflation of artefacts deposited over archaeological timespans with events and processes that are observed ethnographically (Stern 1993, 215).

Atemporality does, however, come with its own set of issues. The unrecognized introduction of serious bias in the data structure can mask the range of variability in assemblages by filtering the material (Schiffer 1988; Zvelebil et al. 1992, 197; Shiner 2004, 46), which complicates the goal of drawing inferences about pre-Columbian cultural landscapes at larger spatial scales (Markofsky 2010, 291). This can be summarized as modification of the surface record by post-depositional processes, which ordinarily diminish the ability of investigators to draw diachronic narratives from data (Bailey 2007, 204). As discussed, however, achieving such a narrative is not a goal of this research. As surface deposits are formed over potentially a very long timeframe, it is unwise to assume that dense scatters of artefacts are necessarily due to "a lot of behaviour" occurring in a given place (Shiner 2004, 55), as the vertical position of artefacts (in addition to the horizontal) is also undeniably affected by post-depositional processes. Deposition over multiple millennia can be collapsed into a single horizontal axis in due to deflation (see Foley 1981b; Diez-Martin et al. 2008; Markofsky and Bevan 2012). Conversely, cycles of surface formation and deflation can lead to the mixing of multiple contexts and depositional events. Deriving the synchronicity of cultural locations from this type of dynamic geomorphological context is particularly problematic. Unlike the high representativity of deposition events in deflated surfaces (see Wandsnider and Camilli 1992; Fanning and Holdaway 2001; Holdaway and Fanning 2008; Douglass 2010), artefact scatters can be hidden as well as exposed. Alternative strategies are required to infer process from the surface record.

2.6 Scale, space, and pre-Columbian surface archaeology

Scale in an archaeological context refers to several conceptually distinct theoretical constructs which determine how investigators gather, handle, and interpret data (Mathieu and Scott 2004, 3; Lock and Molyneaux 2006). Holdaway and Wandsnider (2006, 184) discuss three different aspects of scale that inform the design of this research. The phenomenological scale refers to the scale at which real processes and events occurred in the past. Some examples would be the *chaîne opératoire* of a stone tool, an annual cycle of planting and harvesting, or the diffusion of a vessel type across a region. The cultural content of the archaeological record is produced primarily on phenomenological scales. It is obvious that these processes have both spatial and temporal dimensions, implying in spite of its name that phenomenological scale does not necessarily match with that of individual agents. Next, analytical scale corresponds to the spatio-temporal domain of investigation, how archaeological data is recorded within it and the level of preservation of its material and environmental record. This will inform the design of the data collection strategy, as well as the type of spatial analytical approaches that can be deployed. It also implies developing an understanding of the post-depositional formation. Finally, the scale of interpretation identifies how and at what level meaningful knowledge and patterns can be drawn out from the analyzed archaeological data. This is synonymous with "effective scale" (*sensu* Crumley 1995), and is clearly impacted by the analytical scale, but is nonetheless conceptually distinct (Ashmore 2002, 1177; Lucas 2008, 59).

Critical spatial theory posits that time-extended contact with terrain is the means by which people and societies establish recursive relationships with their social and physical environments (Bourdieu 1977; Kirby 2009, 3). From a spatial perspective, it is argued that the fields of action generated through such processes transcend the agency of single individuals or single characteristics of a social structure (Soja 1980; Pred 1981; Bourdieu

1985; Lefebvre 1991). In other words, the recursive nature of human societies gives rise to patterns that can only be analyzed and interpreted in aggregate. By way of analogy, single data points are meaningless, significance lies in the whole picture. Patterns in archaeological data are the outcome of practices in relation to particular physical spaces. Due to the fact that archaeology more often than not operates on data which is disconnected from its original cultural context (Schiffer 1988; Gosden 2004, 38-39; Knappett 2008, 82), how might this problem be approached through the surface record? Knappett (2011) suggests that the focus of research forms around points where material culture and features are "concretized" into assemblages of objects as a result of long-term repetition of actions in the past, some of which enter the material record. The observable empirical structure of material practices in space provide the most direct route to understanding the cultural context which produced them (Pred 1984, 286; Lefebvre 1991, 413; Kirby 2009, 16), which for present purposes means the variability of material culture across different landscape settings.

How past phenomena are apprehended by archaeologists rarely matches how they unfolded on a phenomenological scale (Mathieu and Scott 2004, 2; Holdaway and Wandsnider 2006, 184; Lucas 2008, 61). From face-to-face interactions on a daily basis between individuals, to the integration of thousands of people in complex polities stretching across continents, there is no single "correct" scale embodied by the material record (Lovis et al. 2006, 271; Kantner 2008, 43-44). Furthermore, the presence of many different processes composing the archaeological record allow for potentially very different aspects of it to be interrogated, preserving details of different perspectives on the societies under investigation (Strathern 1991, xvi). In order to maximize scarce data, this research will attempt to capitalize on *multiple* analytical scales of cultural and natural systems in the Alto Paraná (Brenner 2001, 601; Lock and Molyneaux 2006, 2). The surface record of any given location is seldom fully representative of the full range of activities which unfolded in the past, which implies that the analytical scale ought to increase the representativity of the data where possible. The data collection strategy, in other words, must incorporate well-distributed and extensive sampling frames. This has implications for how to conceptualize surface recorded data.

To this end, the remainder of this section evaluates two archaeological models of the phenomena inscribed into the surface record. This is informed by the above perspectives on scale and space, which will in turn guide the implementation of multiscalar spatial analyses in later chapters of this research.

2.6.1 Models of spatial structure in surface archaeology

The surface record encountered in the field is the result of complex sequences of events linked to how people organized themselves and interacted with the landscapes in the long term. Additionally, environmental and anthropogenic post-depositional processes modify the detectable cultural content of surface assemblages. In order to impose a measure of top-down order on surface collected data, researchers tend to employ one of two theoretical models of spatial structure (whether implicitly or explicitly). These models reflect different assumptions on the significance of patterning in surface assemblages, although both agree on their palimpsestic nature.

The first, or *distributional*, model (Foley 1981b; Dunnell and Dancey 1983; Ebert 1992; Holdaway et al. 2010) assumes that the surface record contains many episodes of deposition which are superimposed, mixed, partially destroyed and otherwise altered. Consequently, it is virtually impossible to reconstruct their initial condition and satisfactorily separate distributions into entities that correlate with phenomenological events, ethnographic constructs, or functional categories of sites (Whallon 1973, 266; Dunnell 1992, 27; Stern 1993, 202). Arriving at a series of discrete occupations within a study area misrepresents of what surface material is: the totality of all discard that occurred in an area over the long term, mediated through the formation of the surface(s) (Holdaway and Wandsnider 2006, 192). Identifiable patterns reflect the extreme long-term adaptational behaviours which led to the inhabitation of the environment. On the other hand, the *occupational* model (Carr 1984; 1987; Sullivan 1995; Wandsnider 1998a; Johansen 2010) contends that degrees of spatial information are retained by surface distributions. Artefact scatters can be considered the accumulated remains of sets of related activities. Spatial variability at different scales allows distinct events of deposition, and hence activity, to be detected (Jones and Beck 1992, 169; Sullivan 1995, 50).

Habitual re-occupation of places leads to an affinity for certain spaces, which contributed to the cognition of a cultural landscapes by its inhabitants (Wells et al. 2004, 646). In the long term, an overall low rate of deposition in more or less the same locations will coalesce into loci of repeated deposition (Bintliff and Snodgrass 1988, 507), creating "persistent places" in the landscape (Schlanger 1992). Although the activities and use of space can be different from occupation to occupation or even within the same period of use (Wandsnider 1992), the previous use of spaces will inform and structure subsequent uses.

As discussed in section 2.5.2, in the absence of supporting data the surface record must be treated as atemporal. The models do nonetheless imply a degree of temporality, which essentially consider surface data as resulting from cultural-evolutionary timescales (in the distributional model) or individual episodes of deposition (the occupational model). In Bailey's vocabulary (2007, 204-207), the two models correspond to *cumulative* and *spatial* palimpsests. For present purposes, it is worth noting that both models of spatial structure rely on testing their assumptions (Ebert 1992, 135; Sullivan 1995, 50). There is no reason to assume that one model is inherently correct. They can be thought of as two different hypotheses on the significance of spatial structure in the surface record, with the aim to infer the types of processes which produced it. As noted, societies by and large do not operate within discretely bounded space-time zones. Furthermore, the material record cannot be fully represented solely within "hotspots" of artefact clustering. Approaching this problem of representativity from a non-site perspective provides the advantage of being able to consider patterning in continuous rather than prescribed and predetermined parcels of space (McCoy and Ladefoged 2009, 280). The above conceptual models of palimpsests provide this research with a theoretical backdrop to enable the inference of process from patterns.

2.7 Summary

This chapter discussed the broad strokes of archaeological research in Brazil and Argentina, as well as a cultural-historical framework of the eastern La Plata basin more specifically. Additionally, it established the theoretical non-site framework that will inform the data collection strategy, execution of fieldwork and spatial analyses. In lowland South America, the dearth of archaeological studies in many regions has by necessity led to prioritizing site discovery over detailed characterization of the surface record (Zeidler 1995, 12). This chapter argues instead in favour of systematic non-site surveys in the Alto Paraná which affords the collection of a relatively representative sample of the archaeological landscape, high flexibility in survey design, and the potential to investigate patterns at multiple spatial scales. Lacking a strong history of settlement-focused research on pre-Columbian groups in Misiones leaves little preceding work to bias the exploration the surface record. The spatial structure of surface assemblages has untapped potential for investigating the role of long-term land use in the indigenous cultures of the eastern La Plata basin. Seeking to understand the pre-Columbian occupation of the province in this manner is incompatible with the limitations imposed by carrying out fieldwork with the goal of arriving at a distribution of 'sites' and arbitrarily-designated assemblages of material culture. This will be reflected in the survey design outlined and discussed in the next chapter.

3. Data collection strategy

3.1 Overview

This data collection component of this research consisted of two main parts. The first was a field-based project named the *Piray Mini Exploration* project (henceforth PME project) that took place in June-July 2013. Following the research questions, the survey sought to characterize the distribution of archaeological material on the modern surface of Misiones, in order to enable an assessment of its relationship to long-term depositional patterns and pre-Columbian land use. To this end, the fieldwork sought to achieve a sample of surface data in as wide a distribution as possible within the Alto Paraná floodplain. In an ideal scenario, this would have taken place through stratified random sampling of the region, but the approach eventually adopted (see below) ultimately provided more flexibility in the survey design. Overall, the design aimed to offer the fieldwork the ability to assess small- and medium-scale patterning in the distribution of sites and material culture. The second part was a laboratory-based analysis of the lithic artefacts collected by the fieldwork, which took place in parallel to the survey. The lab analysis aimed to record a range of metrics consistently across the entire PME survey assemblage in order to later carry out a technological analysis of the lithics in the study area.

This chapter describes the fieldwork data collection strategy in detail. Additionally, the results of a pilot survey led by the University of Exeter in 2010 will be outlined for the purposes of informing the survey design and building upon its findings. The survey design implements the distributional perspectives on the material record that were discussed and developed in the previous chapter. Finally, the methods used in lab analysis of the PME project lithic assemblage are described.

3.2 Survey design

3.2.1 Introduction

The use of systematic survey in archaeology has a long history of use for the purposes of detecting locations of potential interest for excavations (Lloyd 1938; Redman and Watson 1970; Mueller 1974; Schiffer et al. 1978; Killion et al. 1989; Cowgill

1990; Wandsnider and Camilli 1992; Bevan and Conolly 2002; White and King 2007). Reconnaissance survey of this nature principally aims to define the coarse distributional patterns of archaeology across a landscape (Ammerman 1981, 73), while more systematic approaches provide a stronger empirical basis for distinguishing the range of variability in the archaeology of modern land surfaces. In brief, survey data that is sufficiently controlled and representative can be highly suited to exploring the long-term occupational history and land use trajectories of a given region (Orton 2000, 78-79). Moreover, where severe limitations exist on the depth and breadth of prior archaeological knowledge, intensive systematic survey provides a framework for the initial efforts to characterize the material record at a larger spatial scale than excavation can permit on its own. To this end, non-site survey provides the means to furnish answers to the research questions, and functioned as the main data collection strategy used in the PME project survey.

As discussed above, a coarse chronological scheme exists. Nonetheless, archaeological knowledge in Misiones deals in cultural entities of largely unknown spatial and temporal dimensions outside of a few well-studied contexts. An emphasis on surface deposits can provide a first glimpse at strategies and processes at a landscape level, reflected in the long-term accumulation of material culture sampled from a range of settings. From the conception to the execution of the project, both spatially-extensive prospection and systematic sampling were prioritized. Although Brazilian material provides a useful basis for comparison, the survey design of the PME project was mainly influenced by a pilot systematic survey led in 2010, detailed below.

3.2.2 Prior surveys and preparation

Within the project 'Investigating the socio-political organization of Early Formative Taquara/Itararé societies', a season of fieldwork was carried in April 2010 in the upper Piray Mini valley (north-eastern Misiones) led by PI José Iriarte (University of Exeter) with collaboration by J. Chris Gillam (University of South Carolina) and Ruth Poujade (Universidad Nacional de Misiones), funded by the National Geographic Society. This is henceforth referred to as the upper Piray Mini survey. The survey aimed to document regional settlement patterns of southern proto-Jê groups in Misiones (Iriarte et al. 2010b; Riris 2010b), particularly in relation to previously-documented ritual complexes pertaining to this archaeological culture (see Menghin 1955/56; Iriarte et al. 2008). In actuality, the study area straddled the watershed of the Piray Guazú valley as well as the Piray Mini. PM01, one of the largest and most elaborate southern proto-Jê mound and enclosure complexes, lies close to the base of the latter river valley. Furthermore, the area of survey lies in the transitional zone between semi-deciduous forests of the interior Atlantic littoral and the mixed *Araucaria* forests of the southern Brazilian highlands (Gessert et al. 2011). This represents the highest parts of the middle ranges of the Sierra Central de Misiones. Assessing the patterning of cultural remains across this gradient could permit differences in land use by southern proto-Jê groups in Misiones to be detected. The project methodology consisted of pedestrian survey and small-scale test pit excavations, in order to document the broad spatial distribution of archaeological material. The pedestrian survey consisted of two principal components, *a)* systematic fieldwalking for settlement remains and *b)* an opportunistic survey of hilltops for mound complexes, as well as caves with the potential to preserve organic remains and stratified sequences of occupation. Test pitting took place over high-density scatters of surface material to prospect for sub-surface cultural features.

The systematic survey was informed by a deductive predictive model of site location (*sensu* Kohler and Parker 1986, 399) constructed by the principal investigators (Figure 3.1,

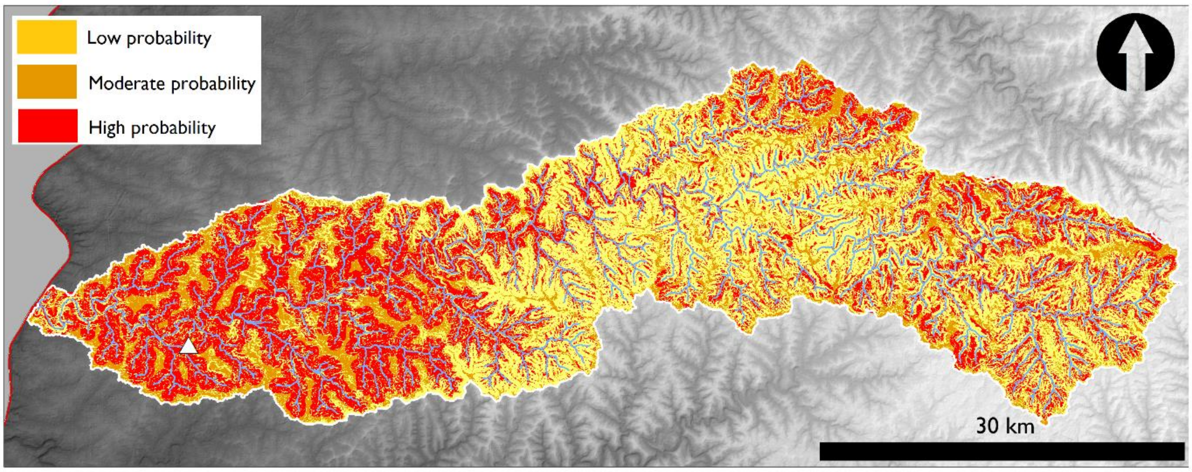


Figure 3.1: Predictive model of site location in the Piray Mini watershed, based on the simple overlay of two variables: slope and Euclidean distance to water. White triangle represents the PM01 mound and enclosure complex in Eldorado. After: J.C. Gillam (personal communication); Iriarte et al. 2010b.

Iriarte et al. 2010b). Fieldwork in Bom Jesus and Pinhal da Serra noted that archaeological sites were typically located within 600 m of major watercourses and located on relatively flat areas of land (<10° slope) (Copé 2007). A simple overlay of these criteria was used to produce a model of low-medium-high probabilities for encountering cultural remains. Leaving aside the well-developed critique of predictive models of site location in archaeology (Wheatley 1995; Ebert 2000; Wheatley and Gillings 2002, 162), when possible, locations of high and medium potential were targeted throughout the survey. The second major influence on the systematic survey was the accessibility to areas of survey, both in terms of permissions granted by landowners,

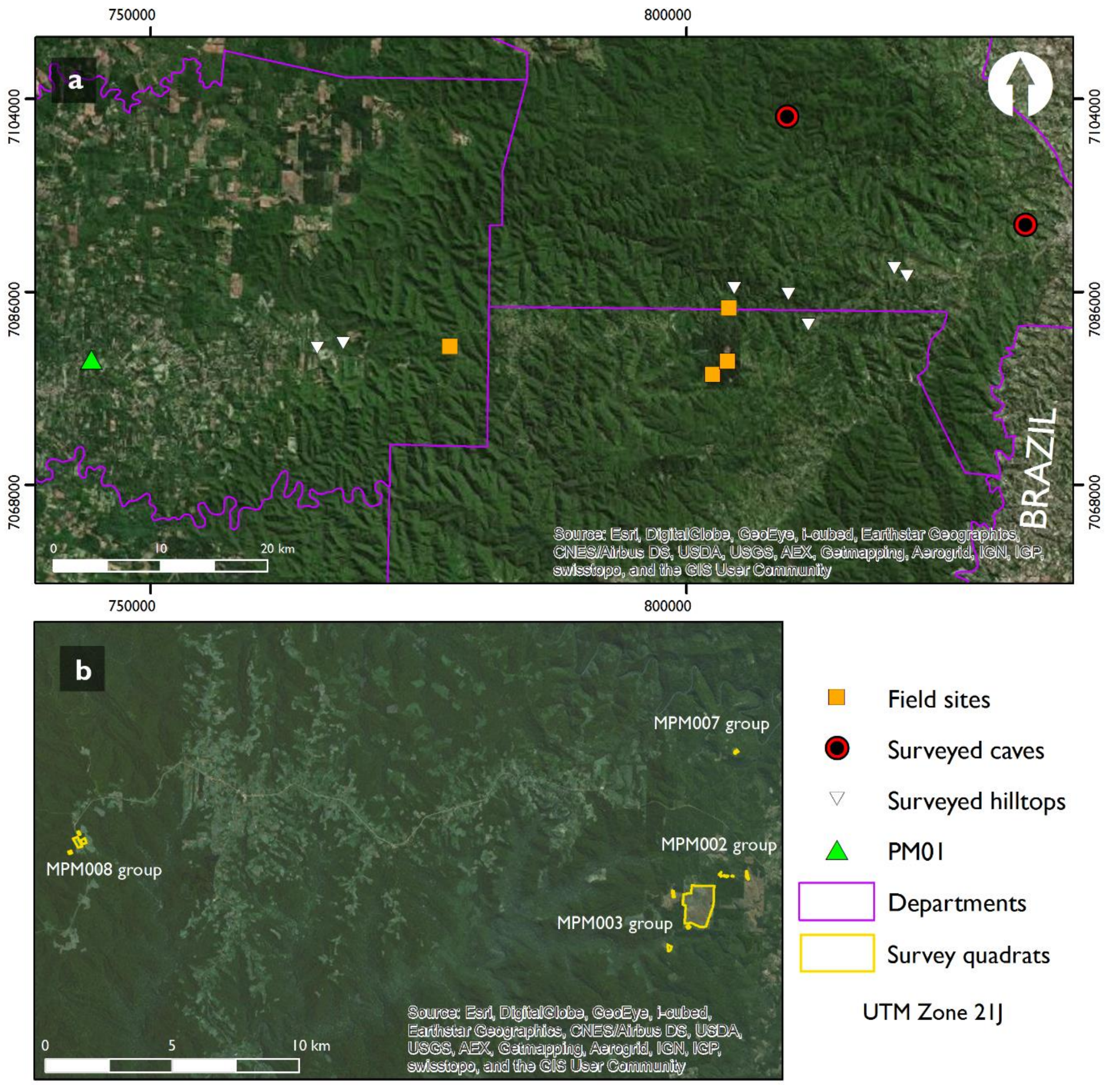


Figure 3.2: *a)* Distribution of locations surveyed in the April 2010 fieldwork in the upper catchment of the Arroyo Piray Mini. Note location of PM01 in relation to the field sites. *b)* Distribution of survey quadrats in four main groups. Test pit excavations took place in MPM003 (largest quadrat) and MPM007. After: Iriarte et al. 2010b.

and in the sense of physically being able to reach places with vehicles and survey equipment. Consequently, the investigated field sites can be described as generally lying quite close to major provincial thoroughfares, on land under cultivation.

In the course of three weeks, the systematic survey covered four field sites of varying sizes (Figure 3.2). These were surveyed by teams of three to seven individuals at a time, while the spacing of surveyors varied from 10 to 25 metres between sites. In total, the area surveyed made up just over 1.8 km^2, the main constituent of which was a pine plantation termed MPM003. The remainder of the coverage was also located within newly-planted pine plantations, or maize fields (Riris 2010b). The conditions created by plantation activity were noted as being ideal for fieldwalking, the occasional heaps of charred plant matter left from clearances notwithstanding. The bare or lightly-covered ground produced in the wake of clearances is vastly superior to the native subtropical forest in terms of the rate of detection of archaeological material (Figure 3.3c and d). Due to this, several thousand artefacts were collected, predominantly flaked stone, with an additional 214 ceramic finds and none of any other material. Out of the assemblage produced by the

Figure 3.3: a-b) Hilltop survey, c-d) plantation and field surveys. After: Iriarte et al. 2010b

surveys, however, only 450 artefacts were recorded with georeferenced points. For the most part, finds came from excavated contexts (highly disturbed in the wake of plantation clearances) or collected en masse in roadside surveys without additional associated spatial data (Riris 2010b). Despite this, the true number of collected items is likely to have been underestimated; in the project records many find locations have names which imply conjunctions of artefacts, such as a "scatter". The unstandardized recording terminology and survey method resulted in an artefact database whose main utility is a coarse distributional characterization of generalized artefact categories across a relatively large area.

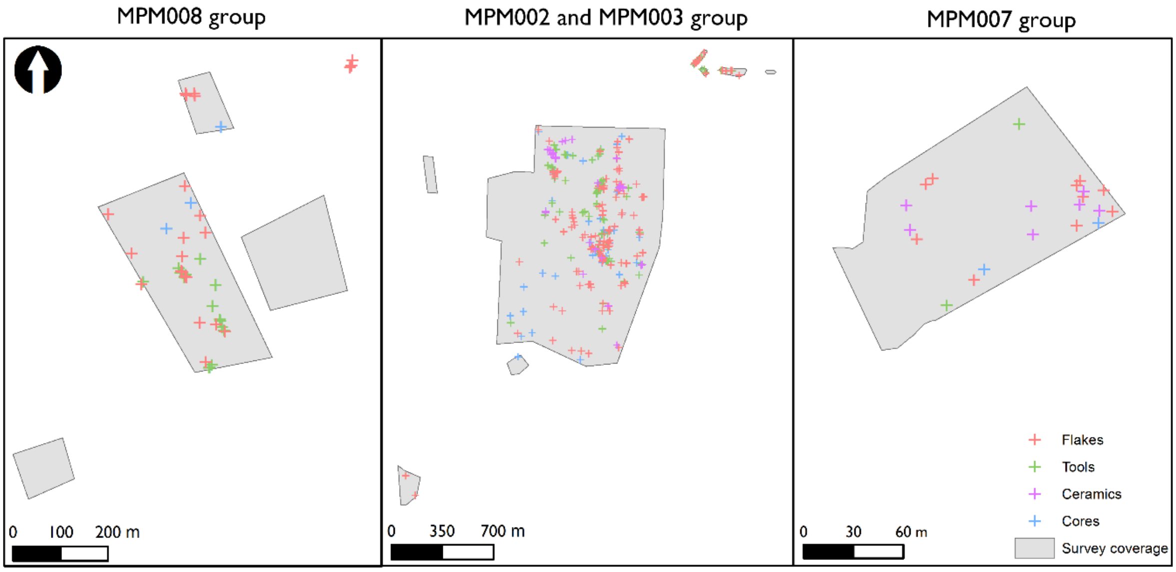


Figure 3.4: Distributions of four general classes of artefacts in three groups of quadrats in the upper Piray Mini and Piray Guazú valleys. Artefact types were inconsistently recorded by surveyors (e.g. as "group of flakes", "flake scatter" or "flake and core scatter", diminishing the utility of this dataset for rigorous comparative spatial analysis, but nonetheless, they illustrate the potential of non-site survey to detect meaningful patterns in pre-Columbian material over large areas. Note differing scales. After: Riris 2010b; Iriarte et al. 2010b.

A parallel survey targeted hilltops in the region, which aimed to expand the regional sample of southern proto-Jê mound and enclosure complexes, and possibly document clusters of pit houses in association with these ceremonial complexes. Both of these categories of structure are typically located very close to the crests of ridges or summits of hills (Iriarte et al. 2008, 948; Iriarte et al. 2013). Furthermore, the bottoms of valleys were traversed at length to record caves with the potential to yield undisturbed anthropogenic deposits. Caves in Brazil with deposits associated with southern proto-Jê occupations have yielded organic remains, including maize cobs (Miller 1971), as well as burials.

Rockshelters investigated in Misiones have also yielded bone, stone and ceramic artefacts linked to this archaeological culture (Rizzo 1968; Loponte 2012). A total of seven hilltops and two cave sites were visited in the opportunistic survey, as well as a considerable distance along riverbeds and the plateau in order to access them, but did not produce any positive results.

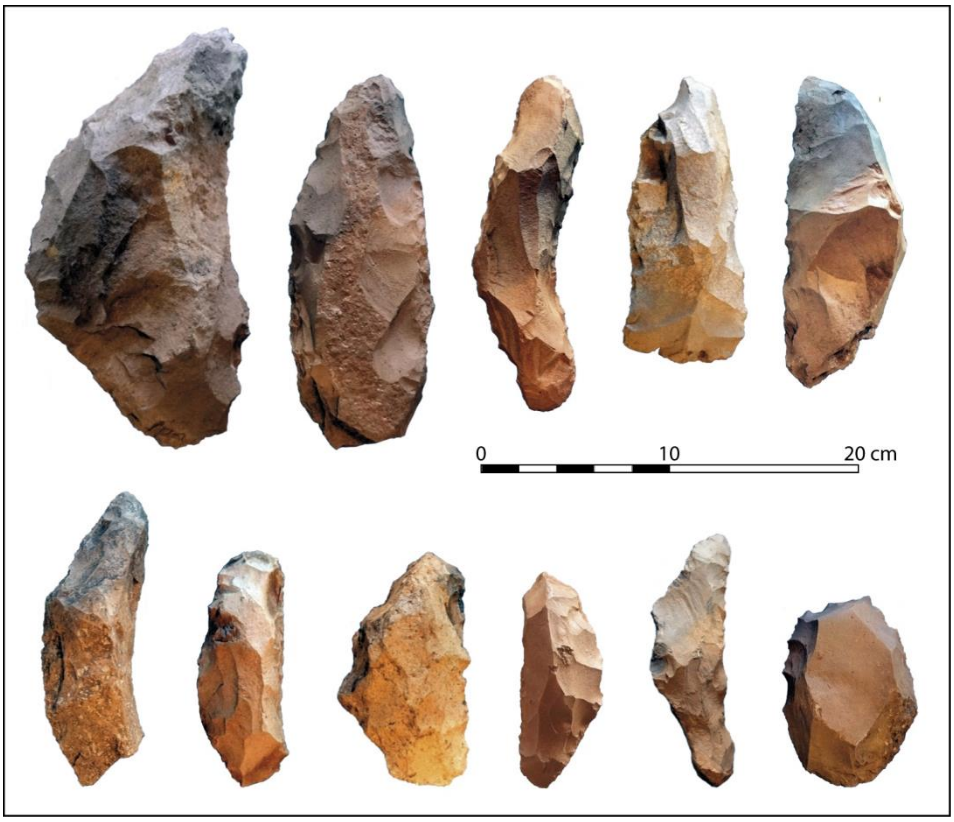


Figure 3.5: Bifacial and unifacial stone tools recovered during April 2010 from the upper Piray Mini valley. Compare with Humaitá and Altoparanaense (Chapter 2). After: Iriarte et al. 2010b.

Test pit excavations took place in three survey quadrats: MPM003, MPM007 and MPM008. Four pits at the former site and three each at the latter two were placed over surface artefact clusters representing possible domestic loci. A feature which superficially resembled a southern proto-Jê pit house at MPM008 was confirmed through excavation to be the remnant of a tree-throw. None of the test excavations yielded stratified archaeological deposits, although subsurface investigation at MPM008 reached a horizon of decomposed basalt at a depth of 1 m. In the meantime, field observations of the creation of a new pine plantation indicated that ploughing affects the integrity of archaeological deposits to a depth of at least 50 cm. Disturbance to this depth by heavy machinery is likely to homogenize and destroy any cultural features it occurs. The subsurface investigations confirmed that artefacts were likely moved by tillage, but no features or remains of features were encountered that could indicate the extent of these disturbances (Riris 2010b, 34).

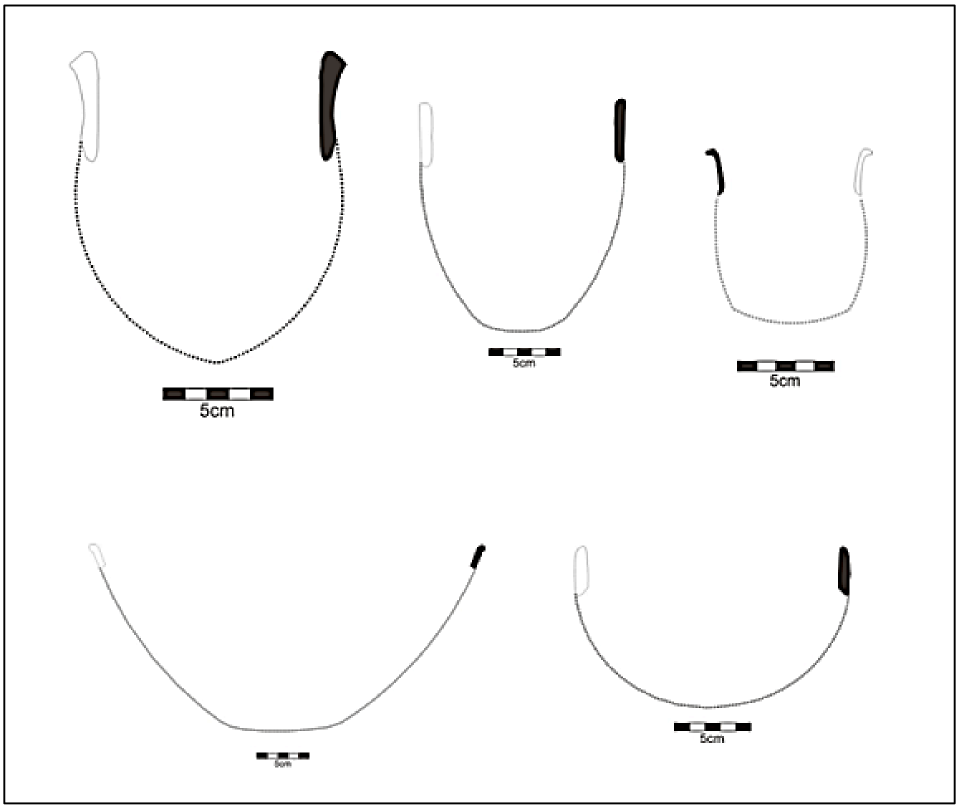


Figure 3.6: Reconstructed vessel profiles of Taquara/Itararé tradition ceramics. After: R. Corteletti; Iriarte et al. 2010b.

The results of the pilot survey allow some conclusions to be drawn about the viability of systematic fieldwalking survey in Misiones. In terms of yield, the systematic survey generated large quantities of archaeological information. Almost every agricultural field or plantation visited over the course of three weeks yielded some trace of pre-Columbian occupation, if only a handful of flakes or sherds. The high rate of response to survey gives the impression of a high rate of deposition through time, suggesting that parts of the landscape may have been occupied relatively intensively at certain points. Although patterning is difficult to infer from this data due to its heterogeneous origin, the fact that it was encountered in the first place implies that the empirical reality of archaeological distributions fit with the predictions made prior to the fieldwork.

On the other hand, in-depth interpretations of pre-Columbian land use cannot be made with the project data as it stands. Without gathering more detailed information, there is little to no basis for distinguishing different trends of settlement in the landscape through time, following current both cultural-historical chronologies (Poujade 1992; Rodriguez 2001) and the basic characterization of cultural material made during the survey. Artefacts that could be attributed to both pre-ceramic (Humaitá lithics) and southern proto-Jê cultures (Taquara/Itararé tradition ceramics) appear to intermingle. Humaitá bifaces, notably curved cleavers (Nami 2006), co-occur with expedient technology and ceramics more typical of the later southern proto-Jê occupation of the province (Figure 3.5 and Figure 3.6). Therefore, without developing a deeper understanding of pre-Columbian technological systems in the study area, the usefulness of the surface record as a primary source of data is clearly limited. Furthermore, any spatial data collected needs to integrate directly with the corresponding artefact records. These conclusions function as points of departure for developing the data collection strategy for this research.

3.2.3 Field methods

The impact of systematic fieldwalking has the potential to be significant, with respect to the present state of archaeological knowledge in Misiones. Previous fieldwork indicates that the rate of detection of archaeological material in prospected locations can be good given the right methods, and that a variety of artefact categories can be encountered in this way. Furthermore, the conditions created by modern land use practices facilitate data collection in many cases. Bearing this and the goals of the research in mind, this section will develop the parameters of the Piray Mini Exploration project survey methods. The conventions for field site names used by the University of Exeter project will be continued, with the prefix MPM (**M**isiones, **P**iray **M**ini) followed by the site number. This follows the convention mandated by local cultural heritage laws. As MPM009 was the last site recorded in April 2010, the PME project began with MPM010. To distinguish them further, however, they were also named after the landowners and numbered sequentially.

Following Kowalewski (2008, 227), the *coverage* is the total area that will be investigated by systematic survey, while *intensity* is defined by the effort invested in surveying a given area of coverage. The former concept may be thought of as the sum of the sampling frames (survey quadrats) that are applied to the study area. Assuming for the moment that no other factors affect the rate of detection, intensity is a strong conditioner of the rate of discovery of artefacts within a sampling frame, since it determines the percentage of ground actually investigated by the surveyors. Hence, intensity correlates directly to the number of artefacts likely to be discovered. This is highlighted by comparing detection rates of crawl surveys over regular fieldwalking, which result in a significant increase to the number of artefacts recorded (Schiffer et al. 1978; Burger et al. 2004, 197; Burger and Todd 2006). Defining this factor permits a realistic approximation of the total percentage of the areas of coverage that will actually be investigated by surveyors, and hence the relative representativity of the sample of the archaeological record within the coverages (Schofield 1987). The spacing of surveyors is a direct measure of this factor, together with an estimate of the width of the walkers' field of vision on the ground. From a statistical perspective, there is no intrinsic requirement that sampling frames be identical in shape or size across the study area (Orton 2000, 86). Intensity, on the other hand, must be consistent to allow for the meaningful comparison between survey units, since it is a much stronger determinant of the outcome of the survey and the final dataset (Banning 2002, 62).

The fieldwork strategy engaged with the project goals in light of the logistical realities of conducting fieldwork in Misiones. In this case, the native forests and the barrier to pedestrian access posed by them were the main limiting factors taken into account. The rationale for site selection was therefore primarily determined by the nature of the vegetation in the lower catchments of the Piray Mini and Piray Guazú. As a result, areas of relatively open ground similar to those encountered in 2010 were specifically sought out. Selecting young pine plantations for survey allowed for well-defined and easily accessed parcels of land to be used as units of coverage, which also have the benefit of presenting comparatively little obstruction to pedestrian movement. Both river valleys were readily accessed via dirt roads that branch off National Route 17 running between Eldorado and the eastern border of Misiones with Brazil. Farmers and local business owners functioned as informants on the condition of land use both before and while the field season was in progress. Specific questions were asked about the ground cover, nature of cultivation (field or plantation) and location of fields of suitable size. Potential field sites were investigated with guide Mario Lapchuk, while the survey team, which varied between three and five individuals, surveyed sites that had previously been identified. Upon encountering a survey location during reconnaissance, its coordinates were noted for later investigation. Despite the restrictiveness of these criteria, the final survey achieved coverage across a range of topographical settings and environmental gradients, which are discussed in detail in Chapter 4.

The topography of the Alto Paraná is flat to undulating, with occasional areas of sharper relief. The surveyed field sites lie mostly within areas of shallow slope, although occasionally steeper inclines were covered. No locations were visited that posed any significant challenge to pedestrian movement, however. As forest clearance, cultivation and re-growth is a piecemeal, spatially fragmented process, the final number of field sites was expected to be broadly distributed and of variable size, shape and type of cultivation. Pine saplings are planted by hand in straight rows that are spaced five meters apart, which served as convenient transects for fieldwalkers to follow. Each field was covered using the trees as a guide, covering every 5 m wide corridor between rows. Where this was not possible, 5 m spacing were maintained without guides and rectified when necessary. While some rows occasionally deviated to follow the contours of the landscape, the spacing of fieldwalkers was ultimately maintained irrespective of ground cover. The lone exception was the presence of heaps of charred wood and brush left over from previous episodes of slashing and burning in plantations. These were walked along instead. Overall, the fieldwalking methodology ensured that the intensity of survey was consistent, assuming that fieldwalkers scanned a 3-5 m wide area in front of them. The level of experience of surveyors varied between first-year undergraduates to doctoral candidates.

Fieldwalkers carried a supply of labelled bags, pens with indelible ink and a notebook for recording the find coordinates, unique numerical identifier, and simple description. This information was also written on the finds bags. Coordinates were noted in decimal degrees using a Garmin eTrex handheld GPS unit. This normally achieved accuracy of 4 m, but on overcast days or when close to the canopy, this number could be up to 10 m. The coordinates of the corners of fields were noted down separately as they were reached by fieldwalkers, in order to define the covered areas in post-processing. Artefact locations are also linked to the field site (survey quadrat) in which they were encountered. For simplicity and expedience, the PME project employed four classes of artefact in the initial recording of material in the field. These are mutually exclusive, and were later corrected as necessary in the lab analysis: flakes, cores, tools and ceramics. The description of the stone artefact analysis gives more detail on how these classes are defined. All stone modified by humans above the size of 2 cm in all dimensions was collected, as were all ceramic fragments. Although establishing this arbitrary cut-off point for the collection of extremely small debitage will result in elements of technological systems such as fine edge rejuvenation being unpresented in the sample, this was deemed acceptable for two reasons: 1) the time-consuming activity of determining whether extremely small pieces of stone are truly modified in distributions containing large quantities of diminutive natural shatter, and related to this, 2) since the survey sought the coverage of large areas, in the specific case of very small (potential) debitage expediency was preferred over total collection of artefacts of dubious origin. This strategy did not prevent very small artefacts from being collected; as stated the 2 cm threshold had to be in all dimensions, meaning that very thin or narrow flakes were still collected when the other measurements were 2 cm or above. No other artefacts in different materials were encountered, with the exception of a boulder of decomposed basalt possibly used to polish stone (see Chapter 4).

The role of the spatial data collection was to create a point pattern dataset for integration with the artefact database in a geographical information system. The accuracy of each reading was dependent upon several factors, most of which are beyond the ability of surveyors to control, such as satellite positioning and availability, atmospheric conditions and variations in local topography. Unavoidable systematic error of this magnitude is acceptable for certain analyses, however, for others it is be less so. Therefore, to complement the spatial point data, a grid of 10 x 10 m squares was generated within the quadrats that defined each field site, and the number of artefacts within each grid was also counted. This dataset allows for some distance to be put between the data and the spatial variance introduced by the factors listed above. Boundaries between grid squares can be flexibly dissolved or grid squares subdivided to expand or contract the analytical scale applied to the survey data. Additionally, the centroids of grids with positive responses can be used as a surrogate point pattern for assessing coarse distributional patterns in the data (Markofsky 2010, 216), although it does limit the ability to perform other types of point pattern analyses.

3.3 Stone artefact analysis

3.3.1 Theoretical introduction

The laboratory analysis of the lithic assemblages aimed to provide an empirical basis for evaluating variability in the surface collected data from the field sites, and to provide the means to integrate these data with spatial information gathered in parallel. To this end, technological approaches, which emphasize situated action and cultural practice, afford the ability to explore reduction strategies and depositional patterns across landscape contexts. Recent reviews of "technological organization" (TO) in lithic analysis have demonstrated how large and complex this school of thought is (Andrefsky 2009; Carr and Bradbury 2011). Out of the literature, the mobility of the resource in the landscape (Shott 1986; Cowan 1999; Holdaway et al. 2010), the management of different raw materials (Andrefsky 1994; Blades 2008; Downey 2010) and how long-term depositional patterns influences place occupational histories (Henry 1989; Andrefsky 1991; Bamforth 1991; Schriever et al. 2011) are aspects of this school that relate to the aims of this research. The decision to place primary emphasis on stone artefacts follows from two main advantages that they afford: *i)* the level of preservation of lithics is superior to ceramics in the wake of plantation activity. Breakage due to the actions of tillage is in most cases easily distinguished from actual knapping in the laboratory analysis. Furthermore, *ii)* experience would indicate they are the most abundant and accessible class of pre-Columbian material culture on the modern land surface of Misiones. Taking into account the process of surface record formation, stone artefacts facilitate the development of hypotheses on how past land use may have unfolded.

The act of reducing stone into lithic artefacts is directly related to the material and environmental context of the knapper, affording the analyst the ability to infer aspects of past social systems from the final state of a given assemblage (Carr 1994, 1; Harrison

2011). In other words, the dynamics of daily life are reflected in the archaeological evidence of acquisition, reduction, maintenance and discard of lithic artefacts (Carr 1994, 1; Andrefsky 2008, 4; Grills 2008, 131). This has a direct link to the aim of this project to generate landscape-level perspectives on the regional prehistory of Misiones province, through the interrelation of deposition, land use, and the spatial organization of stone technology (see Section 1.3). As established in the previous chapter, non-site survey is atemporal and palimpsestic, but has key advantages with regard to the research problematic. Rather than describing a single story about sites in the abstract, the technological analysis is more concerned with "following the materials" (Ingold 2011) in order to define an envelope of possibilities and develop interpretations based on the exploration of "maximum likelihoods".

Consequently, this space be considered analogous to a material *habitus* (Bourdieu 1977), in which action is culturally guided and informed by the situational priorities of the knapper(s). Nevertheless, although past cultural systems were once dynamic, the priorities of the archaeologist lie where cultural and natural action shaped artefacts into the forms recovered from the material record (Knappett 2011, 47-48). The laboratory analysis therefore followed a standardized method of recording, taking a consistent set of metric measurements and additional attributes such as cortical cover and scar counts on each artefact. The database that resulted from analyzing the survey assemblages could thereby accommodate a range of measures of assemblage composition, spatial patterning and the variability between different field site assemblages. This stands to furnish a broader look than hereto possible into the processes and strategies that unfolded within the archaeological landscape.

3.3.2 Artefact categories

As the initial classification of an assemblage underpins subsequent analyses, the classificatory scheme employed here was not dependent on pre-existing typologies laden with cultural-historical significance (Rinehart 2008, 69). The significance of the principal terms used to identify artefacts – flakes, cores and tools – has only a heuristic significance in relation to their means of reduction. This is to avoid functional or behavioural interpretations of the surface record (Carr 1984; Ebert 1992; Wandsnider 1996; Connolly and Sullivan 1998). These classes have explicit assumptions about how the stone has been modified by human hands into its final form before deposition. "Types", in this sense, are a device for managing the diversity of the material record (Shott and Nelson 2008, 26), which in this case were derived primarily from the terminology of Andrefsky (2005) and Ebert (1992):

- *Flakes* are artefacts detached from a larger piece of material, exhibiting a bulb of percussion on the ventral surface. The dorsal surface may have several negative features (flake scars), cortical material or a mixture of these features. Edge modification can be present, either from use or intentional shaping, on either face and along all edges.

- *Cores* exhibit only negative percussion features (i.e. no bulbs of percussion). They can have prepared or unprepared flaking faces. As a general rule, knapping products (flakes, debitage) rather than the cores themselves are the intended end-product of core reduction.

- *Tools* are separated into <u>bifacial</u> and <u>unifacial</u> subclasses. Biface tools exhibit reduction on two sides, while unifacial tool exhibit reduction on one face only. Unlike cores, tools can possess both positive and negative percussion features, as they can be produced from blank flakes and retain a bulb of percussion as a result.

- *Other lithics* include debitage and shatter which is too small to reliably identify as modified (<20 mm), raw material transported from a source but not worked (e.g. river cobbles in an upland context). These were not collected for analysis.

These categories are construed from the processes incorporated into the biographies of the artefacts. Because a classification scheme with universal validity does not exist for flaked stone (Rinehart 2009, 69), it is reasonable to expect that definitional overlap exists in certain cases. An artefact identifiable as beginning its life as a large flake blank could in later stages be shaped into a form more appropriately described as a core (a flaked flake *sensu* Ashton et al. 1991). Likewise, flakes clearly identifiable as originating from a core could exhibit extensive retouch and therefore be considered tools. As the focus is ultimately the variability in the distribution of artefact attributes in space, however, the only provision of the schema is that consistency in analysis be maintained between site assemblages.

3.3.3 Metric analysis

The attributes to be recorded vary slightly between classes, and are described in detail in , below. The key to each attribute follows the table.

Dimensions

The basic measurements of length, width and thickness were recorded for all classes of artefacts to the nearest millimetre. The maximum linear axis was measured for all the categories. Broken artefacts received the same procedure and their condition noted. These elementary measurements of stone artefacts can provide an approximation of the volumetric characteristics the items in an assemblage. At the level of whole assemblages, they can draw out and describe broad trends in the collected data.

Mass

Mass is measured to the nearest gram for all artefacts.

Cortex

Cortex is the material present on the surface of lithic raw material due to either chemical or mechanical alteration. In Misiones the presence of cortex on basalt is due to *in situ* weathering of the native rock, resulting in a change in texture but not necessarily colour. A simple interval scale was followed to estimate cortical material on the surface of a piece: total, over 50%, below 50% and none (Andrefsky 2005, 105) (Figure 3.7). Notation of cortical material is a common way of indirectly estimating the stage or intensity of reduction which has taken place at the location of artefact deposition or, conversely, in a different locale. This synergizes effectively with other indices of reduction intensity (Dibble et al. 2005; Douglass et al. 2008; Douglass 2010).

Retouch extent and retouch type

Retouch denotes the presence of edge modification on an artefact and is recorded as two related variables: extent and type. Retouch can be the intentional shaping of the artefact or slight removals through usage. After Inizan et al. (1995), the *extent* indicates the amount of edge modification which has taken place along the margins of an artefact: total, single edge or discontinuous. The second, *type*, indicates how invasive the scars left by the retouching process are on an ordinal scale. The interplay of these factors is illustrated in Figure 3.7 and Figure 3.8.

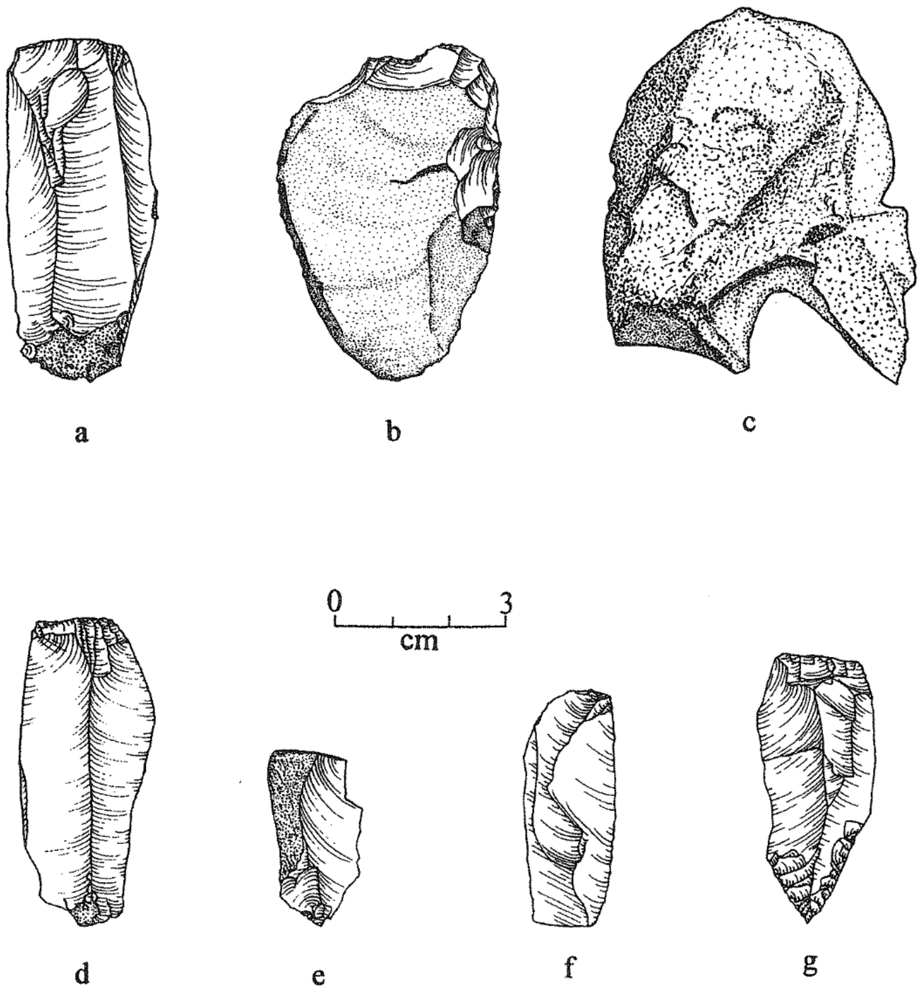
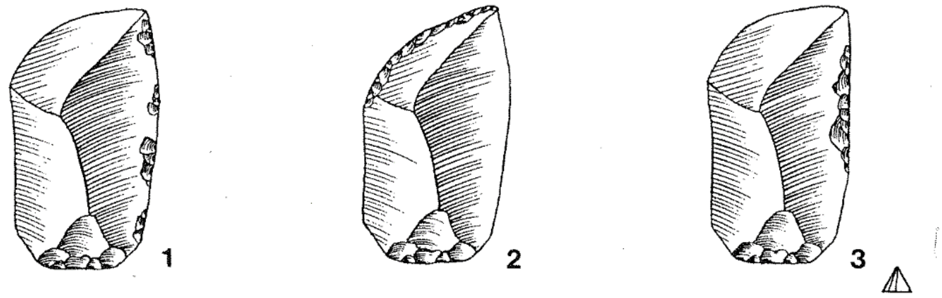
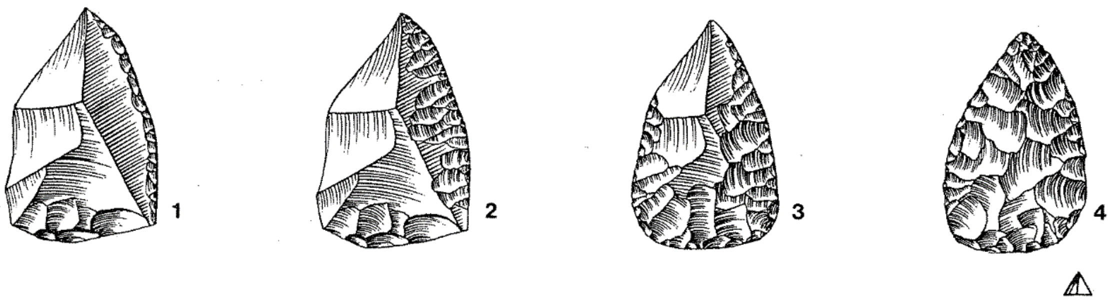


Figure 3.7: Classes of cortical cover in stone tools. (c) total, (b) above 50%, (a) and (e) below 50% (d) and (f-g) none (Source: Andrefsky 2005, 105)



Retouch type: (1) Discontinuous, (2) Total, (3) Single edge



Retouch extent: (1) Short, (2) Long, (3) Invasive, (4) Covering

Figure 3.8: Types and extent of retouch present on stone artefacts (After: Inizan et al. 1995)

Flake scars

Although the number of scars on a piece is affected by a host of complex factors (Andrefsky 2005, 107), this variable is informative if carefully defined. Consistency application is of primary importance in this regard. As a precise count of the total number of flake scars on a piece is time- consuming and difficult to do consistently (Andrefsky 2005, 109), an ordinal scale was used to simplify the process. In decreasing order, this was: three or more scars, two, one, and none. The final of these corresponds to total coverage of the dorsal surface by cortical material, meaning that the flake in question is a primary removal. Counting the number of scars on the dorsal surface of a flake has long been used as a measure of the amount previous detachment events from a hypothetical flake core, and hence the intensity of reduction (Blades 2008).

Table 3.1: Lithic classification summary table

Class	Features	Recorded attributes
Flake	▪ Bulb of percussion present (ventral surface) ▪ Only negative percussion features on dorsal surface ▪ Edge modification may be present	Dimensions Mass Cortex Retouch Type Extent Flake scar count
Core	▪ Flakes detached from only a single surface ▪ No bulb of percussion ▪ Prepared or unprepared flaking surface	Dimensions Mass Cortex Scar count
Tool	Type A – Bifacial ▪ Flakes detached from multiple surfaces ▪ Bulb of percussion may be present ▪ Edge modification may be present Type B – Unifacial ▪ Flakes detached from single surface surfaces ▪ Bulb of percussion may be present ▪ Edge modification may be present Other ▪ Hammerstones ▪ Anvils	Dimensions Mass Cortex Retouch Type Extent
Other	Modified – shatter/debitage ▪ Abundant, but impossible to distinguish as cultural or natural ▪ Extremely small ▪ Not recorded or collected Unmodified – native cobbles ▪ Native material with water-smoothed cortex ▪ Deposited by human transport away from riverine origin ▪ Not recorded or collected	None

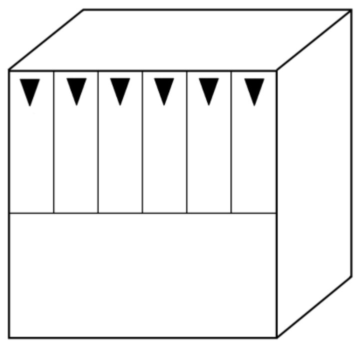
Raw material

Although the variability in raw material can provide valuable information on resource management and mobility (Andrefsky 1994), to date few stone artefacts encountered in Misiones have been observed to be produced from any material but the native red or reddish brown basaltic rock. This can vary in colour to brown, grey or black, yet red is by far the most common. The apparent lacuna could be due to the high local abundance of good quality knappable stone, or perhaps from relatively low levels of inter-regional exchange. In any case, experience suggests that the pre-Columbian lithic record of Misiones is almost uniformly basaltic in nature. It was therefore redundant to record this attribute in all cases. It was only noted down in exceptional cases, such as striking differences in texture or colour.

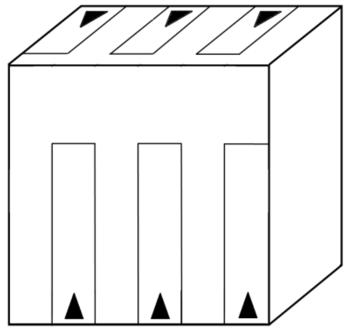
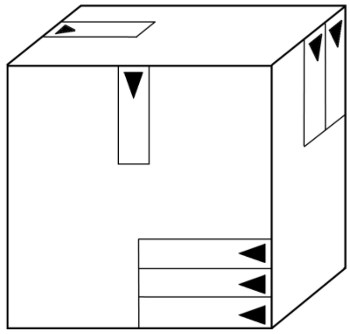
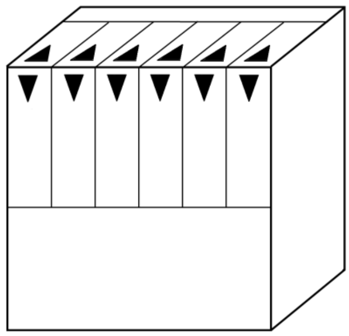
3.3.4 Core classification

In addition to the metric measurements above, a sub-sample of cores were subjected to a separate effort at classification. This was carried out while the metric analysis was in progress, as the chosen method was not able to fully characterize the variability in core reduction strategies on its own. The core assemblages from two field sites, Aumer I (MPM015) and Ziegler II (MPM018), were therefore selected for their sizes in the context of the relative richness of the field site records in general. This focused analysis augmented the database of lithics substantially. Due the lack of an established convention for describing flake and core reduction systems in the study region, the classification scheme was simple and aimed to synthesise the wide range of informal core morphologies into a small number of categories (Table 3.2). This was achieved by drawing upon the scheme of de la Torre and Mora (2005). As one of the goals is to develop an understanding of the spatial relationships between knapped pieces and knapping products, bifacial reduction (only applicable to tools) and their pre-forms is included for completeness below.

Table 3.2: Core reduction strategies identified in the sample (after de la Torre and Mora 2005).

Strategy	Description	Scheme
Unidirectional	Single striking platform in the horizontal plane from which flakes are detached.	

N.B. Table continues on next page.

Alternating	Systematic changing of striking platforms by alternating	
Multiplatform	Multiple striking platforms located on independent planes resulting from multiple rotations of the core.	
Bifacial	Two striking platforms circumscribing the artefact which together form an edge.	

3.4 Summary

This chapter has defined the means to create an interface between TO approaches to lithic analysis and spatial point pattern analysis from the results of the Piray Mini Exploration project fieldwork. The advantages of the method have been explained with reference to the unique challenges of archaeological data collection in Misiones province, as well as the research objectives.

The next few chapters will focus on developing an understanding of the data which resulted from the above data collection strategy. The upcoming chapter is concerned with describing the immediate outcomes of the fieldwork in terms of its coarse distributional patterns and structure of the field site assemblages. Landscape taphonomy and record formation processes will also be evaluated. Chapter 5 will analyze the lithic data in detail in order to provide a deeper understanding of variation in technological strategies across the study region. Chapter 6 develops the spatial analytical component of this research, which will first seek to characterize spatial dependency in the dataset using measures of spatial autocorrelation. Specifically, a family of spatial statistics derived from Ripley's K function (Ripley 1976) and the pair-correlation function $g(r)$ (Stoyan and Stoyan 1994) will provide the statistical basis for assessing spatial trends within field sites and for making comparisons between them. Secondly, the surface record will be approached with fine-grain by testing for spatial trends between technologically-sensitive traits of the lithic assemblage with the bivariate K function. Finally, local interaction will be considered through local indicators of spatial autocorrelation (LISA) to evaluate the concept of noise in surface archaeological data.

The PME project data collection strategy diverges from previous investigations in Misiones in three key aspects. First, the survey method is standardized and the intensity of survey is held constant between sites, both in order to enable greater comparability between field sites. Second, data from the lab analysis are closely integrated with the spatial data collected in the field. Finally, the strategy as a whole has an exclusive focus on surface collected data. This is due to the effect of modern land use on subsurface stratigraphic relationships, the general lack of horizons in the Misiones soils and the overall focus on non-site analysis and interpretation of this research project.

Recognizing the necessity for extensive coverage of the landscape of Misiones, and in absence of subsurface data, these mutually-reinforcing lines of evidence can provide a strong first step towards apprehending trends and patterns in pre-Columbian land use. In summary, the 2010 surveys provided a set of general guidelines for the PME project as to what worked well and what did not, in terms of the particular circumstances of archaeological fieldwork in Misiones. As outlined here, this had a strong influence on the decisions taken both before and during the PME project. Although the survey and laboratory analysis are primary components of this research, their main function is to support and enable the technological and spatial analysis of the archaeological landscape of Misiones province. With the historical lack of preceding research in the study area, this will be necessary from the viewpoint of capitalizing on the outcomes of the season of systematic survey that was achieved in June-July 2013.

4. Survey results

4.1 Overview

The fieldwork of the *Piray Mini Exploration project* was carried out between 17 June and 15 July in Eldorado Department. The reconnaissance and systematic surveys took place almost entirely between the left bank of the Piray Mini and the right bank of the Piray Guazú. In this time, the team visited and surveyed a total of 18 field sites with a combined area of approximately 1.36 square kilometres. The goal of the project was to achieve total collection of all observed archaeological material in order to characterize pre-Columbian deposition and land use in the investigated areas. The survey methodology was consistent

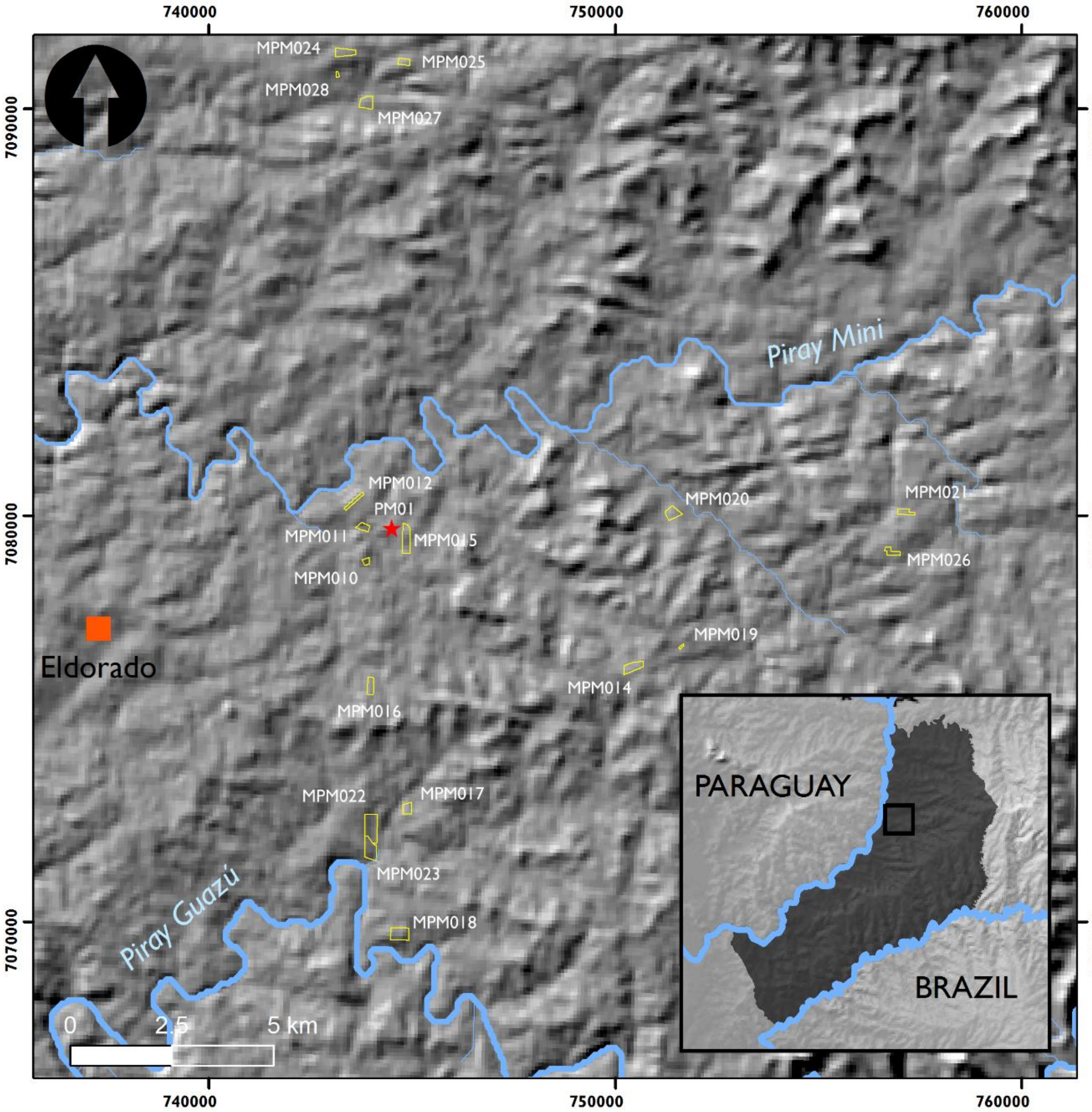


Figure 4.1: Distribution of field sites within the study area in the hinterlands of Eldorado city, Eldorado department. Note that MPM022 and MPM023 are immediately adjacent to each other. Inset: Location in north-western Misiones province.

between field sites with different modern land uses. Additionally, a southern proto-Jê mound and enclosure complex (Circle 8) was partially excavated during the fieldwork. This is reported on in Appendix B.

At the point of completion of the surveys, 927 individual spatial data points were collected. The vast majority of the physical assemblage was stone, in addition to a negligible amount of pottery (82 sherds, <1 kg total mass). Artefacts were catalogued and processed in the field laboratory using the methods described in Chapter 3. This chapter uses the term "total survey assemblage" to denote the complete lithic dataset used in this research for studying the surface record of Misiones. Although density of material is generally low, the spatial distribution of the total survey assemblage is broad and highly heterogeneous (Figure 4.1 and Section 4.4). Due to the method being applied consistently between field sites, the individual datasets are comparable within the same framework. Section 4.3 introduces and discusses some important caveats on record formation, following field observations made during the survey. Throughout this chapter, 'site' or 'field site' is used to designate areas where survey was carried out by the PME project. In line with the non-site perspectives used for this investigation (Dunnell and Dancey 1983; Ebert 1992; Schlanger 1992), these serve as shorthand terms for the units of coverage rather than as an epistemological assertion of the existence of (discrete, time-bounded) archaeological entities on the modern surface of Misiones.

The locations visited for survey depended primarily on the logistics of site access and the type of land cover, as discussed extensively in the previous chapter. The second of these factors had the greatest influence on the final shape of the survey, as travel time and landowner permission were not significant obstacles. It can be considered analogous to the likelihood of discovering a location during reconnaissance with land cover amenable to survey. Although the Alto Paraná is widely cultivated, fields will be in different stages of growth at any one time. Yerba maté and manioc fields are accessible irrespective of the age of the plant, due to the plant essentially being a bush or low shrub. The sparse and low ground cover of these crops present good surface visibility in ploughed fields, and are planted spaced by 4-5 meters in a manner similar to pine. Pine plantations beyond a certain age have ground cover that renders survey fruitless. Regular pruning and clearances of the brush leaves a carpet of decomposing vegetation on the surface that mixes with the large quantity of pine needles shed from the trees. The newest and youngest plantations (<2 years old) do not share these qualities. The ability of the project to locate these types of fields was therefore the strongest conditioners of the survey. Although stratified random sampling would be ideal to acquire data on a variety of landforms under different conditions (Orton 2000, 30), in the end the survey resulted in a distribution of field sites broadly spread out over a variety of topographical and geomorphological settings. In the end, the survey as actually performed resulted in an adequate sample of the study region. These aspects of the sample are discussed in detail below. The selection of field sites, while not random, is distributed satisfactorily with regards to the constraints of the PME project survey. In light of the limited history of systematic research across this region, these are acceptable limitations of data collection.

This chapter will describe the findings of the survey and sketch the nature of the material encountered. It also deals with the representativity of the archaeological sample in light of introduced and induced biases.

4.2 Description of cultural material

Of the total number of data points taken and collected in the field, 736 correspond to the lithic find locations constituting the final dataset. This is due to using the handheld GPS unit to mark the corners of fields during survey and points of interest during reconnaissance. Furthermore, opportunistically collected material was point-plotted where encountered. Though interesting, these finds cannot be incorporated into the same spatial framework as the survey assemblage due to their less secure spatial context. Out of the locations surveyed, only those of MPM010 and MPM019 resulted in the collection of no artefacts whatsoever. MPM013 (not listed) is the code for the southern proto-Jê mound and enclosure complex, named Circle 8 in Wachnitz' convention (Wachnitz 1984).

Table 4.1 summarizes the cultural material, land cover and extent of survey by site. The breakdown demonstrates that large differences exist in the distribution of surface material. This is commensurate with the expectations of the appearance of the surface record outlined in Chapter 3; a low-density "carpet" of artefacts punctuated by the appearance of areas with higher concentrations of cultural material. The area surveyed by the PME project is only a small fraction of the Alto Paraná valley that is located within Eldorado Department. The types of field sites visited, however, can be considered representative of the environment as a whole. The topographical and geomorphological aspects of the survey are discussed in greater detail below. Riverine settings, the foothills of the Sierra Central, inter-fluvial ridges and floodplains are all in the sample of field sites. Second, the survey included areas with a variety of modern land uses, which are assessed under the topic of record formation processes and biases.

Table 4.1: Summary of field site and artefact data.

Field site	Area (km^2)	# Artefacts	Artefacts/m^2	Flakes	Tools	Cores	Ceramics	Land use
MPM010	0.0226	0	0	0	0	0	0	Plantation
MPM011	0.0441	35	.00079	23	2	10	0	Mixed
MPM012	0.0402	4	.000099	3	1	0	0	Plantation
MPM014	0.0938	2	.000021	1	0	1	0	Agriculture
MPM015	0.129	231	.0018	180	14	34	3	Mixed
MPM016	0.0616	39	.00603	7	3	1	28	Plantation
MPM017	0.0573	6	.0001	4	1	1	0	Agriculture
MPM018	0.132	137	.001	71	20	46	0	Plantation
MPM019	0.0628	0	0	0	0	0	0	Barren
MPM020	0.0821	4	.000049	0	0	4	0	Plantation
MPM021	0.0471	4	.000085	2	2	0	0	Agriculture
MPM022	0.192	61	.00031	24	9	14	14	Plantation
MPM023	0.131	112	.00089	71	11	28	2	Mixed
MPM024	0.0817	44	.00053	11	0	0	33	Barren
MPM025	0.0417	4	.000096	2	1	1	0	Barren
MPM026	0.0454	3	.000066	0	1	2	0	Agriculture
MPM027	0.0866	18	.00021	8	5	5	0	Plantation
MPM028	0.0092	32	.0034	20	1	9	2	Plantation
Total	1.3602	736		426	71	156	82	

It was noted above that the Southampton-INAPL collaboration involved the rediscovery and excavation of a southern proto-Jê mound and enclosure (MEC) in Eldorado Department (see Appendix B). After Menghin's initial recording of the PM01 mound complex, six of the eight MECs were destroyed at unknown points in time by intensive ploughing. At the time of rediscovery in 2006, only parts of the large central MEC (PM01) and the monument hereafter referred to as Circle 8 remained in a relatively good state of preservation (Wachnitz 1984; Iriarte et al. 2008). In the present day, Circle 8 is located in a mature stand of eucalyptus trees with an area of approximately 6 hectares. The understory of this plantation is not maintained and presents a significant obstacle to pedestrian access. Even for skilled *macheteros* the rate of movement through the forest is affected, and visibility is poor beyond 5 meters. Thick brush and a layer of decaying organic matter impede vision of the ground.

To understand the impact of non-site discovery methods in terms of information yield, it is useful to bear these observations in mind when considering the ancillary survey to locate Circle 8. The height of the central mound feature above the forest floor was eventually measured at 1.6 m, and took a team of three surveyors two full working days to conclusively locate in a relatively small parcel of land. Despite possessing directions and photographs of the site (J. Iriarte, personal communication), the ability to carry out archaeological survey in areas with any significant ground cover is curtailed to a great degree. By taking advantage of comparatively open terrain in the systematic survey, the number of georeferenced artefact locations in Misiones was increased by a factor of one and a half over the 2010 survey (see Riris 2010b). On the basis of raw numbers and time expenditure alone, plantation and agrarian survey can be seen to boost the level of archaeological knowledge on a regional scale substantially.

4.3 Record formation processes and biases

Multiple natural and cultural processes affect how cultural material is perceived on the surface in the study area. This section evaluates a specific set of factors in order to develop a clearer image of how to characterize the field site assemblages in a spatial non-site framework. Establishing the viability of these methods in tropical settings is a crucial part of this exercise. While this project specifically avoids conceptual biases (*sensu* Van Leusen 2002) such as claims to discover and analyze "sites", or over-emphasizing putatively diagnostic artefacts, a number of observational biases remain. The agencies operating on the formation of the material record that place at multiple temporal and spatial scales. Collectively they introduce a boundary between the ancient practices and processes that produced the archaeological record and the archaeologists whose goal is to understand it (Schiffer 1972; Wood and Johnson 1978; Lewarch and O'Brien 1981). Moreover, no archaeological survey can claim that 100% of a given coverage was sampled. Training and level of experience also vary between and within teams. Biases in survey design like these are addressed in detail in two conceptually distinct sections.

4.3.1 Record bias

Record bias is defined as the post-depositional processes that operate on the archaeological record. A conceptual difference between cultural and natural effects is not employed here (see Schiffer 1988), preferring simply to discuss them together. Following observations in the field, three principal formation processes are identified in the PME project study area. The soils in all field sites were the deeply weathered ultisols and oxisols typical of the province which are composed of fine-grained red silts and clayey silts (Morrás et al. 2009).

Tillage of the soil, as noted, is widespread in Misiones. Indeed, the PME survey targeted locations under cultivation exclusively. Differences exist between fields, however, depending on the priorities of the cultivators or landowners. Smallholders, meaning farmers not tied to a cooperative or contracted by larger corporations, were for instance observed planting manioc between rows of pine saplings (Figure 4.2). Combinations of cultivars create types of coverages that are different from pure plantations, for the purposes of survey. Two other lot management strategies were observed that alter visibility: *(1)* herbicides significantly thin the growth of non-arboreal plant species in fields, facilitating visibility of the surface, and *(2)* piling up burnt organic matter in rows after clearing a field for cultivation obscures the surface of specific transects. The former is almost universal in new fields, so economic species are not outcompeted by the vigorous annual growth of native flora. The latter, creating heaps of charred trees in linear arrangements, has a serious effect on the coverage of survey where present. In one field site in particular, Ziegler III (MPM022), one transect in ten was totally inaccessible to surveyors. This field site was the only surveyed location where heaping had a significant effect on surface visibility, resulting in approximately 10% reduction in intensity.

Three types of cultivated fields are distinguished between here: plantations, agricultural fields and mixed fields (Figure 4.2). Barren fields are suggested as a fourth type, but in all observed instances these were essentially agricultural fields that were prepared but not yet planted. They are therefore best thought of as a subtype of agricultural fields with near-ideal surface visibility. Plantations are open fields with rows of *Pinus* saplings (no other tree species was encountered, although *Eucalyptus* and *Araucaria* are both grown in Misiones), where the undergrowth is managed for the first few years of tree growth. These fields are subject to burning of the native vegetation, after which they are tilled to a depth in excess of 50 cm.

Figure 4.2: Different types of modern land use in Misiones. Clockwise from top-left, Plantation, Mixed (plantation with manioc), Barren and Agriculture (yerba mate field).

All the surveyed fields with cultivation were either manioc (*Manihot esculenta*) or yerba mate (*Ilex paraguariensis*). Two barren fields (MPM024 and MPM025) were in the process of conversion to maize fields. Informants confirmed that the tillage in agricultural fields is shallower than in plantations, but could not give an exact depth. In the case of Aumer I (MPM015), tillage by hand before planting manioc was observed. Annual or semi-annual growth cycles are associated with subsistence and cash crops such as these. It can be inferred that while tillage in these locations affects the soil profile to a lesser depth, there is a much shorter interval between each ploughing event in comparison to plantations. Finally, mixed fields are young plantations where the spacings between rows of saplings have been turned over to cultivation, for reasons of profit maximization and soil retention. This adds an additional obstacle and visual impediment to surveyors. After the initial ploughing event for the plantation, the spacings were observed to be tilled by manual labour. It can be assumed that after a certain age, pine trees will out-compete cultivars for nutrients and sunlight. Although this would make it a less viable management strategy with time, mature pine were observed with yerba mate interspersed, indicating that these shrubs may only be planted (and the ground tilled) once. Manioc would require re-tilling by hand after every harvest.

Under all types of cultivation, however, ploughing destroys soil horizons and collapses the temporal axis of the archaeological record by mixing material of different stratigraphic depths. Radiometric dating of deposits is rendered useless and cultural features are obscured or erased (Roper 1976; Lewarch and O'Brien 1981; Dunnell and Dancey 1983; Steinberg 1996; Navazo and Díez 2008). Taphonomic and experimental studies have long sought to quantify and control for the effects of tillage (see Lewarch and O'Brien 1981; Wildesen 1982; Francovich et al. 2000). For present purposes, the most important finding of these investigations is that the effects of tillage are not random, nor do they induce randomness in an archaeological population (Cherry et al. 1988, 170). In addition to tillage, erosion and surface relief are the most important factors biasing the perception of surface material in the present day. Together, these three processes affect the movement of cultural material and modify artefact positions and proportions as a result. Figure 4.3 presents a synthetic model which summarizes the main points visited below.

Movement of material can of course occur in both lateral and vertical directions. Experiments on site formation in agricultural contexts have confirmed the intuitive expectation that lateral displacement follows the direction of tillage (Roper 1976). This "average cumulative displacement of artefacts" (Odell and Cowan 1987) has been found to peak and attain equilibrium in a relatively small number of ploughing events. As a result, the final horizontal distance from the original locus of deposition of an artefact is argued to be no greater than 2 m in any direction, irrespective of how "ploughed out" the surface context becomes (Odell and Cowan 1987, 481; Navazo and Díez 2008, 331). All else being equal, this body of work on surface record formation implies that the relative spatial positioning of a given distribution of artefacts remains for the most part intact, at least at a large scale (Bintliff and Snodgrass 1988, 508; Steinberg 1996; Taylor et al. 2000). As discussed below, this is not necessarily the case in the sites surveyed, as several other post-depositional processes have potentially altered artefact locations. Furthermore, this is not applicable to features whose definition is naturally dependent upon their coherence, for instance a hearth or stone tool cache. It can be surmised that artefacts recovered from tilled surface contexts retain the potential to contribute to our understanding of the landscape as a palimpsest of past occupations, movements and processes. Although a fine-grained investigation of surface material cannot be achieved, large-scale patterns and relationships hold within tilled areas (Steinberg 1996, 370). The challenge, then, becomes to characterize the variability in these aspects of the material record from place to place using appropriate methods (Holdaway and Wandsnider 2006, 192).

Second, a relationship has long been posited to exist between the size of an artefact and its relative vertical position in ploughsoil. The presence of such a "size-sorting effect" meant, in its original conception, that large subsurface artefacts are disproportionately exposed on the surface by tillage due to a greater likelihood of being caught by mechanized farming equipment (Baker 1978; Lewarch and O'Brien 1981, 310). In turn, this increases the probability that they are encountered during survey. More recent work overturns this and argues convincingly that tillage actually has the effect of forcing small artefacts downwards in the soil profile. This would in effect increase the probability of retrieval of large artefacts by eliminating many smaller artefacts from the sampling population (Navazo and Díez 2008, 331). In effect, the results are similar to preceding taphonomic studies but with different consequences for interpreting surface record formation. The inversion of the topsoil also eliminates vertical relationships between artefacts, a problem compounded by surface deflation or formation by erosion (Steinberg 1996).

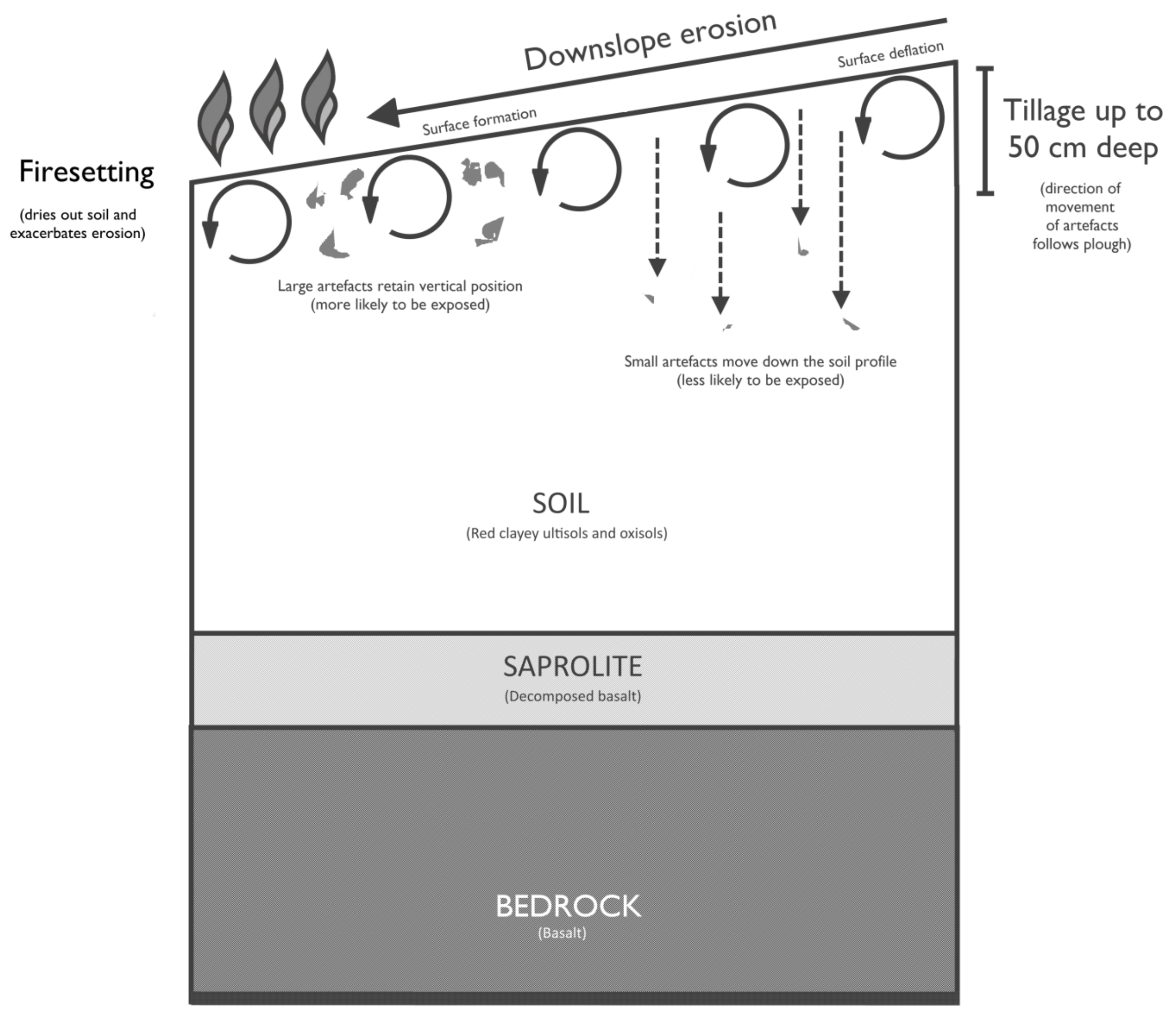


Figure 4.3: Model of field site soil profile, showing major processes that may affect surface record formation: tillage, downslope erosion (due to rainfall and topographical relief), and firesetting. Not to scale.

Erosion is likely not a significant contributor to record formation in areas of native *monte* forest, except for general movement of small artefacts downslope (Rick 1976; Fanning and Holdaway 2001). Vegetation mitigates the effects of direct water transport of artefacts, and reduces erosion through soil retention. Where the forests have been removed, as is the case for the field sites, this does not hold true. While there are many factors influencing the erosive potential of soils, tillage raises their susceptibility to these processes to a substantial degree (El-Swaify 1997; Bryan 2000). Furthermore, an additional effect in play in Misiones is due to firesetting in the waste vegetation that results from forest clearances. Intense heat leads to crusting of the topsoil, which accelerates alluvial erosion and gullying, which has been observed in Misiones specifically (Eidt 1971, 138; Johansen et al. 2001). Reports by Rau (2005, 99) suggest that clearances and burning is performed in July-August, before the wettest period of the year begins. The consequences of the high volume of annual rainfall and runoff in Misiones was observed to be particularly egregious where either *a)* there were pre-existing natural dips in the surface or *b)* where human activity, especially paths and trails, had previously cut some way, usually no more than a

Figure 4.4: Moderate gullying observed in dirt track between plantation stands in MPM018.

few centimetres, into the soil. Further illustrating this point, plantation roads in the 2010 pilot survey were subjected to a "grab" collection which sought total recovery of all cultural material at the expense of detailed recording. At its conclusion, over 2000 artefacts were collected in MPM003 alone. In comparison, 450 find locations were recorded in the systematically surveyed portion of the field site (Riris 2010b). The surface in this area was far less deflated, and despite a much wider area being intensively investigated, uncontrolled road surveys appear to yield a disproportionate number of artefacts relative to the investigated area, likely due to surface deflation.

To explain this, may be useful to make a comparison with Foley's (1981b, 177-178) discussion of artefact visibility in eroded surfaces. This model deduces that a lower volume of soil relative to the surface area investigated (i.e. in a survey of a deflated surface) would increase the perceived abundance of artefacts, due to increased likelihood of exposure (Figure 4.5). Although this effect was considered on a geological timescale and at a regional level, it may be suggested that the short-term erosional processes operating on cleared areas in Misiones could have produced a similar end result through the removal of topsoil due to heavy episodes rainfall. Water transport also disproportionately affects small artefacts over heavier ones (Shott et al. 2002), as well as artefacts lying on slopes (Gouma et al. 2011). The cumulative effects of rainfall therefore have the ability to expose

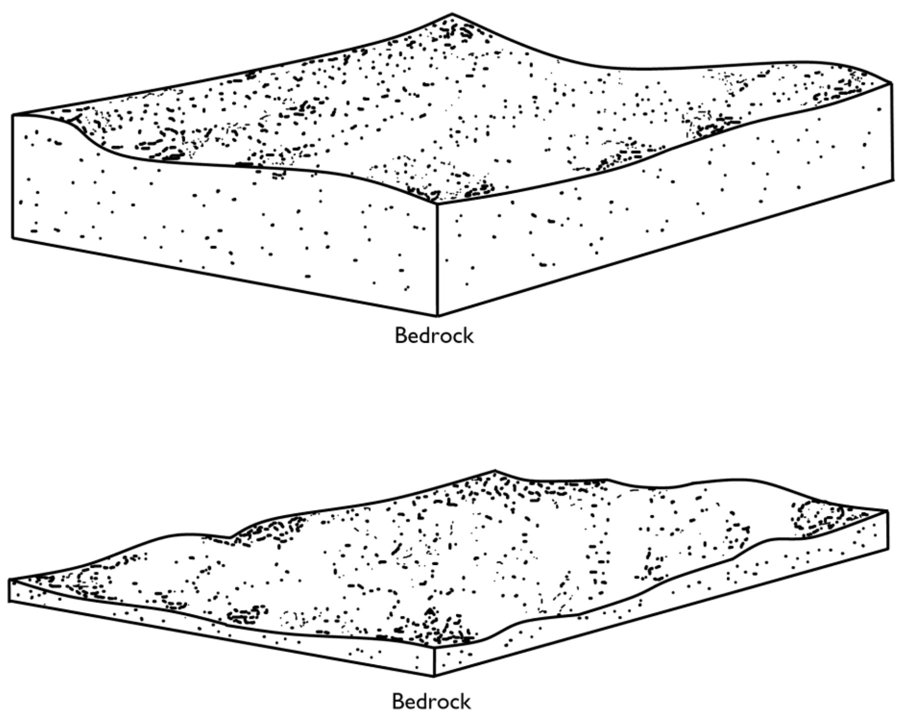


Figure 4.5: Effect of a lower volume of soil on the visibility of artefacts on a surface. After Foley (1981b)

and to move artefacts further from their original loci of deposition than ploughing can alone. Small artefacts, once exposed, can be expected to move downslope at a faster rate than heavy artefacts (e.g. lithic cores) and covered by waterborne sediment as part of surface formation. The large artefact inventories collected along roads and ditches in 2010 were likely to have been recorded due to the effects of several mutually-reinforcing natural and man-made processes.

Returning to the PME project, a specific example can be used to illustrate the some of the potential effects of these types of record formation processes on the archaeological population. The survey in MPM022 (see Table 4.1) yielded 46 cores. Lab analysis revealed that the minimum number of detachments per core was 2 and the maximum was 20, with an average of exactly four removals. Following McNabb (1998), this would suggest that the total number of flakes in the assemblage is between 92 and 920. Comparing this to the actual quantity of recorded flakes in MPM022 ($n = 71$) makes it apparent that these numbers cannot be reconciled and that additional forces must be at play. Although this may also be due to other induced factors related to record formation (e.g. selection of flakes for use elsewhere) or imperfections in the sampling design, it is worth highlighting the fragmentary nature of the assemblage due to the site formation processes outlined above. Constructing interpretations on land use and discard will necessarily be a tentative exercise.

Different modern land uses have different effects on record formation. Running an analysis of variance (ANOVA) on the number of recorded artefacts by land use suggests that the type cultivation has had a significant effect on the final number of artefacts recorded by the survey (Figure 4.6). The result shows that fields under "Agriculture"-type cultivation yielded much fewer artefacts on average, perhaps related to the shallowness of the tillage. Barren fields, being Agriculture-type without any cover by vegetation, have a higher number of artefacts recovered on average when compared to the former. Plantation- and Mixed-type field sites are subjected to tillage which affects artefact exposure and erosion to a much greater degree than shallow agricultural tillage. A post-hoc Tukey's HSD test of the ANOVA indicates, however, that the only significant difference between factor variances is the pairing of Mixed-Agriculture ($p < .05$), as suggested by the tremendous differences illustrated in the graph. Together with the Mixed-Plantation and Mixed-Barren pairings being slightly significant (albeit only at the 0.1 level), these results suggest that surface archaeology in Mixed fields is quantitatively different from the rest of the surface record. Obviously, the large variance is related to the underlying archaeological population. Perhaps the most remarkable result is the jump in absolute numbers of artefacts recovered in Mixed fields versus Plantations; these are fundamentally very similar types of surface, with the addition of tillage by hand to plant subsistence crops. It is unlikely that this alone can account for the observed differences, and is more likely to be related to the structure of the sampled population.

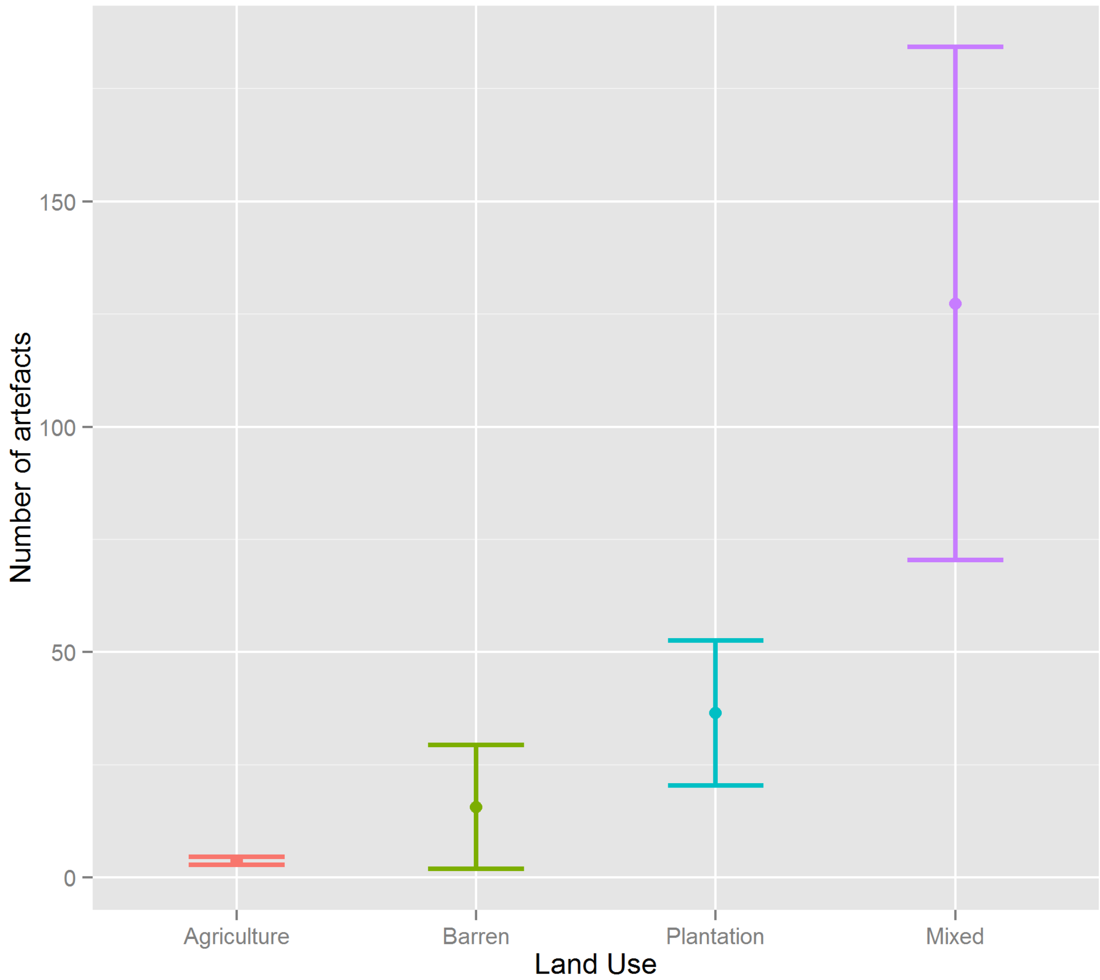


Figure 4.6: Summary graph of ANOVA performed on artefact numbers by modern land use. Points are field site means, whiskers represent the standard deviations of the datasets. Variance is significant ($F_{1,3} = 4.003$, $p < 0.05$) between land uses.

Finally, material recycling and artefact reuse can affect the structure of the surface record, potentially introducing bias through the selective alteration of deposited material (Camilli and Ebert 1992). Detection of this activity is problematic in deposits lacking an absolute chronological context, but is discussed here due to some noteworthy finds of the PME survey.

The surface of the artefact in Figure 4.7 is weathered and smoothed by water action. This is likely the result of deposition and prolonged immersion in a river or stream; no analogous form of mechanical or chemical was recorded on any other artefact in the total survey assemblage. As a result, the removals indicated in the above image were made following the original episode(s) of deposition. These are not random flakes detached due to post-depositional movement, but represent the intentional rejuvenation of what was formerly a cutting edge. In another case, the edge of a biface was used as a platform for regularizing flake removals in a single direction. All were recorded as tools. The total assemblage only contains three examples of this kind of recycling, all on artefacts that

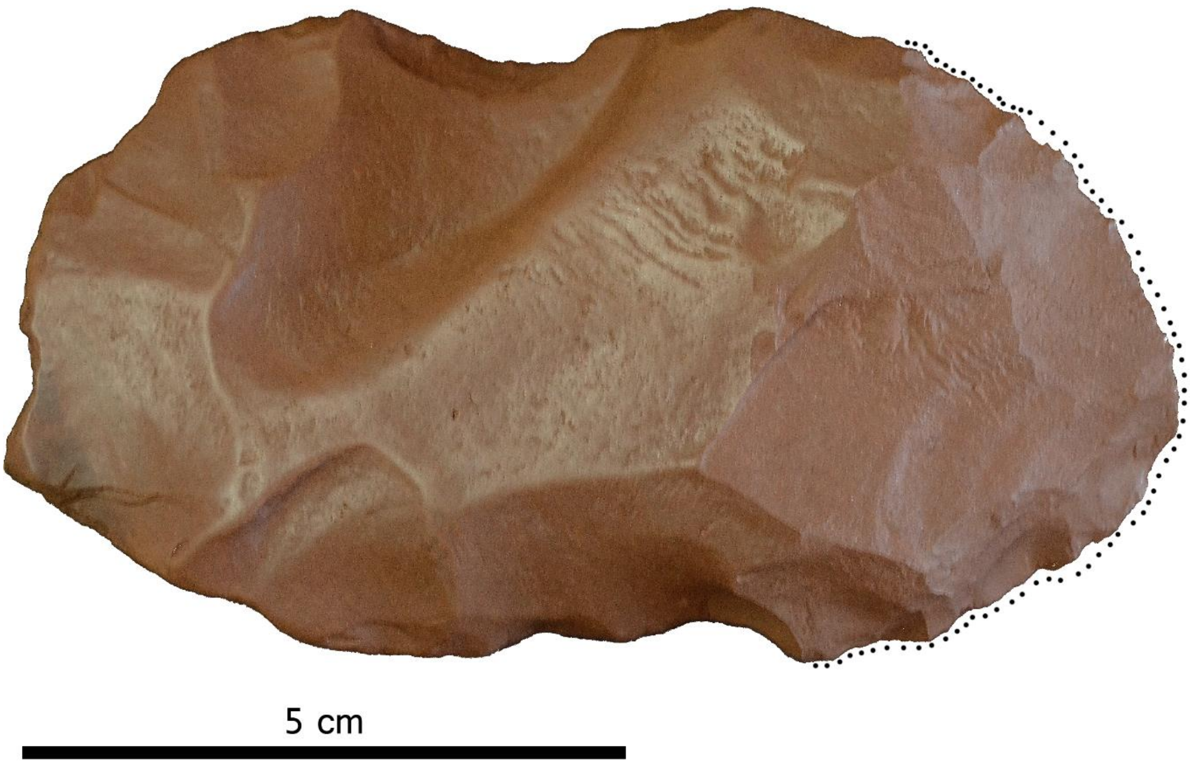


Figure 4.7: Weathered and smoothed bifacially flaked artefact, with more recent removals from the edge indicated by the dotted line.

were originally worked as bifacial tools. This suggests that recycling was an uncommon, but nonetheless present, activity in the landscape of Misiones. The PME dataset is not suited for drawing stronger conclusions about the true extent of artefact re-use. The term "mining" (Carr 1984, 123) to describe re-use of artefacts implies a level of economic intent that is difficult to infer from the limited amount of evidence collected. The evidence does, however, imply long-term settlement and visitation of places in the landscape (Schlanger 1992; Camilli and Ebert 1998).

4.3.2 Researcher bias

The design of the survey itself had effects on the shape of the final survey assemblage. All the accessible terrain encountered in the surveys was fieldwalked in 5 m spacings and crew were instructed to sweep 5 m wide transects. Between 2 m and 4 m function as upper and lower estimates of the maximum amount of actual area surveyed. Assuming for sake of argument that bare earth was being surveyed, this equals 40-80% of the total area (1.36 km^2) actually being viewed with the possibility of encountering archaeology. In most cases the percentage of ground actually seen by any given surveyor is likely much less.

Observational bias as defined by Van Leusen (2002, 7) is concerned with the ability of a given surveyor to record archaeological data, all other factors being equal. In the most important sense, surveyors may vary a lot in levels of experience and archaeological knowledge, and hence in their ability to "get an eye in" to the area being surveyed. Van Leusen (2002, 7) also rightly points out that the stature of field crew can have an effect, as an increase absolute distance from the prospected surface would diminish how much detail can be cognized. This is supported by findings of experimental crawl surveys (e.g. Burger et al. 2002). In this case, crawling resulted in a 3.5 times increase in the number of recorded artefacts over walking in the same space, due to ground proximity and time spent per unit of area (Burger et al. 2002, 416). As the crew were at different stages in their professional development (two undergraduate students, one postgraduate and two doctoral candidates), care was taken to rotate surveyors between different field sites and transects within sites. As already noted, the soils of Misiones are a deep red-brown. The

Figure 4.8: Basalt core encountered on surface, salient against the exposed soil. Exposed side is cortical material exhibiting some battering.

most common raw material for lithic artefacts is the native basalt (Figure 4.8). The contrast between the soil and lithics makes this class of object very obtrusive to any surveyor due to the colour and lustre of the rock. Consequently, the PME lithic assemblage likely represents the majority of the archaeological population that was actually exposed on the surface at the time of survey. With reference to Taquara/Itararé tradition pottery, which was the only type recorded during the survey, ceramics appear much less visible against the soil. The colouration of these ceramics matches the ground, and pots are fragmented to a great degree. This makes detection difficult even to experienced crew, and this class of artefact is likely underrepresented in the total survey assemblage. Because the focus of this thesis is lithic technology, the relative absence of ceramic data is not an analytical problem.

4.3.3 Summary

The surface record of Misiones has been shaped by a combination of natural and anthropogenic factors. This has altered the archaeology in several important ways, which have been discussed in detail here. Tillage and post-tillage environmental processes are expected to have introduced the most far-reaching changes to our perception of the surface record, most notably in terms of assemblage composition. Secondary impacts, such as exposure by erosion and artefact recycling also affect the surface record as it is encountered in the present, but are minor in comparison to the effects of deep ploughing.

The field sites, while unequal in many respects, were surveyed with the same intensity throughout the fieldwork. While the identified biases clearly affect the nature of the PME archaeological sample, the individual site assemblages retain comparability due to having a low degree of *relative* bias with regard to the collection strategy. As the compositions and spatial properties of full site assemblages are being compared, the results of the field survey are less confounded by design than they might be (Orton 2000, 165), as in preceding projects in Misiones (see Riris 2010b). Cultivated areas in Misiones have a clear value as hugely productive areas for archaeological survey, chiefly in terms of the extent of coverage, but also the massive increase in the numbers of recorded artefacts. Coupled with the relative accessibility of cleared zones and the low level of archaeological knowledge in the province in general, analyzing the results of this strategy will be instrumental to gaining deeper insights into the pre-Columbian landscapes of Misiones.

The surface record is a valuable archaeological resource in a dynamic geomorphological landscape. Although artefacts that were deposited millennia apart may have been recorded by the PME project in close spatial proximity, the non-site approach enables analytical insights to be sifted from the data in spite of the deep time involved in the genesis of this palimpsest. Viewed in aggregate, the components of admixed technological systems may still retain their distinctive topologies and horizontal relationships to one another (Douglass 2010, 47). The challenge for the upcoming research is to thoughtfully apply appropriate procedures for disentangling complex information in the absence of traditional stratigraphic or chronological data. This requires moving from coarser to finer scales of analysis, beginning with the distributional qualities of the total survey assemblages. The approach adopted here towards controlling for surface formation processes is to examine the scale of spatial patterning within and between different components of the surveyed field sites, and to put forward plausible cultural and natural causes for their formation (Ebert 1992, 212-213).

4.4 Assemblage distribution

The above discussion of biases, seen mainly through the lens of formation processes, has helped to contextualize the results of the PME project survey in their modern landscape setting. Bearing the highlighted issues in mind, this section aims to characterize the raw distributions of the survey assemblage by the categories that were recorded in the field: flakes, cores, tools and ceramics. In addition to the case made throughout this research for landscape-level comparisons between surface assemblages, the richness of the record provides an unparalleled point of departure in the study area for enabling answers to be pursued. Before examining individual field sites, a brief attempt at landform classification will seek to draw some generalizations about the types of terrain that field sites were located on. The Alto Paraná valley, although low-lying and with gentler relief than the Sierra Central, has a variety of geomorphological units whose definition is best handled through specialized computational analysis than through subjective judgement (Murrieta-Flores 2011, 93). This will in turn enable a more detailed discussion of the landscape under study.

As already discussed and shown in Table 4.1, major differences in assemblage compositions exist between areas of coverage. Other than the formation processes, this is of course a reasonable expectation of an archaeological record dominated by hunter-gatherer groups; i.e. one whose individual components likely reflect the passing of transient day-to-day activities over the long term. A lack of immediately apparent strong patterning is therefore not a weakness of the data in a non-site perspective. This theoretical impetus will be tempered against the requirements of the analytical approaches that have been adopted. Although spatial methods using Monte Carlo simulation do not have a strict minimum sample size in order to function (Werdelin and Lewis 2013, 2), field sites with <20 lithic artefacts are not included in the spatial statistical analysis in Chapter 6. The field sites are separated into those used in the distributional analysis of surface data envisioned as part of this investigation, term the *analytical sites*, and a group of *low-density sites* that are reserved for a later comparative analysis. MPM011, despite having a sufficient quantity of material, was not analyzed to completion in the laboratory and is not discussed under the analytical sites.

4.4.1 Landform classification

Two types of landform classification were attempted in order to better define the distribution of field sites across topographical settings. The first of these was a simple reclassification of a slope raster derived from version 4 of the SRTM digital elevation model (DEM), which has a horizontal resolution of 90 m. Although this is less than the ASTER DEM used for analysis and display elsewhere in this research (30 m resolution), the former DEM is preferable because resampling the latter to 90 m from its original resolution at the scale of the whole study area introduces undesirable artefacts which obscure potential detail. The SRTM elevation raster was reclassified into five groups using natural breaks (jenks) in the dataset, rounded up to the nearest whole number. The groups span the spectrum from terrain which is mostly flat, to very steep inclines.

Second, a morphometric analysis of the landscape around the field sites was undertaken with the Landserf 2.3 software. Technical details of the analysis are given in Appendix A. This analysis assigns the cells of a given DEM membership in terms of six morphological feature types, based on the elevations of cells within a user-defined window (Wood 1996). The features are planes, ridges, channels, peaks, pits and passes, and are defined by their relationship to neighbouring cells in the DEM through the use of a quadratic function (Wood 1996, 112). The study area was defined by generating a minimum bounding rectangle around the survey quadrat polygons shown in Figure 4.1 and buffering it by an additional 1000 m to mitigate edge effects on the area of interest. As feature definition is

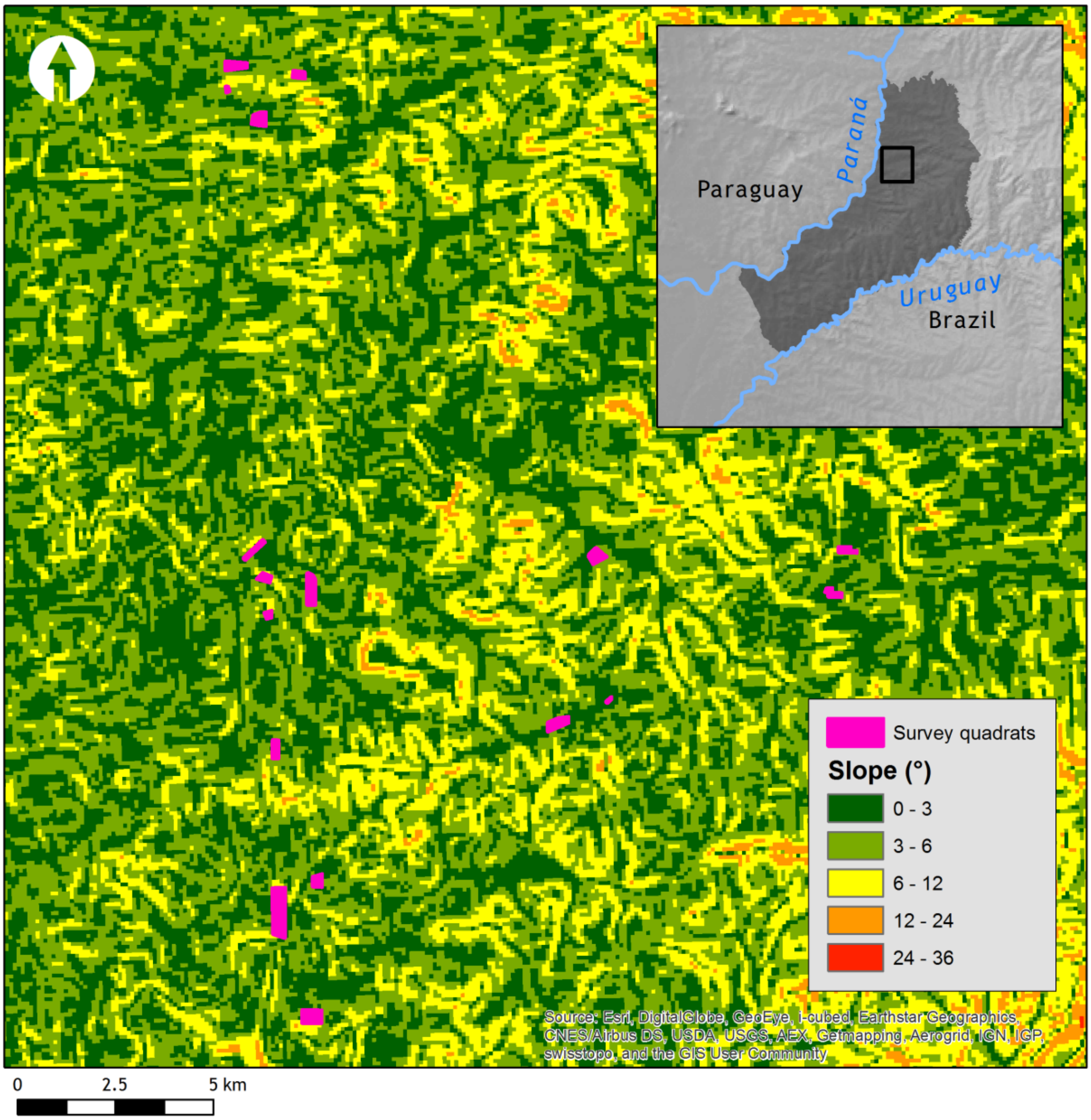


Figure 4.9: Slope classification of a digital elevation model (SRTM version 4.0) in the study area, showing field sites and the classified surface. Field sites tend to be located on fairly flat ground.

a scale-dependent analysis, an iterative approach to the surface in question is recommended, using a variety of window sizes (Wood 1998). In this case, window sizes of the default (3 x 3 cells) were, used as well as 5 x 5, 10 x 10, 15 x 15 and 25 x 25. These were visually compared, and the 15 x 15 window size judged suitable for the scale of the investigation. The window is equivalent to a 1.35 x 1.35 km parcel of land on the ground. In other words, the analysis picks up on large-scale landscape geomorphometry at the expense of finer detail (which the low-resolution SRTM data would partially obscure regardless). The result is the raster dataset shown in Figure 4.10.

The slope classification indicates that the vast majority of the terrain (93.5%) within the field sites is flat or gently inclined (<6°). This is most likely related to the clearance of areas with the highest agricultural potential in the modern era, which then affects the range of terrain available for survey. Approximately half of MPM023 (Mixed-type) is in the 6° – 12° range, the potential effects of which are discussed in greater detail in section 4.4.2. None of the terrain surveyed fell in the two steepest categories of slope shown in Figure 4.9 (>12°). This must be taken into account when interpreting pre-Columbian land-use, as zones of sheer relief in the Alto Paraná are not included in the sample of field sites.

The geomorphometric analysis supports the slope classification, with some additional variation. Over half of the cells within field sites are located on planes (51.7%), meaning relatively flat areas of land. The next most numerous cells are channels (37.9%), which is unsurprising given the fluvial environment of the Alto Paraná. The low number of ridgetop cells (9%) is interesting given that upland areas were also surveyed, but can be explained by the fact that the Alto Paraná floodplain topography is less sheer than the uplands proper to the east. Finally, passes and pits make up 0.7% of the cells in field sites (1 cell each), very few in the overall picture.

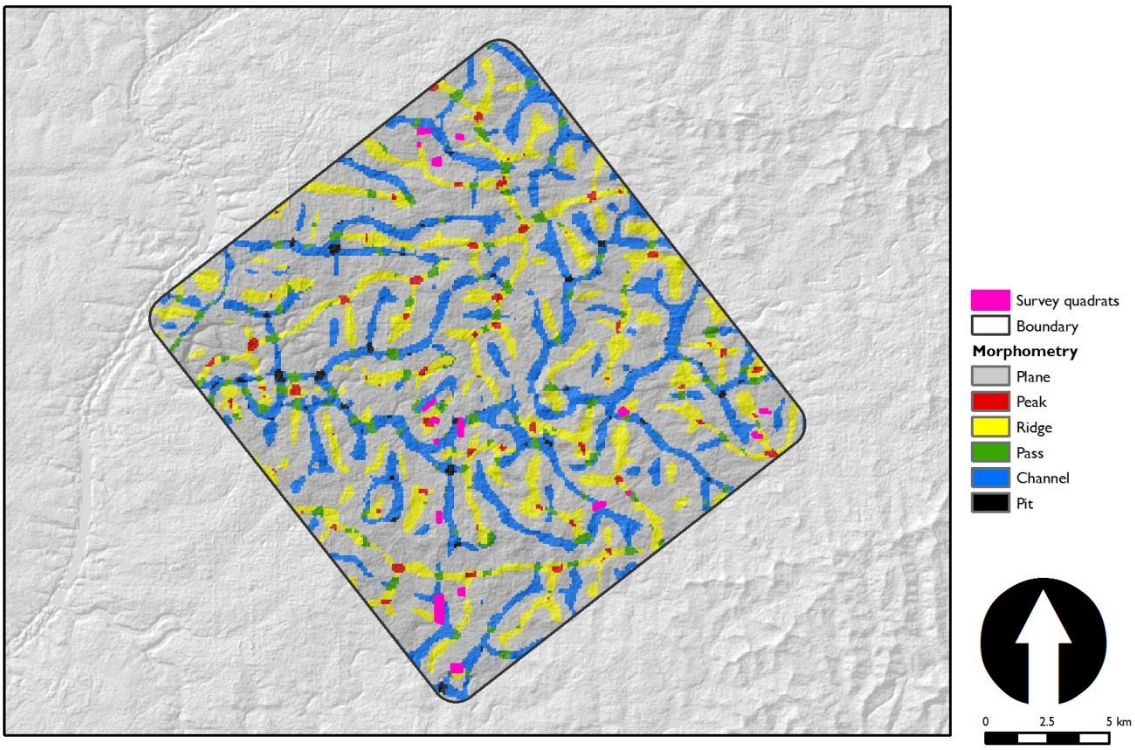


Figure 4.10: Surface classification of the SRTM digital elevation model using a window size of 15 x 15 cells, showing major morphological features as planes, peaks, ridges, passes, channels and pits with survey quadrats superimposed. Field sites tend to be located on a variety of landforms.

These two types landform classification provide complementary information on the types of terrain that the field sites are located on and within. While the areas surveyed were generally on surfaces with little or no slope, they fell within a variety of topographical settings. This bolsters the confidence in the representativity of the data, and will be taken into account when interpreting the results of later analyses.

4.4.2 Analytical sites

Aumer I (MPM015)

Located in the near vicinity of the PM01 mound complex, Aumer I is the largest field site in terms of artefact count and also features one of the wider areal extents. It in the modern era, it has recently been converted to a pine plantation with manioc planted between rows of saplings. The site appears to have been tilled along an east-west axis, while the topography is gently undulating in the northern half of the plantation to flat in the southern half. Visual inspection of the distribution (Figure 4.11) shows that there are two main high-density scatters of material. While both are composed primarily of flaking debris, the northerly scatter has a greater proportion of non-flake lithics. Depending on the definition of a scatter, it may also be distributed over a wider area. Besides these features of the Aumer I survey assemblage, a large spread of dispersed

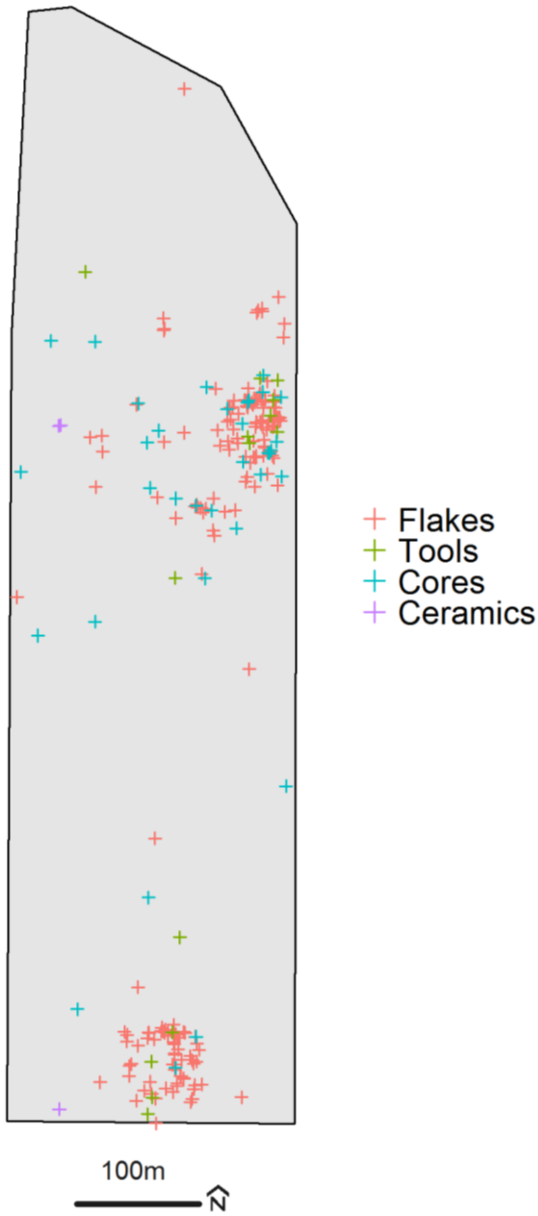


Figure 4.11: Aumer I material distribution.

material appears across the site. This "background scatter" also follows a loose north-south divide with a large and relatively empty space located in between. A dirt track bisects the site down the centre along a north-south line. This does not appear to have had an effect on the perception of material density to the same degree as in previous surveys (Riris 2010b). Tools and cores appear to be associated with flakes within the clusters, but the association between cores and tools is less clear.

Ziegler II (MPM018)

This field site is located in the extreme south of the study area, within 200 m of the Arroyo Piray Guazú. It is a plantation that slopes gently downwards from north to south with a bigger dip in the western edge along a treeline. A road runs through the centre along an E-W axis, and is heavily eroded and channelled in places. This has resulted in a degree of linearity in the point pattern along this feature due to gullying, most obviously in the arrangement of a group of cores and flakes in the central-west portion of the plantation (Figure 4.12). This is perpendicular to the directions of tillage. Additionally, several

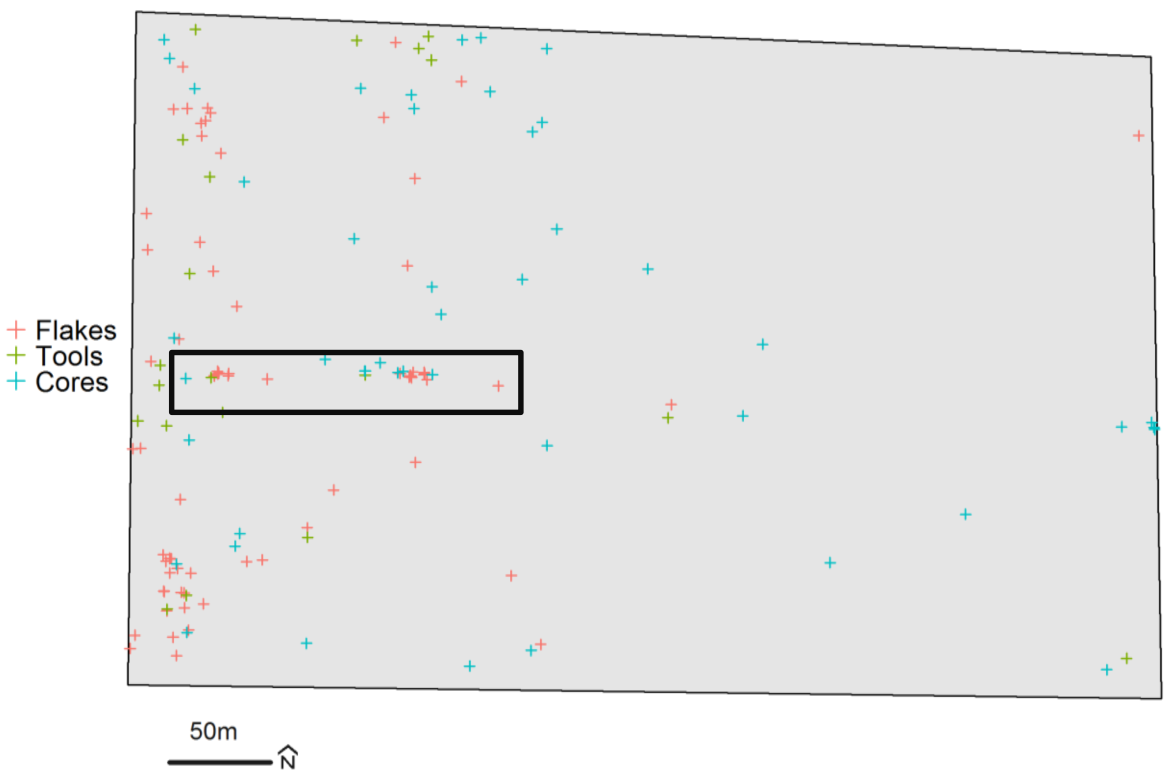


Figure 4.12: Ziegler II material distribution, with box indicating a linear arrangement of finds in located in the gullied dirt track.

transects were obstructed by lines of tree trunks and branches piled up following the field clearance. These were located primarily in the eastern half of the plantation. Although the piles probably hindered the discovery of a small quantity of material, the material is overall far less dense in this area in comparison to the western half of this field site in a general view. Despite the potential confounding effect of the piles, they realistically impeded vision of, at most, 10% of the areas where they were encountered (see above discussion). The distribution of artefacts, as presented here, is probably representative enough of the visible archaeological population despite the obstructions presented by the piles.

By weight, the assemblage in Ziegler II is dominated by cores ($n = 46$) by a factor of two, which appear to be spatially dispersed. Less heavy finds, notably a large percentage of the flakes, are more common in the lower-lying north-western corner of the plantation. In this specific case, it seems possible that artefacts have been eroded out of the hillside or swept down by rain after exposure on higher-lying ground, or a combination of these processes. Bintliff and Snodgrass (1988, 512) term such sorting by weight in the surface record "lagging". The presence of lag is supported by the second large scatter of flakes located in the higher-lying south-western corner as a potential source of eroded material. On the other hand, the incline is gentle and both concentrations could equally represent the traces of an ancient occupation or series of occupations. The overall impression of the material is one of a series of loosely agglomerated scatters, representing possible reuse of space. A fragment of a polished stone tool in a non-native grey material was recovered in this area. It was tentatively identified as a *mano* (*mão-de-pilão* in the Brazilian literature), typologically considered part of the Taquara/Itararé tradition lithic toolkit (Beber 2005; Schmitz and Becker 2006). A spheroid stone bearing characteristic peck-marks was identified as a hammer, and suggests reduction may have occurred in this place.

Ziegler III (MPM022) and Ziegler IV (MPM023)

These two field sites are discussed together due to being directly adjacent (see Figure 4.7). They are separated only by a small creek that runs along their southern and northern edges, respectively. Due to this feature in the landscape, both field sites have a marked slope towards the edges where they meet. The topography of Ziegler IV is sharper than its neighbour and has several areas of exposed bedrock due to the thinness of the soils. This has likely increased the odds of exposure and movement by erosion of artefacts deposited here. Flat and less exposed areas within the site appear as voids or dispersed scatters in the plotted maps (Figure 4.13). The pine in Ziegler IV is mixed with some cultivation, mainly manioc, onion and squashes, while the first site consists simply of pine. Ziegler III has a north-south dirt track running through its centre, linking it to Ziegler IV by a bridge over the creek. Archaeological material appeared less dense close to this feature. If artefacts were ever present in this area, it suggests that fluvial events have hidden or removed them from their locations of deposition. There is circumstantial evidence to support this hypothesis, as a water-weathered and reworked bifacial tool was recorded in close proximity to the creek. It is impossible to know the distance this artefact has moved from its original context of deposition but its presence in such proximity to a hydrological feature makes the find intriguing.

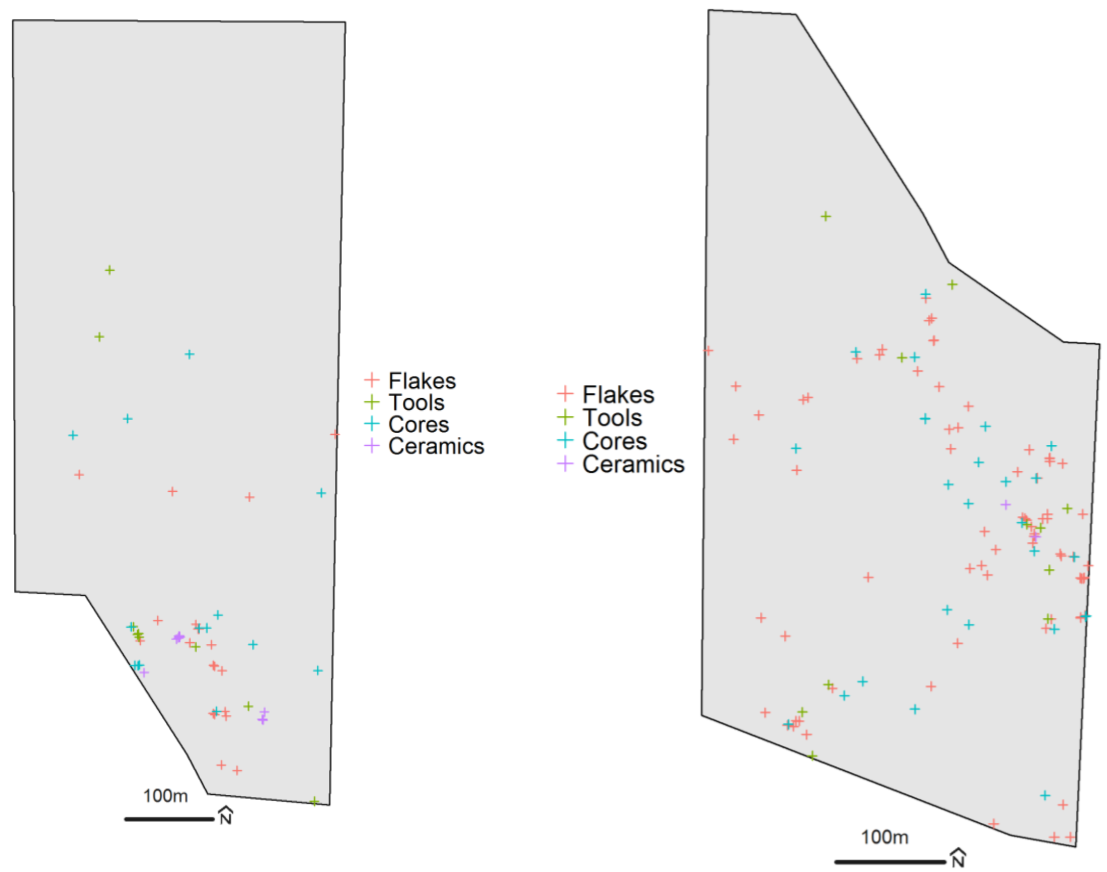


Figure 4.13: Material distribution in Ziegler III (left) and Ziegler IV to the south (right)

The larger of the two sites, Ziegler III, has half the number of find locations as its neighbour, although one of the largest ceramic assemblages of any field site recorded by the survey. It also has a low ratio of tools to cores; flakes are especially underrepresented in the assemblage. Of the knapping products that were recorded in this site, however, few show signs of use and were overall intensively reduced (85% of the assemblage has 25% or less cortical cover). This is supported by the core assemblage of the site; four cores have over ten removals, while the majority of the remainder have more than five removals (median 6.5). Additionally, half the tool assemblage from Ziegler III consists of final-stage bifacial tools that were broken, possibly through use or attempts to rejuvenate.

The larger assemblage of Ziegler IV also appears more spatially aggregated, in part due to being recorded within a smaller unit of coverage. As noted, soils are thinner in this location, exacerbating the likelihood of exposure, and hence recording. To this end, the main concentration of artefacts to the north-east lies directly below one of these heavily deflated surfaces, on one of the steepest inclines identified in the study area by the landform classification analysis. Flakes represent a greater percentage of the sample, and appear to co-occur with both tools and cores. Cores are almost universally reduced to an intensive degree, with only a single specimen having fewer than five removals (a tested cobble with a single flake detachment). Flakes with retouch are also more common than in Ziegler III, however, so are flakes with 100% cortical cover. Sample size likely has an effect on the flake assemblages of these two sites, giving a sense of diminished range of activities in Ziegler III in a comparative assessment. Tools and cores co-occur only occasionally in Ziegler IV, suggesting that spatially distinctive practices are associated with each of the two classes in this location.

Gruber IV (MPM028)

This is the smallest of the sites that are presented in this section, both in terms of area and number of recorded artefacts. It is also the only analytical site located in the Arroyo Pareha locality of Eldorado department. Consisting of a clearance of pine plantation bordered on three sides by *monte* forest, it lies on flat ground on the crest of a hill. Three larger field sites were surveyed in the near vicinity of Gruber IV (see Figure 4.1), none of which produced the same quantity of lithic material. Visibility and accessibility were both good in this location, with no major topographic barriers to survey.

Visual assessment of the distribution of archaeological material in this site does not reveal any immediately obvious spatial patterns within it. Bearing in mind the small area of the site, it is probable that Gruber IV is part of a broader scatter of material currently located under the adjacent forest floor. The recorded distribution would therefore appear more clustered at a smaller scale of analysis. The frame of reference for this field site makes it difficult to infer any clear trends using basic methods of investigation, and more robust analyses must be used to tease out any associations in the assemblage.

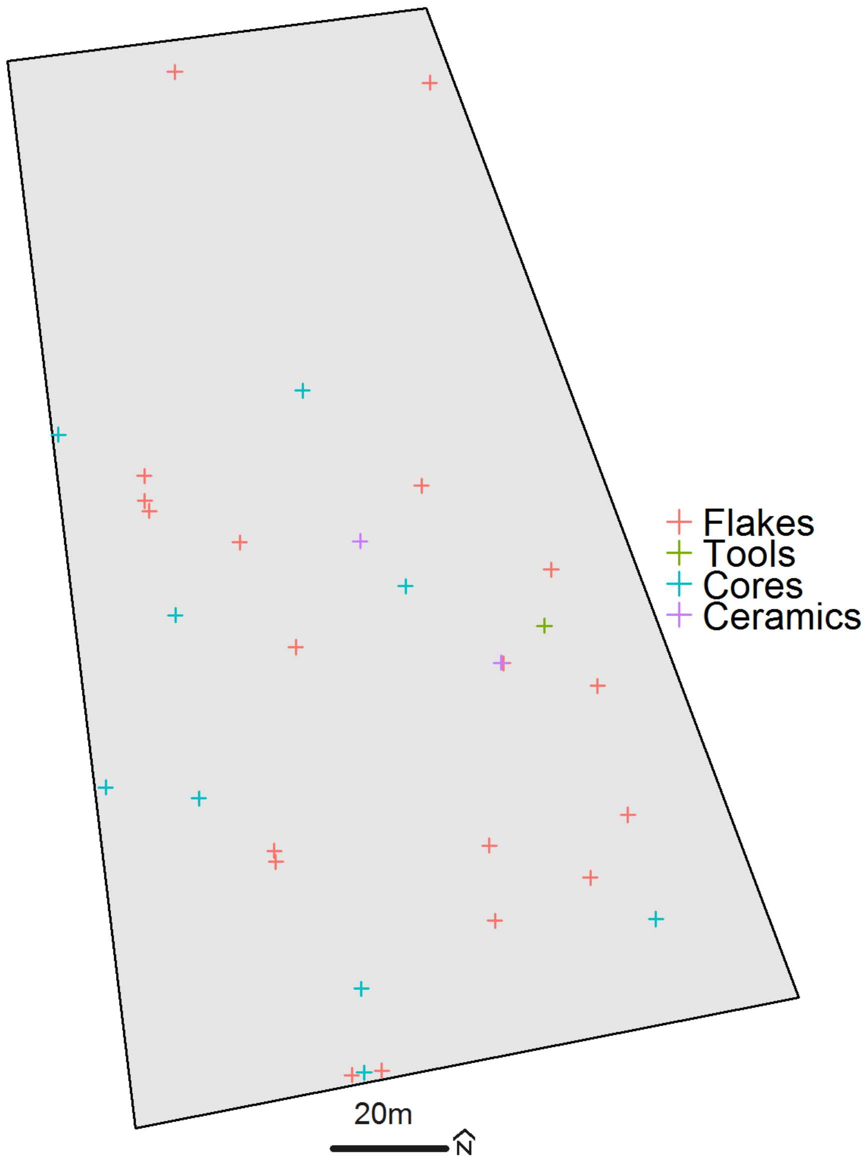


Figure 4.14: MPM028 material distribution

Briefly, the flake assemblage appears to be intensively reduced; very little cortical cover and a high scar count characterize its composition. The core assemblage would seem to corroborate that intensive reduction episodes took place in this location, with a mean number of removals per core of 12. How these assemblages relate to each other spatially and technologically will be the subject of a more in-depth investigation later.

4.4.3 Low density and ceramic scatters

Field sites with a very low density of lithics constitute the majority of the archaeological landscape of Misiones recorded by the PME project. Apparently lacking spatial structure and consisting mainly of what is conventionally termed "noise" (Gallant 1986; Steinberg 1996; Crema and Bianchi 2013), these "off-site" locations (Thomas 1975) consist of areas where formation processes, deposition rates, modern conditions, research design or a combination of these factors has led to little material being recorded. As argued throughout this research, however, these locations contain culturally meaningful information on the use of space. It is a question of scale which patterns are significant (Ebert 1992, 9) and, contrary to received wisdom, low-density sites are informative by virtue of their existence in *relation* to patterns that can only be seen in a landscape perspective.

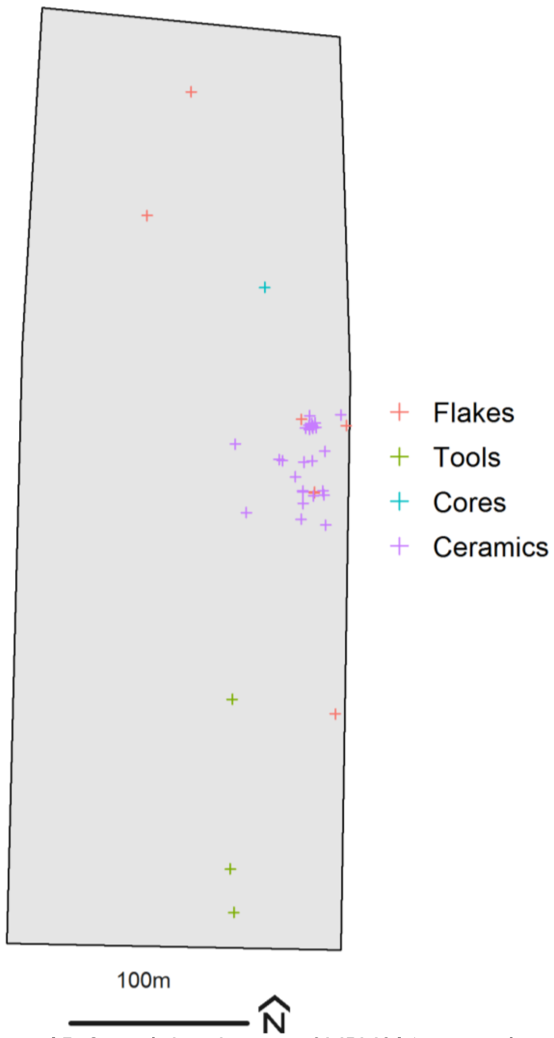


Figure 15: Spatial distribution of MPM016 material, showing comparatively large ceramic assemblage.

Some low-density sites, for instance MPM016 and MPM024, have the requisite number of spatial data points to be considered candidates for the spatial analysis. The paucity of lithics in these locations and comparatively high numbers of ceramic fragments (Table 4.1), make them unsuitable for generating insights into the issues tackled by this research. Ceramics are, however, useful in a different capacity. While not subjected to a detailed laboratory analysis in the same way as flaked stone, they were all examined and deemed to be Taquara-Itararé tradition pottery (see Beber 2005). Groups of southern proto-Jê

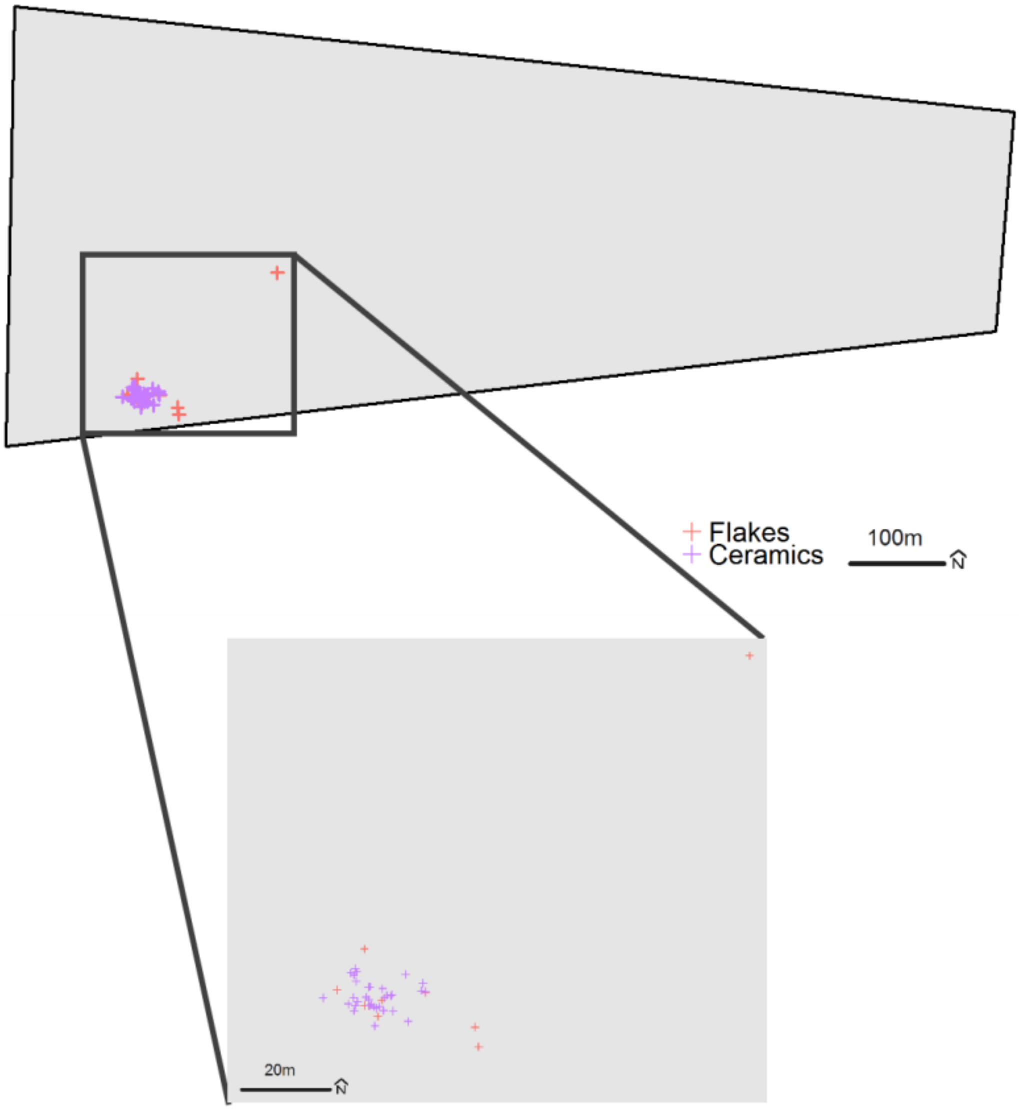


Figure 4.16: Clustered material distribution in MPM024.

stock appear in the material record of the eastern La Plata basin in the last two millennia before present (Araujo 2007), and possibly earlier in Misiones (Rizzo et al. 2006; Loponte 2012). Where ceramic fragments occur in numbers they are strongly autocorrelated with one another. Intuitively this makes sense, since depositional and post-depositional fragmentation will rarely move artefacts very far from their original archaeological context. Furthermore, except for comparisons with formal tools similar to those observed in southern proto-Jê sites in Brazil (Rodriguez 2001), the technological organization of these

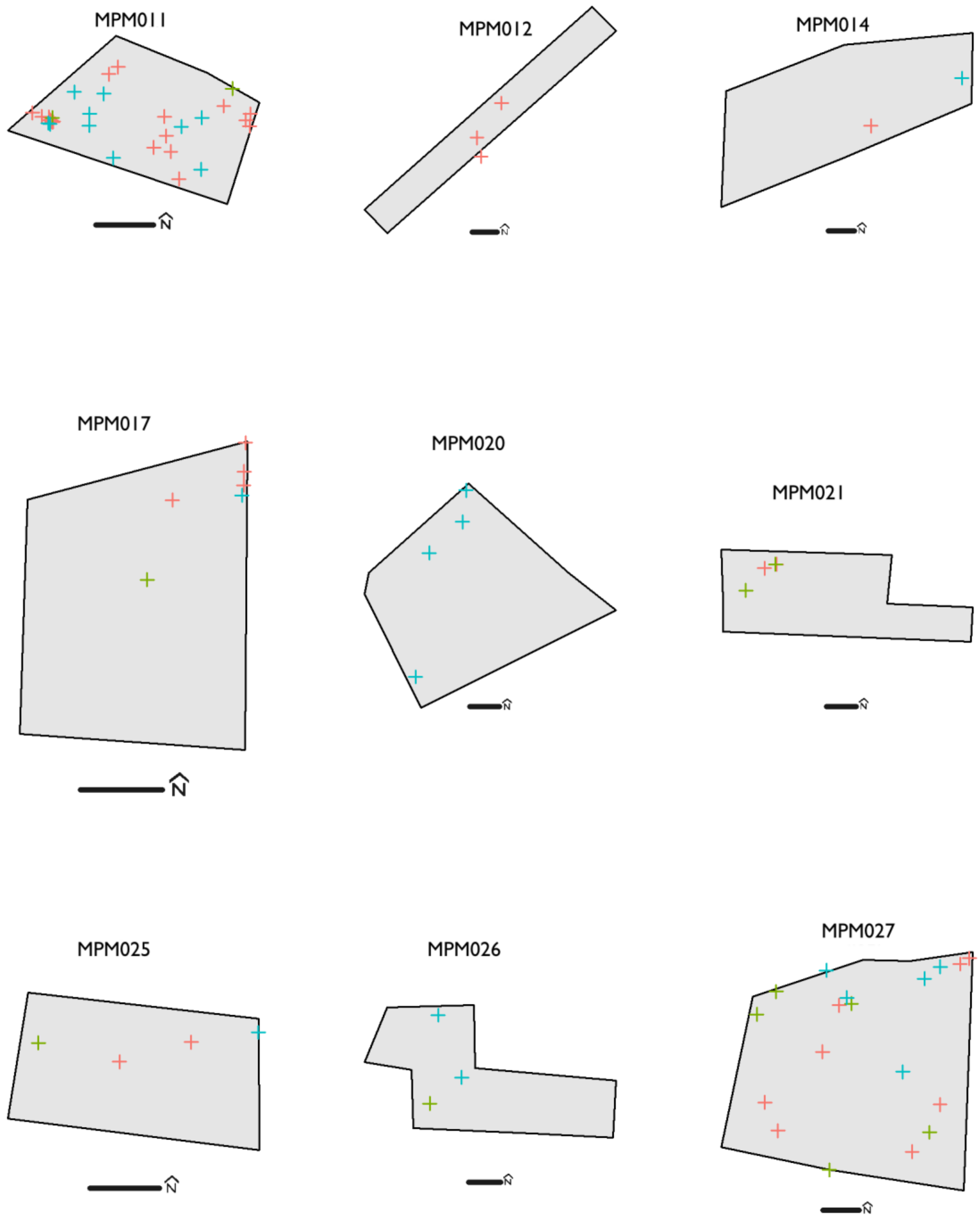


Figure 4.17: Low density field sites. Scale bars are fixed at 100 m, map legend follows previous figures.

groups in Misiones remains unexplored in all but the broadest strokes. The practice of inferring associations in time through only horizontal spatial relationships was critiqued previously (see Section 2.4). Although ceramics in palimpsestic datasets might provide a means of testing hypotheses about the co-variance of artefacts with less temporally sensitive artefacts, no secure or independent dates exist yet for complete ceramic series in Misiones. Any such analyses performed on the data from MPM016 and MPM022 would be dealing with extremely broad and generalized temporal envelopes, but with the pretence of studying a single archaeological culture through time. Furthermore, based on the available sample size of ceramics (only MPM016 has any abundance), it is extremely challenging to draw more extensive or significant conclusions. This is a potential direction for future research, but nonetheless, in exploratory non-site research this is problematic to sustain any further.

The remaining nine sites that yielded pre-Columbian evidence are low in cultural material (Figure 4.17), with an additional two lacking any archaeological data. These locations lack an adequate quantity of archaeological material to characterize any intra-site spatial structure. Although this is insurmountable with the present information, these places may still be usefully understood within the non-site framework. Following an in-depth investigation of the analytical sites and the spatial organization of material culture in them, the low-density site can form part of a landscape-scale interpretation of technological variability in Misiones. From the distribution of the data alone the viability of this approach cannot be evaluated, and must be judged on the basis of informative potential after the fact.

4.4.4 Other finds

The dataset that was procured as part of the PME project is, fundamentally, intended to enable a spatial investigation of lithic technological organization in the Alto Paraná. A small number of finds that were recorded as part of the survey, however, do not fall into the broad categories defined in the previous chapter, or were collected in an opportunistic manner. Two classes of finds are discussed which broaden our understanding of the archaeological record of Misiones, but cannot provide specific information on the spatial structure of occupational contexts in the same manner as the survey data.

Gruber plantation

As part of the reconnaissance for field sites during the PME project, a number of locations in the middle course of the Piray Mini were visited to evaluate their suitability for survey. Consisting of a single large lot of pine plantations in various stages of growth owned by the *Gruber Hermanos* company, ground cover was found to obscure too much of the surface to make it a viable field site. While the plantation was being explored artefacts were encountered on the surface by chance. The increased visibility of archaeological material in eroded contexts has already been demonstrated above, which in this case consisted of the dirt tracks linking different lots. A small sample of the material was collected (n = 10), half of which are bifacially flaked stone tools. Analysis of this material showed two of them to be finely worked and in a late stage of manufacture before deposition (Figure 4.18). Both can be typologically attributed to the Altoparanaense culture, a local subset of the Humaitá tradition encountered across much of southern Brazil (Schmitz 1987; Dias and Hoeltz 2010). The latter is contested (see Hilbert 1994; Dias 2007; Riris and Romanowska 2014), meaning that these tools are in no way temporally sensitive, especially in an area with as weak chronological controls as Misiones. While they are relevant to broader distributional questions on the provincial archaeological record, they are less capable of providing information on the systemic spatial questions pursued by this research. The finds serve as indicators of the potential of the Sierra Central for targeted investigations in the future.

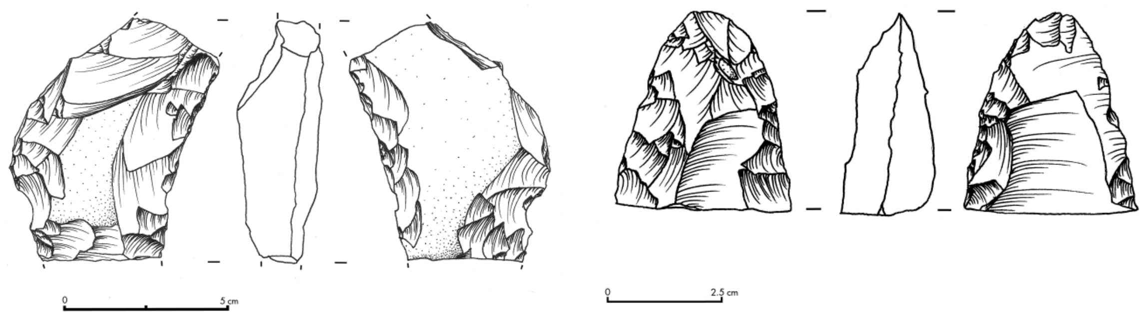


Figure 4.18: Tools from roadside collection. Left: Tool in exotic dark grey basalt material, a "curved cleaver". Right: Tip of broken bifacial artefact. Drawings by I. Romanowska.

Modified stone

A large stone artefact, tentatively interpreted as a polishing stone, was recorded during the survey of MPM011. This heavily weathered boulder has two parallel grooves on one surface, the widest of which is approximately 3.5 cm at its widest. These run across the entire length of the artefact and are recessed into the natural surface by up to 2 cm, which is markedly more pockmarked and weathered than the worked surface (Figure 4.19). It was recorded on the south-western edge of the survey quadrat, near a small tributary creek of the Piray Mini.

Figure 4.19: Possible polishing stone recorded in MPM011. Photo: I. Romanowska.

Grooved features were encountered on boulders along riverbeds during the survey by the University of Exeter team in 2010 (J.C. Gillam, personal communication), similar to the ones shown in the above photograph. Ground stone tools are a feature of both Tupiguarani and Taquara-Itararé lithic industries, although typologically quite distinctive. Other examples of stone polishers can be found in the southern proto-Jê material record of the southern Brazilian highlands, including much smaller specimens (e.g. Corteletti 2012, 116). Unfortunately, the artefact from MPM011 is contextually isolated for the time being, which limits the ability of archaeologists to draw wider conclusions beyond the fact that making ground stone tools was part of the technological organization of the region's pre-Columbian inhabitants.

4.5 Summary

This chapter aimed to convey the distribution of the surface record in the study area in general terms, with reference to the broader physical environment and the processes taking place within it. This resulted in data whose qualitative characteristics are broadly comparable within a common framework, particularly in the rich inventories of the designated analytical sites. It is apparent that various forms of patterning exist in the data, just by plotting the distribution of four general classes of archaeological artefacts. These were highlighted before any more rigorous spatial analysis takes place, and indicated the spatial heterogeneity of the data, providing further support to the notion established in Chapter 2 that the behavioural and systemic significance of surface distributions in the wider study area demand evaluation in a non-site framework. Furthermore, the presence of processes which could impede or enhance the perception of the surface record (slope, geomorphology, and erosive potential) were discussed at length to evaluate their effects on the survey. Their impact, although of variable severity, did not restrict the collection of a representative archaeological dataset. In sum they represent a slight limiting factor on this research rather than confound any form of analysis, spatial or otherwise. Overall, this look at the finds confirms that the modern land surface of Misiones is an abundant source of archaeological data that previous studies have neglected, through either a lack of suitable technology or approaches incommensurate with surface collected data.

A potential lacuna in the data that is worth mentioning is the apparent absence of typologically diagnostic Tupiguarani material, particularly large, thick-walled ceramics with corrugated decoration and polished stone axe heads. These types of material culture are well-represented in the municipal museum of Eldorado and in private collections in the region. Furthermore, the historical Guarani presence in the province was so widespread that groups of non-Guarani stock who have a demonstrable archaeological signature, such as southern proto-Jê groups (Iriarte et al. 2008), are barely noted in ethnohistorical sources on the province (for a notable exception, see Ambrosetti 2006 [1895]). No model exists to translate the demography of a historical population directly into an archaeological distribution map; however, in this particular case the absence is conspicuous. Given the non-site and atemporal nature of this investigation, this is not an issue as far as understanding long-term spatial and technological patterning is concerned.

The upcoming chapters will attempt to maximize the interpretative potential of the surface record. Although the time dimension is absent from this treatment, turning the focus to long-term strategies of land use and the spatial organization of lithic technology will furnish this research with a wellspring of potential interpretative strands. The relationship between deposition and actual occupation is complex, yet it is clear that excavating stratified deposits are not the only means to glimpse this aspect of pre-Columbian use of the environment. The next chapter proceeds with an in-depth analysis of the lithic technology of Misiones province obtained by lab analysis of the survey assemblage. This stands to greatly strengthen the case of the spatial statistical component of this research, which is developed in the subsequent chapter using the insights generated from the lithic analysis component.

5. Lithic analysis

5.1 Introduction

5.1.1 Objectives

This chapter presents the results of the analyses performed on the Piray Mini Exploration project lithic assemblage. The analytical objective is to develop a broad view of the assemblage which can be leveraged in the spatial analytical approaches in the next chapter, with reference to non-site archaeology (Chapter 2). Fundamentally then, focus of this lithic study is aimed at identifying patterns of reduction and exploring their potential meaning in technological terms. Consequently, four questions will guide the analytical method:

- Can different knapping systems be identified in the study area, and if so, how are they articulated in the field sites?
- Does the complexity of lithic artefacts vary in terms of reduction intensity, retouch intensity and morphology?
- How is the raw material managed in different knapping systems, and how can the relationship between these systems be characterized?
- What are the implications of the above for understanding the organization of stone technology and land use in the study area?

Three sections structure the chapter into separate analyses of the core, flake, and tool assemblages. These are take place both in aggregate and at the level of the field site, in order to assess variability in lithic organization within and across the study area. In closing, a synthesis of the results illustrates an impression of the surface record from the lithics, and their systemic significance. Plausible models for the strategies of reduction and manufacture that unfolded in the past are also discussed. This will further inform answers to the objectives of this research as a whole: to evaluate the range of variability in land use and occupational histories in the study area within Misiones province.

5.1.2 Approach

Interrogating stone tool technology the surface record is an avenue into understanding the role of stone technology among the indigenous groups of Misiones province. Indeed, this approach may be the only way to develop an understanding of land use in a material record dominated by the lithics of tropical hunter-gatherers and "low-level" food producers (Holdaway et al. 2010), which has led these artefacts to be preferred over ceramics in this research. Nonetheless, the vast majority of this record consists of pieces produced by so-called "expedient" or "informal" industries. A historical lack of attention to this class of knapping products in the epistemology of the macro-region, in favour of a focus on morphologically distinctive tools, has left archaeologists in the present with a poor understanding of the role played by these artefacts in the societies which produced them. Morphology is only one aspect of the life history of a stone artefact, and is incapable of furnishing a great deal of insight into the dynamics of past societies on its own.

As discussed in Chapter 2, the prevalence of type- and shape-based schema for lithic artefacts in the macro-study region is a result of North American and French influences on the discipline in the mid-twentieth century, and based on these, direct correlations between surface distributions and archaeological cultures have been posited. Despite calls for the application of new methodologies (e.g. Gnecco 2003; Bueno 2010a), to date only a small number of researchers in southern Brazil (e.g. Hoeltz 2007; Dias and Hoeltz 2010; Dias 2012; Okamura and Araujo 2014) and northern Argentina (Nami 2006; Riris and Romanowska 2014) analyse stone artefacts using current methods in lithic studies. Stone artefacts are dynamic tools and components of land use, in as much as their roles are conditioned by the changing requirements of daily life (Shott 1986, 15; Odell 2001, 47). Their production, use and discard involve actions that are culturally mediated, guided by a multitude of situational priorities and conditioned by the affordances of the material and its availability (Carr 1994, 1; Holdaway and Douglass 2012).

Furthermore, the accumulation of such tools reflects the engagement of people with the environment through time. This lends structure to social spaces, leading to the development of a "sense of place" through repetitive depositional acts (Pred 1984; Schlanger 1992, 97, 292; Anscheutz et al. 2001, 182). The long-term process of discard feeds into to the appropriation of the landscape as a field of social and material relationships. For these reasons, low-density field sites are included in the analysis where possible. While in traditional discourse, "isolated", "unstructured" and "off-site" zones represent background noise, in the non-site approach the information they provide is different from, yet clearly related to, comparatively rich assemblages. They exist on one end of a spectrum of patterned deposition that reflects the persistent place-like qualities of the landscape as a whole (Schlanger 1992, 101).

It should be clear that a potential wealth of information is overlooked by ignoring the range of modifications made to stone artefacts throughout the reduction sequence. Summarizing this introduction, this analysis explicitly avoids the typological paradigm of lithic studies (Menghin 1955/56; Rizzo 1968) that has persisted, for lack of research, in Misiones. For the chosen method there are no universally applicable indices that can describe all the characteristics of an assemblage (Shott and Nelson 2008, 31). As a result, while occasionally discussing individual artefacts in more detail, the analysis is better characterized as a "best fit assessment" (Rozen and Sullivan 1989, 170) of the information yielded by the assemblages of each field site. This will contribute useful results for incorporation into the spatial analysis that will be developed in Chapter 6. Both scales will be taken into account when discussing and interpreting the lithic material.

Unless otherwise indicated, all artefact dimensions are reported in millimetres (mm) and mass in grams (g), as it was recorded. The convention for drawings is (left to right): dorsal-profile-ventral, with the proximal end at the bottom. Except for where specific reference is made, the raw material encountered was universally the homogenous and hard red-pink basalt of Misiones province.

5.2 Lithic analysis

5.2.1 Cores

Cores are objective pieces with only negative percussion features whose primary function was the production of flakes. They constitute just over a fifth of the total survey assemblage (*n* = 146, or 20.7%). The dimensions and mass of cores are summarized in Table 5.1 and illustrated on a site by site basis in Figure 5.1. As noted in the previous chapter, there is a strong possibility that cores are overrepresented relative to smaller artefacts (mainly

Table 5.1: Summary statistics of the core assemblages from all sites

	Minimum	Maximum	Mean	Standard deviation
Length	9	151	88.32	23.48
Width	27	113	66.06	16.86
Thickness	30	81	42.01	12.35
Mass	42	1239	311.86	191.62

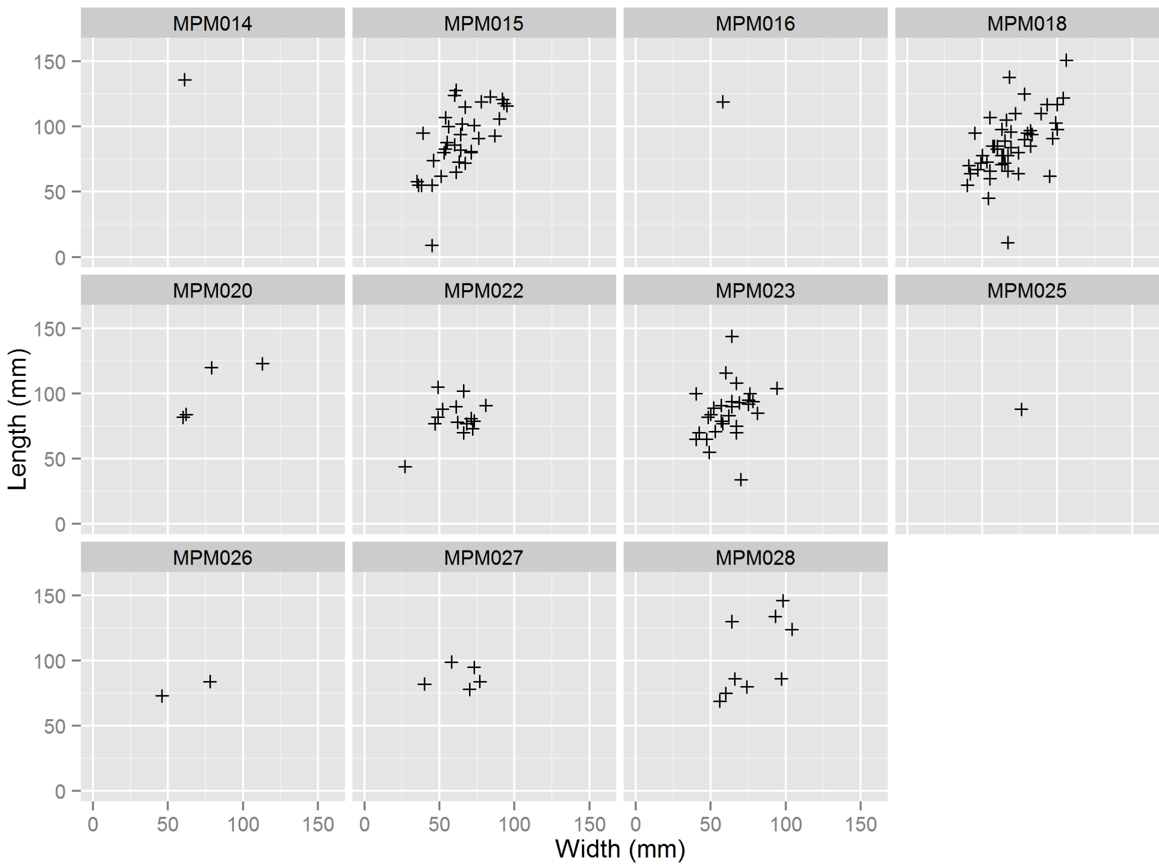


Figure 5.1: Scatterplot of core length over width for each field site yielding cores.

flakes) due to formation processes and the increased visibility of these artefacts on the surface. The core dataset is made up of a heterogeneous mixture of objects that span a spectrum from tested cobbles with a single removal to completely exhausted cores in comparatively exotic raw materials. The aim of this section is to synthesize these trends into a coherent look at how core exploitation systems were organized and to what ends. This will include a more detailed evaluation of core exploitation systems in two field sites, MPM015 and MPM018. The four systems identified in the core dataset were outlined in Chapter 3, and were defined as unidirectional, alternating, and multiplatform.

The core assemblage as a whole can be generally described as nodular cobbles in red-pink basalt, but, as suggested by the low minimum length recorded, certain specimens are more tabular in form. The prevalence of cortex formed by mechanical weathering (battering and smoothing) indicates a riverine origin for many nodules. In terms of the assemblage dimensions, the values appear to be more clustered and with fewer outliers than the flake assemblage (discussed below). Raw material of specific size grades may have been chosen to reduce into cores. Alternatively, cobbles are simply encountered naturally within a range of broadly similar sizes. The wide spread of the data in Figure 5.1 (5-15 cm) indicates that cores are unlikely to have been discarded after a certain size grade (beyond which they would no longer fulfil a purpose). This suggests that the core exploitation strategies may have been standardized to meet certain needs, albeit informal, as shall be demonstrated.

Concerning the availability of raw material, the interior stream network of Misiones is an obvious candidate for places to extract cobbles suitable for reduction. Water-smoothed cobbles were also documented functioning as material for stone-lined cooking pits in the PM01 mound and enclosure complex (Iriarte et al. 2008; Riris 2010a), possibly speaking to the common occurrence of this resource. As to the spatial distribution of workshops, a multi-component site reported in Iriarte et al. (2010b) located the upper Piray Mini valley (MPM003) appears to be centred on a basaltic outcrop. Material clusters around this feature, possibly representing a quarry (Iriarte et al. 2010b). The diversity of preforms (see Figure 2.4 and Figure 5.21) and large quantities of cores recorded in the survey of this site may link the depositional activity there to the initial acquisition of raw material and primary reduction of many lithic forms. Although detailed lithic data for the site assemblage is unavailable, it raises questions on how lithic resources were managed given the apparent wide-spread availability of raw material in the study area.

Cortex and scar count

The amount of cortex remaining on objective pieces in the core assemblage is related to the number of removals it has been subjected to (Figure 5.2). Such a pattern would make intuitive sense, as flake detachments will gradually remove a greater proportion of the original cortical surface as the core progresses through its reduction sequence. The largest group of cores has up to 50% cortical cover, in the centre of the boxplot. Due to this, the category overlaps in large part with both the more cortical and the less cortical specimens. A Kruskal-Wallis test confirms that are significant differences in scar count between each set of cores ($\chi^2 = 34.541$, $df = 2$, $p < 0.01$), Therefore, irrespective of unequal sample sizes, scar count functions as one proxy for the reduction intensity of the core assemblage.

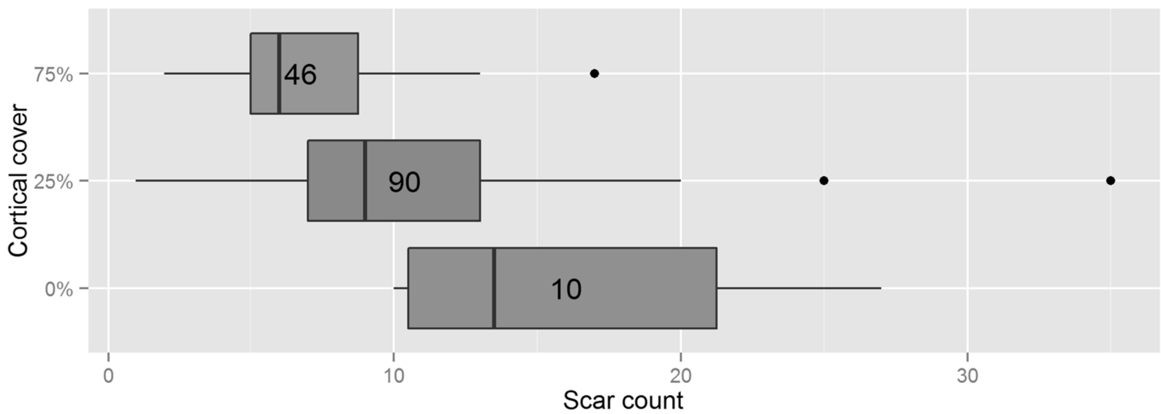


Figure 5.2: Boxplot illustrating the decrease in overall cortex by category as the number of detachments increases, with group sizes indicated.

Volume

A second possible measure of reduction intensity is core volume, used by Holdaway et al. (2004) based on Roth and Dibble (1998). The total mass subtracted from a cobble will increase with reduction intensity, meaning that in the absence of confounding factors smaller cores are generally the outcome of highly reduced assemblages (Holdaway et al.

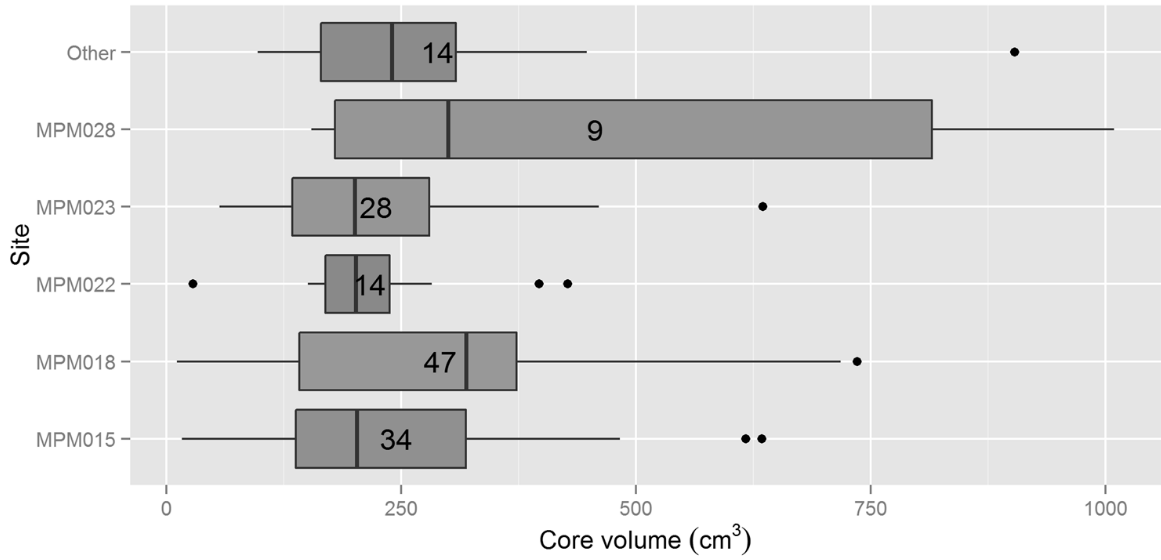


Figure 5.3: Boxplot of core volume in cubic millimetres from each analytical field site and the low-density field sites, listed as Other (see previous chapter for the definition of these terms).

2004, 58). Figure 5.3 summarizes core volume across field sites. The low density field sites have been combined into an "Other" category for simplicity. While the data ranges of the field sites appear to be highly variable, an ANOVA indicates that the differences in means are only significant at the 0.05 level ($F_{1,5} = 2.899,\ p < 0.05$). Examining this finding with Tukey's range test reveals that only MPM028 is significantly different from MPM015, MPM022 and MPM023, at this level of probability. The other field sites are not significantly different from each other. As already discussed, flakes deposited in MPM028 were notably larger than average. The core analysis affirms that the knapping systems in the field site stand out from the rest of the total survey assemblage, likely as an area of blank production. The cores of the remaining field sites are not significantly different from each other, raising the question of how useful volume may be to assess reduction intensity. Taking a more reliable proxy such as scar count (see above) and once again applying Pearson's r, scar count actually appears to be *positively* correlated with volume, but only at the .05 significance level ($r = 0.21,\ \mathrm{df} = 144,\ p < 0.05$), instead of decreasing as would be expected theoretically. Using volume as a general stand-in for reduction intensity therefore seems untenable. Together with the dimensional analysis, this suggests that not discarded due to reductions in size, and hence exploitability.

Reduction strategies

The core assemblages of the field sites MPM015 and MPM018 were selected for additional qualitative assessment of their reduction strategies using the categories identified in Chapter 3. Due to the size of the assemblages of the respective field sites, patterns detected have a greater chance of being significant. In total, this sub-sample consists of 69 cores, with 29 from the former site and 40 from the latter. Figure 5.4 illustrates the dimensions of the core sub-sample separated by field site and symbolized by reduction strategy, while Table 5.2 breaks the assemblages down by percentages.

Table 5.2: Count of core reduction strategies in the sub-sample, separated by site.

	MPM015		MPM018	
	n	%	*n*	%
Unidirectional	22	75.86	26	65.00
Alternating	6	20.69	11	27.50
Multiplatform	1	3.45	3	7.50

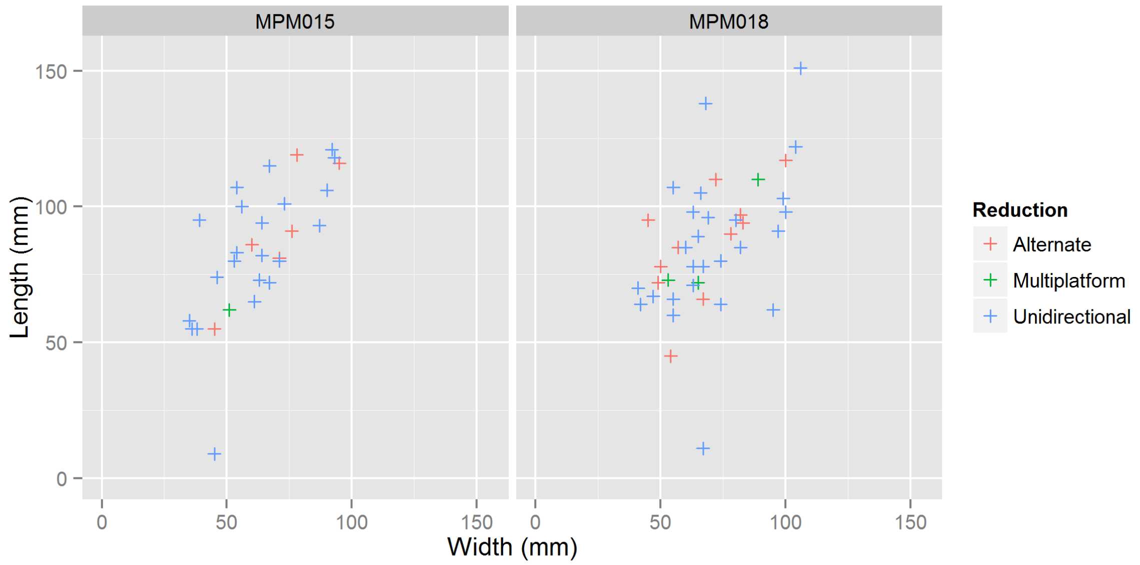


Figure 5.4: Scatterplot of core dimensions in MPM015 and MPM018, symbolized by reduction type.

The use of different core exploitation strategies is often linked to the aim of producing flakes with specific dimensions or shapes. To test this, relationship between flake size and core size was compared by estimating core size using the maximum linear dimension method (MLD) (Andrefsky 2005, 146). This index provides an approximation of core size using the longest dimension (in centimetres) of a core and multiplying it by its mass.

Performing a one-way ANOVA on the MLD index factored by reduction strategy indicates that the differences in between-group means is not significant ($F_{1,2} = 0.13$, $p > 0.5$). In other words, different reduction strategies are not different in terms of a goal to acquire flakes of a certain size. Similarly, there is little to suggest that different reduction strategies reflect differences intensities of reduction, using either scar counts (Figure 5.5) or cortical cover as proxies (Figure 5.6).

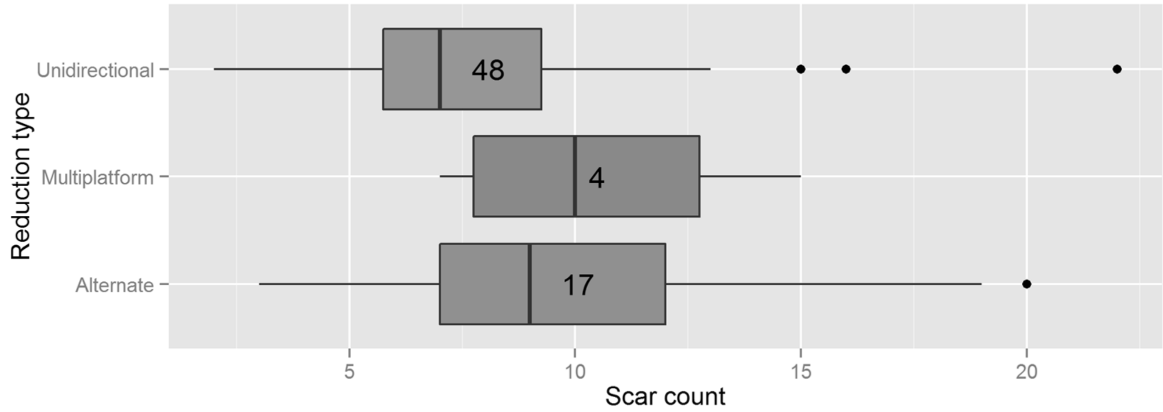


Figure 5.5: Boxplot of summarizing scar count by core exploitation strategy in both field sites. The slightly lower scar count on average on unidirectional tools can be attributed to all tested cobbles being in this group.

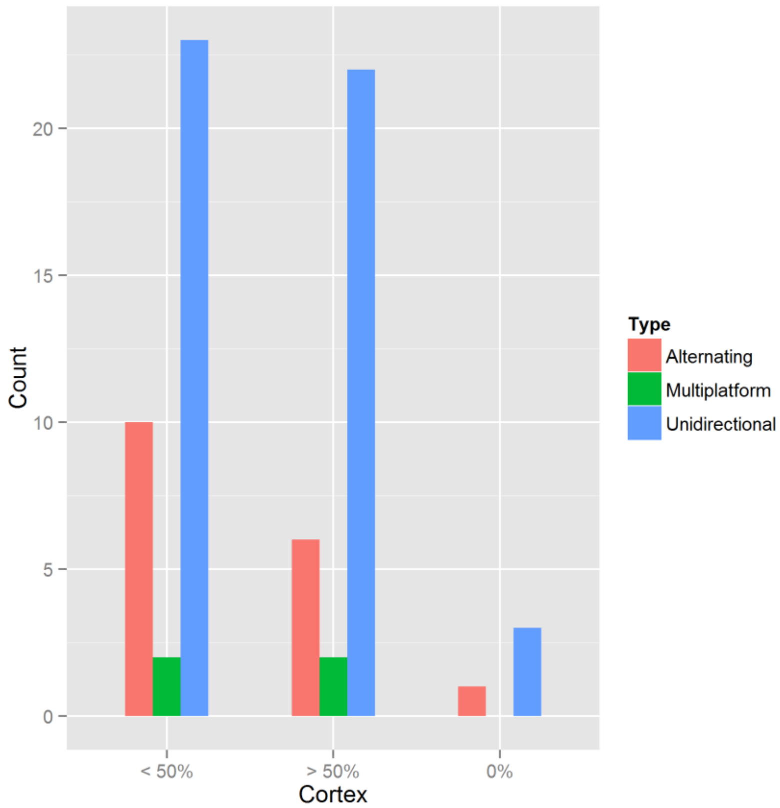


Figure 5.6: Counts of core types in each category of cortical cover.

A majority of the recorded flakes were detached from cores with unidirectional or alternating removals (88.8%, *n* = 347), while the remainder are split equally between bifacial thinning flakes (5.2%, *n* = 21), flakes from cores with multiple platforms (5.2%, *n* = 21), as well as a small group of tool preforms initially recorded as flakes (0.7%, *n* = 3). This is not surprising insofar as the vast majority of the recorded cores in MPM015 and MPM018 display either alternating or unifacial reduction. Multidirectional cores have been rotated multiple times in order to remove flakes from different surfaces. On large cores, the likelihood that removals will overlap may be more closely related to the number

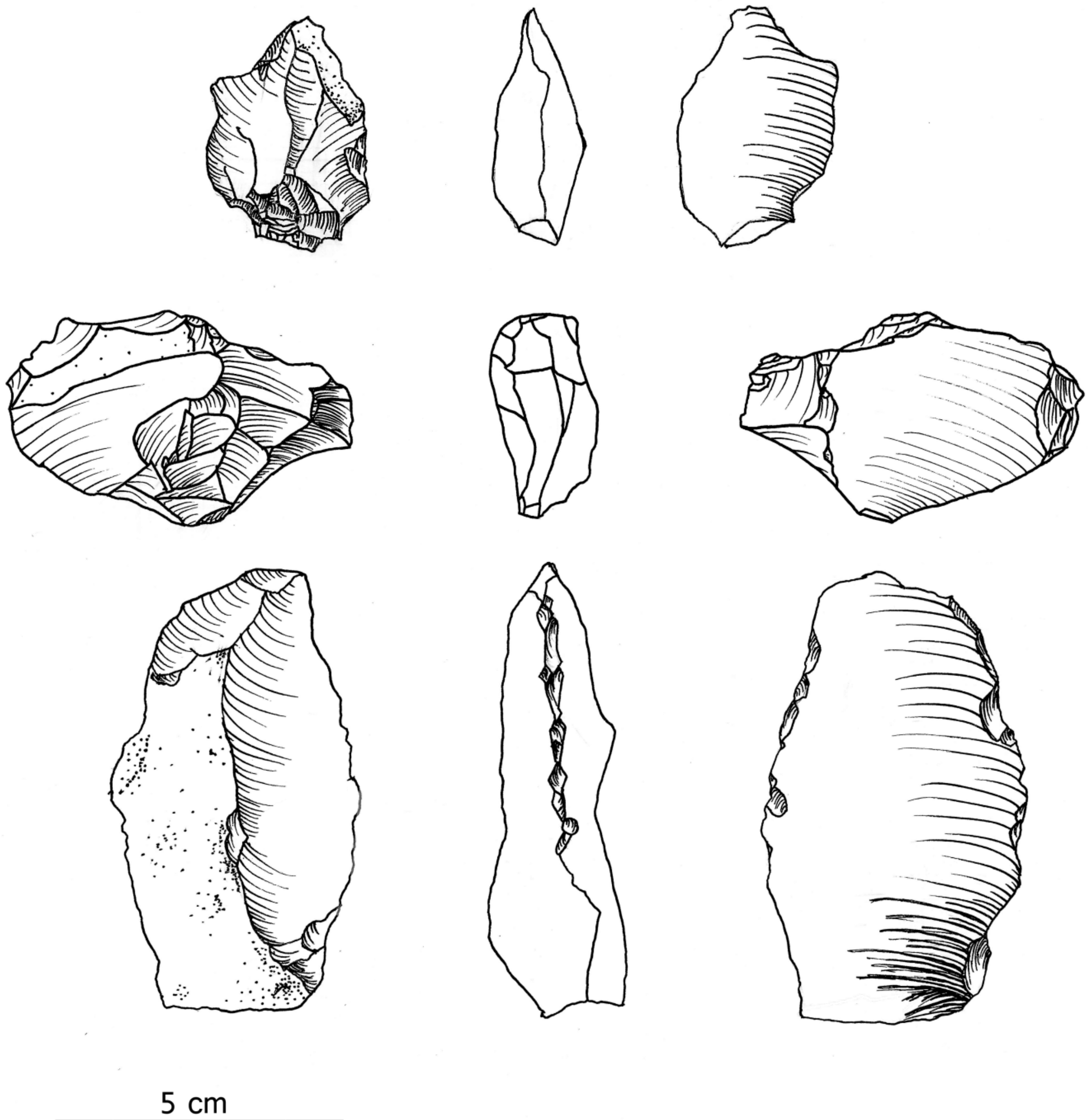


Figure 5.7: Examples of flakes recorded in MPM015 originating from multiplatform cores (From top: #269, #157, #211). Drawings by K. Maynard and C. Schonfeld

of removals (i.e. scar count) than to the number of platforms. This offers a possible explanation for the observed lack of flakes with scars originating from multiple directions. With the exception of a completely exhausted core in exotic grey basalt (#420) with evidence of platform rejuvenation and preparation, none of the multiplatform cores were recorded at the limits of their utility, suggesting that many of the "unidirectional" or "alternating flakes" might be from cores whose multiple, independent planes of removal never met and, hence, are not reflected in the flake scars. As no flakes in the same grey basalt material were recovered, it is not possible to reconstruct how removals may have occurred to maximize the efficiency of reduction in this specific case.

Finally, it is worth noting the low level of investment in platform preparation in the sub-sample. Only six artefacts (split evenly between the two field sites) show signs of detachments to prepare platforms, all of which are unidirectional cores. Returning to the raw material for an explanation, it is likely that the act of preparing or rejuvenating platforms was rarely performed due to the general availability of nodules. In conclusion, abundant high-quality material is in large part what has given the core assemblages their informal character. A synthetic view of the core assemblages suggests that basalt was a managed resource, with clear patterning throughout the reduction sequence but that, nonetheless, very little effort was put towards conserving or curating individual nodules. Along similar lines, even the cores that were intensively exploited, or those flaked with a specific strategy (unidirectional, alternating or multiplatform), do not appear to have a great deal of formality invested into their shapes. The one exception to this overall trend is the aforementioned heavily reduced multiplatform core in fine-grained grey basalt that was recorded in MPM015. Without additional examples like it, however, it is limited in its capability to inform on long-term trends in knapping systems in the study area.

5.2.2 Flakes

Knapping products or flakes, meaning pieces with positive percussion features that have been detached from a larger object (Andrefsky 2005), constitute the majority of the PME project survey assemblage (n = 404). As surmised in the previous chapter from the number of cores, this is probably an underestimate of the true number of flakes deposited in the field sites. The flake dataset is heterogeneous, and likely the outcome of a wide spatio-temporal range of decisions related to lithic resource management. It therefore represents a suite of activities undertaken in the landscape; hypothetically, some will have been carried away from their initial point of reduction, while others were left where they fell. Selected specimens were knapped extensively to produce tools, while others received only the lightest retouch or none at all. Certain flakes represent the very first detachment from the face of a core, while others have so many scars of previous removals that it would be laborious to count them individually. Within this apparent diversity of flake

Table 5.3: Summary statistics of the flake assemblages from all sites

	Minimum	Maximum	Mean	Standard deviation
Length	3	118	40.53	19.71
Width	10	136	41.01	18.43
Thickness	1	226	12.7	12.74
Mass	1	413	38.12	56.22

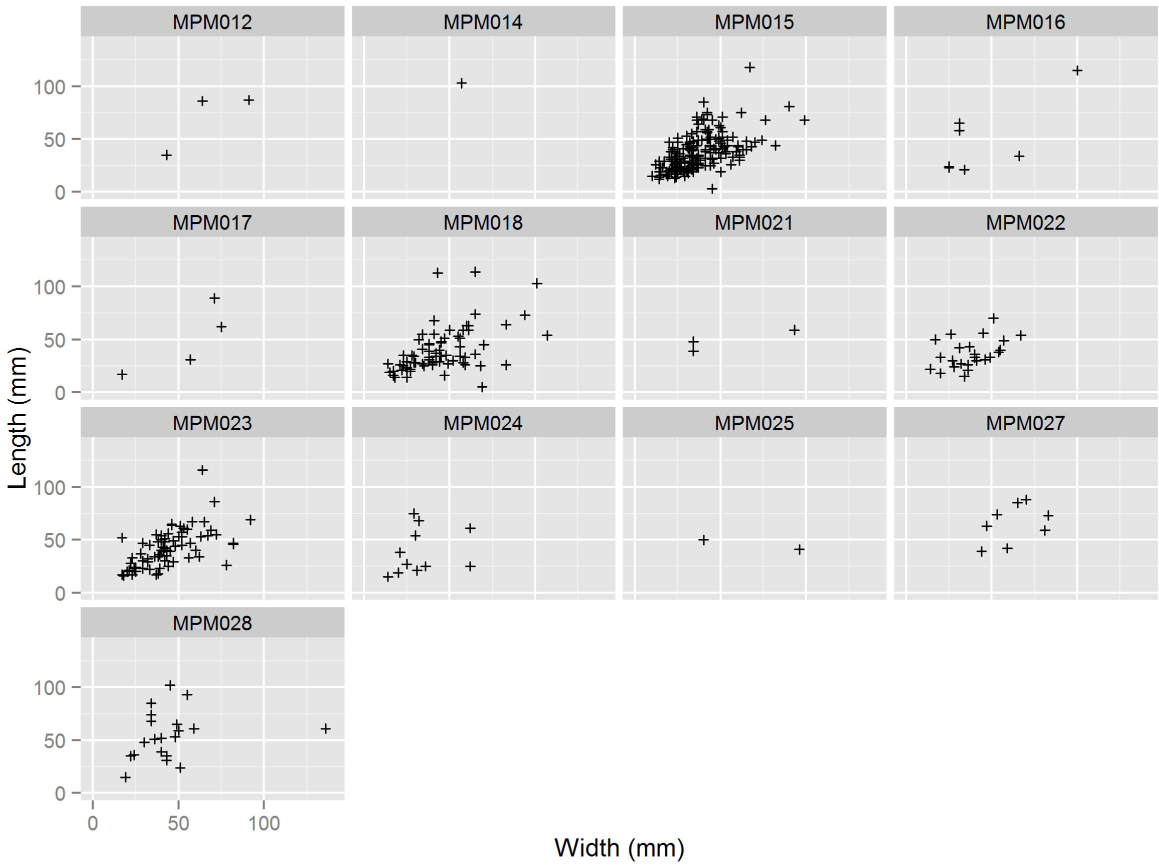


Figure 5.8: Scatterplot of flake length over width for each field site yielding flakes.

morphology and characteristics, baselines need to be established on common ground in order to distil the variance into a more succinct form. While some analysts create flake typologies based on one or more criteria to manage their data (Rickliss and Cox 1993), the problems that typologies are meant to solve (e.g. reduction intensity, core stages) are dealt with separately by the specific analyses employed in this chapter.

Separating the artefacts by site and plotting flake length against width (Figure 5.8) shows that flake dimensions concentrate in the 20-60 mm size range across all the field sites. Without assuming that the source of the flakes are either cores, tool, or a mix, flake dimensions therefore appear to conform to a relatively restricted range, with a slight skew towards flake width. Certain very small flakes (less than <10 mm in any dimension) are probably the result of preparing core platforms. An alternative interpretation is that many are short terminations (hinge or step-breaks) that resulted from inadequate force being applied to the comparatively hard basaltic material for a detachment to happen successfully. To this end, deep negatives of hinge fractures were common on tools and tool preforms with bifacial reduction recorded in the survey. Overall, the distribution suggests that flake reduction resulted in the production of specific size ranges of debitage, with very few long or narrow flakes.

In fact, only 3% of the flake assemblage (n = 15) consists of flakes that are more than twice as long as they are wide, and can therefore be considered blades (Inizan et al. 1999, 34). One such artefact has a dorsal surface that is close to 100% cortical and is most likely a primary flake. Of the remaining 14, three show signs of retouch and are discussed in greater detail in the section on tools. Furthermore, when the blade dimensions are normalized by thickness (Sullivan 1995), only a single artefact shows any significant degree of thinness in relation to its other dimensions. Collectively this suggests that the preparation of cores was not controlled to produce narrow flakes with long cutting edges, and hence that "blades" per this definition were not key components of knapping systems in the study area.

Mass

Summarizing flake mass across sites in Figure 5.9 confirms a degree of uniformity across field sites, with the notable exception of MPM027, which displays a marked skew and departure from the predominant pattern. Furthermore, the size of a field site assemblage appears to be correlated with an increased incidence of massive outliers, as the three largest assemblages demonstrate. For large, heavy flakes in the total assemblage (in the 95^{th} percentile for mass), an intuitive interpretation might be that these are from the earliest stages of core preparation, when basaltic nodules are largest and intensive removal of flakes is necessary to eliminate cortical cover. Taking a closer look at this sub-sample reveals this conjecture is not true; 63% of the heavy flakes (n = 12) are less than 50% cortical, and within this group there are only two examples with less than three prior removals. Three show signs of retouch and use, with one in particular (Figure 5.10) showing extensive short retouch along a single edge.

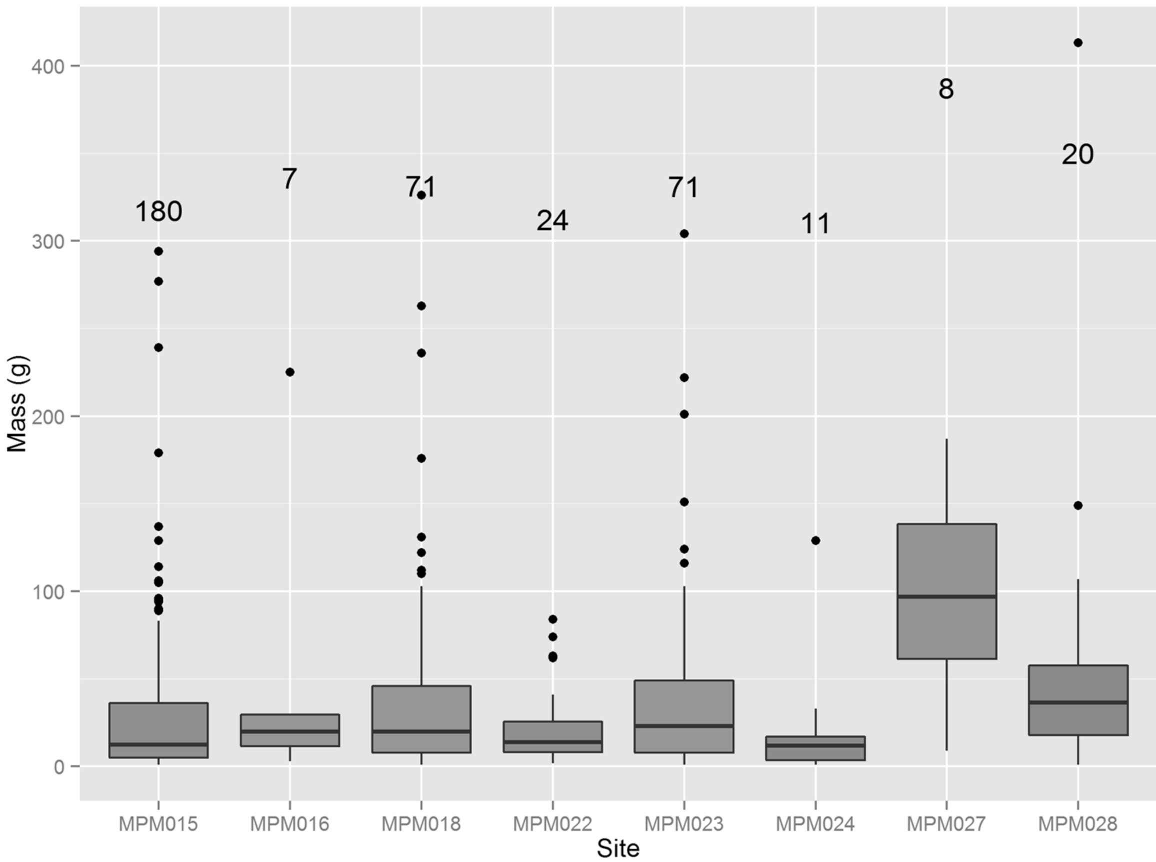


Figure 5.9: Boxplot of flake mass by site, with outliers indicated as black dots. Results show relatively homogeneous patterns of flake mass across sites, with some exceptions.

Artefacts in this group could therefore have been part of a reduction sequence intended to produce medium-to-large sized flake blanks, or were selected as potentially useful during ordinary reduction of large blocks, with the goal of reducing them further into flake tools. In support of this hypothesis, it is noteworthy that two heavy flakes with more than 50% cortical cover also show signs of retouch, albeit low-intensity (short and discontinuous). Within heavy flakes, therefore, the quantity of cortex does not appear to have been a hindrance to further reduction (and use). Evidence of the preliminary flaking of an objective piece does appear, as the remaining five heavy flakes have fewer than three prior removals and up to 100% remaining cortical cover. These two characteristics serve as a functional definition of a primary flake, which are the very first removals from the face of a core.

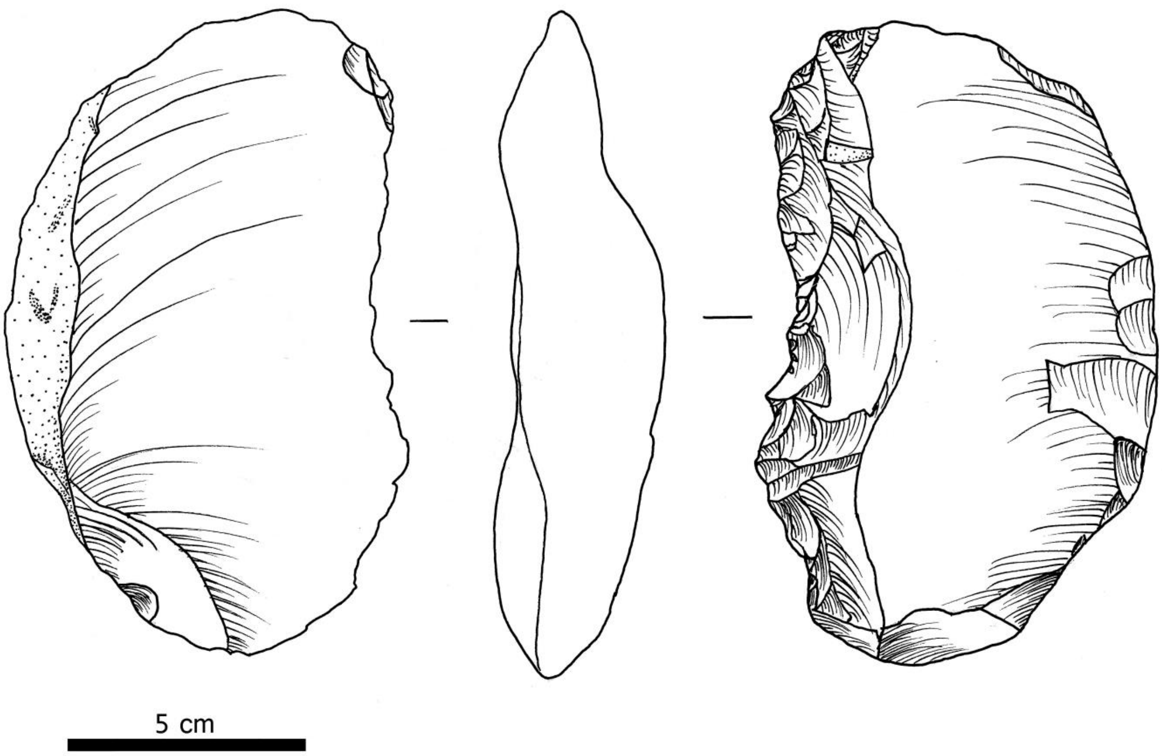


Figure 5.10: Unifacial tool initially recorded as a flake in MPM015 (#55), showing short retouch along a single edge. This piece can be described as a side scraper. Drawing by C. Schonfeld.

Using this definition, a closer look can be taken at the dimensions of primary flakes across the whole assemblage (Figure 5.11). This reveals that their dimensions are not significantly different from the rest of the population. It can be suggested that cores, whose ultimate provenance are nodular cobbles of basalt, were not reduced or prepared with the goal to arrive at a specific morphology. The primary flake assemblage, rather, indicates that cortex was struck off inasmuch as it was necessary to produce platforms that could give flakes with less cortex. Examining only cortical flakes against the entire remaining population can, however, only reveal part of the story.

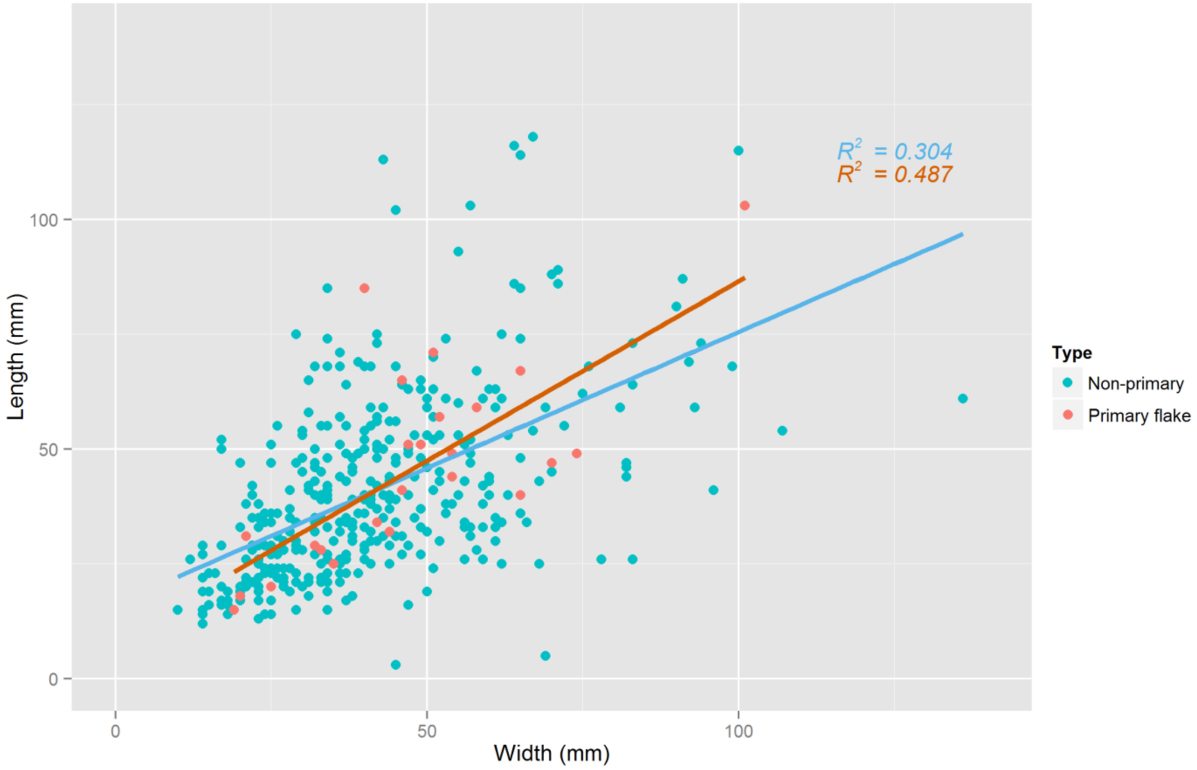


Figure 5.11: Scatterplot of flake dimensions, highlighting the conformity of primary flakes with the overall population. Regression line and R^2 shown for each group of flakes.

Cortex

Knapping is a reductive technology (Ahler 1989, 89). One of the key implications, for present purposes, is that detached flakes will tend to decrease in size as the intensity of exploitation of an objective piece increases. Flakes from early stages will tend to retain a greater proportion of cortical cover on their dorsal surface. It follows that larger flakes should have more cortex and smaller flakes less, and, consequently, that knapping took place *in situ* where this pattern is observed. Deviations from these expectations indicates,

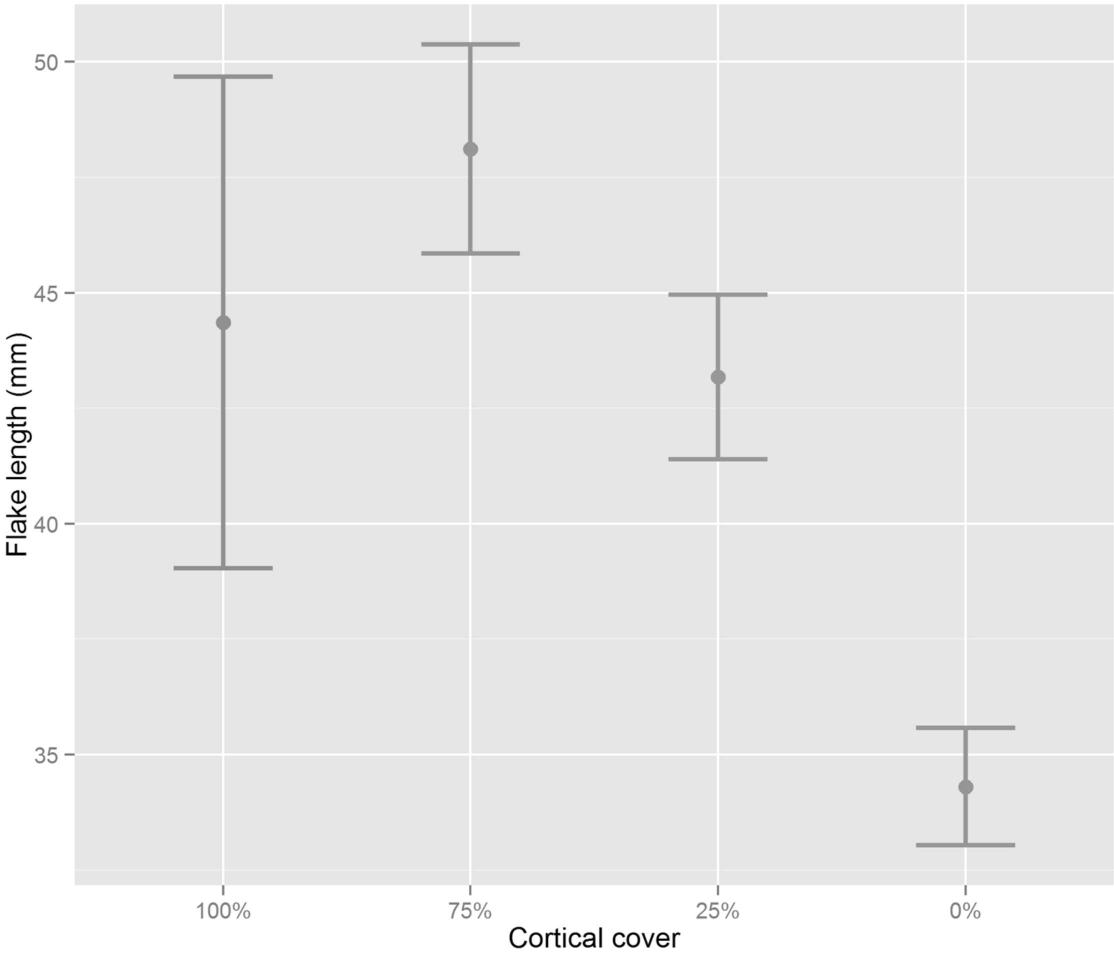


Figure 5.12: Summary graph of flake length by quantity of cortex. Points represent the group mean, and the whiskers the standard deviation.

Table 5.4: Length of flakes (mm) in the analytical site assemblages, by cortex proportion.

Field site	*n*	Statistic	No cortex	25% cortex	75% cortex	100% cortex
MPM015	180	Mean	29.93	41.06	49.11	35.14
		Std. dev.	11.68	19.32	16.39	11.3
MPM018	71	Mean	33.94	44.25	45.62	54.4
		Std. dev.	17.87	17.71	26.67	27.11
MPM022	22	Mean	37.22	34.1	37.33	N/A
		Std. dev.	11.93	11.33	9.03	N/A
MPM023	75	Mean	32.15	45.92	46.21	47.2
		Std. dev.	13.16	19.43	15.87	19.94
MPM028	19	Mean	55.1	52.25	N/A	N/A
		Std. dev.	27.19	17.1	N/A	N/A

conversely, that either flakes were taken away once detached or that cores were deposited away from where they were reduced (Holdaway and Douglass 2004, 50). Figure 5.12 shows the nature of this relationship in the analytical sites. An analysis of variance of the flake lengths by cortical cover confirms the relationship to be statistically significant ($F_{1,3}$ =

$11.92,\ p < 0.01$). Separating the data by analytical site, however, tells a slightly different story (Table 5.4).

The predicted pattern holds in the cases of MPM018 and MPM023; as reduction proceeds, the knapping products decrease in length. This is probably related to knapping taking place in these locations and little movement of material outside the areas captured by the survey. As an aside, the differing results between MPM023 from its immediate neighbour, MPM022, serve as reminder that spatially-associated assemblages are not necessarily related functionally or technologically and may have very different depositional histories. In MPM022, as well as MPM028, it can be seen that highly cortical flakes are rare or absent, while the flakes lacking cortex tend to be similar in size or even larger than those bearing cortex. Besides providing evidence that the primary reduction of cores took place in other contexts, it suggests that, once in these locations, core reduction was directed towards producing flakes as large as possible. Therefore, many of the specimens produced in these two locations may ultimately have been further shaped into tools. The primary flakes in MPM015 are somewhat anomalous when compared to the rest of its flake assemblage, which otherwise follow a straightforward pattern.

Relative-thickness

Using indices of reduction and retouch intensity allows additional patterns in the flake assemblages to be characterized. Relative-Thickness (RT) is an index of flake size, which is calculated by dividing the sum of flake length and width by thickness (Sullivan 1995; Conolly and Sullivan 1998). When set against flake mass, the RT index gives an indication of reduction intensity. RT is useful as an aggregate measure of flaking patterns within field sites as a whole, summarized in Figure 5.13. The field site samples have quite restricted ranges of values for the index on an individual basis, generally falling within the range of 3 – 15. MPM022, MPM027 and MPM028 have a particularly tight range of low values, coupled with a small number of outliers.

Conversely, MPM018 and MPM024 can be pointed to as having quite dispersed values. In the former case, this is probably related to the large population of finds and the likelihood that several activities are being captured in the survey data as a result (see

Chapter 4). MPM024, as noted previously, is a Barren-type field site, with shallow agricultural tillage. The spatial distribution of cultural material in this location is highly clustered, consisting almost entirely of a single scatter of flakes and Taquara/Itararé ceramic sherds approximately 20 m in diameter (see Figure 4.16). Although impossible to date, and indeed antithetical to the methods explored in this thesis, it is possible to suggest that this scatter of material represents the remains of localized and specific cultural activity. The flakes recorded in association with the ceramics are therefore, if not exactly contemporary, then at least likely to be part of the same technological system. An exploratory comparison of these elements, however, was not able to show any outstanding differences between these flakes and those in other field sites.

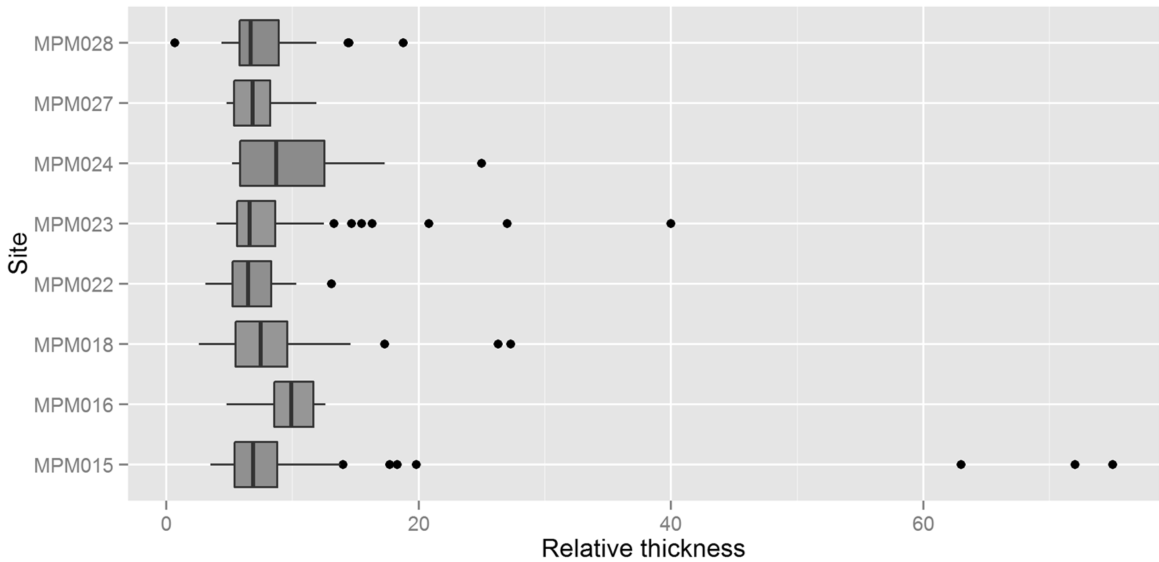


Figure 5.13: Boxplot of relative thickness by site, with outliers.

It is worth noting the 23 outliers in Figure 5.13, all of which have a negative skew except for a single case. These are long or broad flakes that are also unusually thin. A possible interpretation is that they were intended to be detached as flake tool blanks like the example in Figure 5.10, but were ultimately too fragile for further reduction due to the accident of their thinness. Additionally, an independent qualitative assessment of flakes carried out in the laboratory analysis revealed that a small sub-sample of the outliers from MPM015 fit some of the criteria for classification as bifacial thinning flakes (Figure 5.15). The criteria were curved cross-sections, complex platforms and small bulbs of percussion with a lip (Andrefsky 2005, 123). While not all the candidates possessed all the attributes,

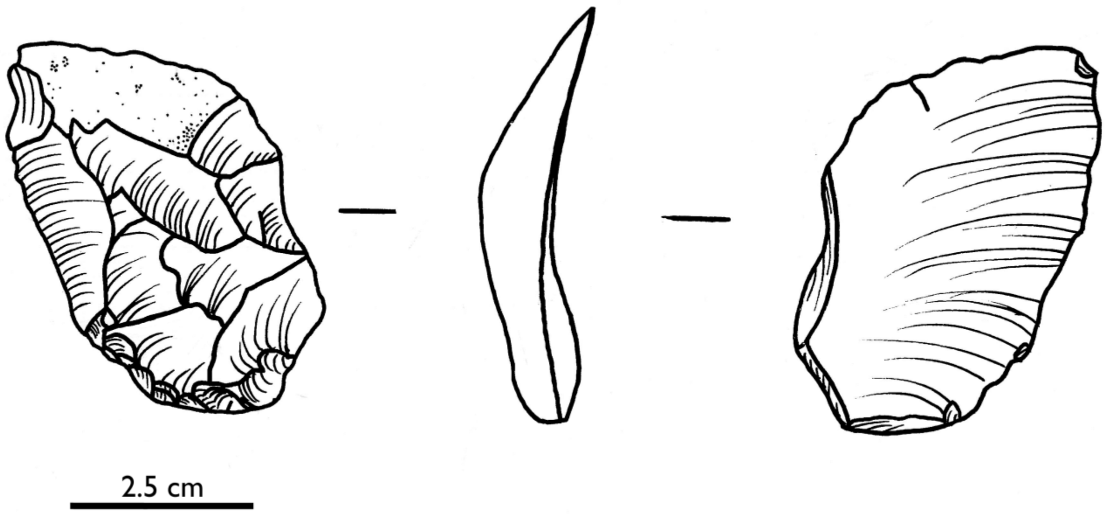


Figure 5.15: Thinning flake candidate (#278). Note curved profile, prepared platform and distal cortex. The final feature may originate due to detachment from a "curved cleaver" (see Figure 5.20) with a central cortical ridge. Drawing by O. Martin.

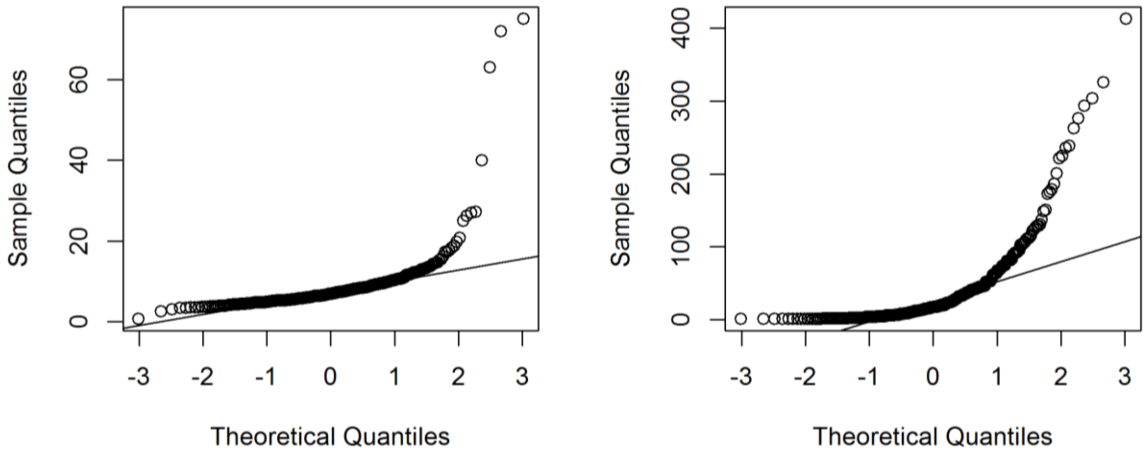


Figure 5.14: Left: Normal Q-Q plot of flake relative thickness (W $= .4561$, $p < 0.01$). Right: Normal Q-Q plot of flake mass (W $= .6293$, $p < 0.01$). The distributions of both variables depart significantly from normality.

or are certainly bifacial thinning flakes, it does conform to the prediction of the index that "high RT" flakes are the result of tool production.

Two Shapiro-Wilk tests for normality on the RT index and mass variables indicates that neither is normally distributed (Figure 5.14). As the means are likely skewed by the data distribution in these cases, the median RT index of each site has been plotted against its median mass (Figure 5.16) to further explore variability in the field site knapping systems.

Following Sullivan (1995, 54), a tool production assemblage with bifacial flaking can be expected to consist of small and thin knapping products. In other words, high values of the index in combination with a low mass indicate that the assemblage reflects this type of reduction. On the other hand, artefacts with a low relative thickness and a more variable (but typically higher) mass are the result of core reduction, as flakes from cores are expected to be thicker and thus heavier (Conolly and Sullivan 1998, 64). Low RT scores follow from high recorded values for thickness acting as divisors on the summed length and width. In the cited works, the patterns observed on archaeological assemblages appear robust with respect to theoretical expectations.

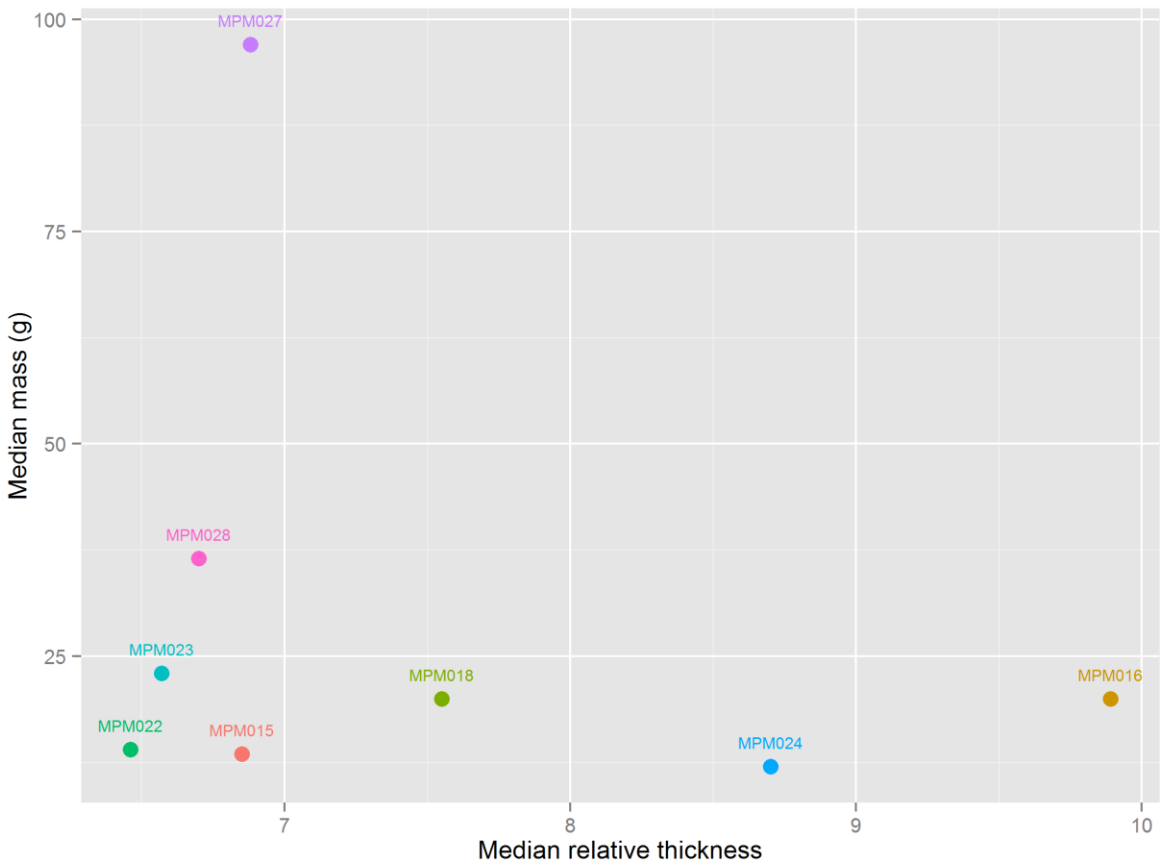


Figure 5.16: Plot of median relative-thickness against median mass by site.

Clear differences exist between the assemblages, which can be discussed as three distinct groups. The largest group of sites (MPM015, MPM022, MPM023 and MPM028) show low values of both RT and mass together, diverging from the core/bifacial reduction dichotomy predicted by the index (see Rozen and Sullivan 1989; Sullivan 1995). In effect, the index is characterizing the flake assemblages of these field sites as made up of lightweight artefacts that are nonetheless thick relative to their horizontal dimensions. This conforms to the point illustrated in Figure 5.8 that most flakes from MPM015, MPM022 and MPM023 fall within a fairly limited size range, representing a population of quite short and broad knapping products. Flakes recorded in MPM028 are overall longer with a tighter range of widths, but also heavy (see Figure 5.9) with a similar range of values in the RT index. Across these four assemblages, artefacts have, on average, high flake scar counts and a low amount of cortical cover. This confirms that this group of field sites have intensively reduced assemblages, indicating that the core reduction occurred in these places with cores that had been prepared in other locations. This can be attributed to the very low numbers of primary flakes recorded in the assemblages, supporting the notion that raw material extraction and initial reduction took place elsewhere in the landscape.

The second group consists only of MPM027, whose flakes are unambiguously heavier than the average across all field sites. In addition to the relative thickness and mass, there is a low incidence of cortex (a single flake has 75% cover) and a high scar count (no flakes with less than 2 previous removals). This suggests that relatively intensive core reduction was the main knapping activity that took place in this site. The large and heavy flakes recorded here may therefore have been intended to be knapped as blanks before being transported elsewhere for further reduction into tools. Some of these preforms were evidently discarded. A Welch's two-sample t-test on core length and tool length, which does not assume equality of variances, indicates that the sample means are not significantly different ($t =$ -.8635, $\mathrm{df} = 4.904$, $p > 0.1$). This supports the null hypothesis that they are part of the same population. The sample sizes involved are small, however, and these results should be interpreted cautiously. There is reason to believe, however, that discard in MPM027 is in some way different from the remainder of the field sites.

The third group of sites consists of MPM018, MPM016 and MPM024, with a low mass and a high score on the RT index which typifies tool maintenance. As previously indicated, the last two field sites do not have large quantities of flakes in their site inventories (seven and ten artefacts, respectively). While this means that conclusions may be difficult to draw from the data, non-site frameworks eschew attempts to separate "noise" from the "signal". In terms of technological organization, however, the small quantities of flakes in MPM016 and MPM024 could reflect a low deposition rate of flakes produced by edge rejuvenation. Although curation is a multifaceted concept, in this case it is applied to describe the practice of transporting and using stone tools on daily itineraries, while performing maintenance in order to sustain their function(s) (Binford 1980; Shott 1996; Holdaway and Douglass 2012). This practice is essential to extending the useful life of a stone tool and is directly linked to patterns of mobility and land use. In other words, these assemblages might be characterized as one of low-intensity occupation, as a result of repeated visits over long spans of time marked only occasionally by the deposition of cultural objects. Due to the shallow tillage of the soil in MPM024, it is interesting to note the apparent spatial correlation of the knapping products with Taquara/Itararé tradition ceramics.

The RT index in MPM018 appears to trend towards tool production, which points to the presence of many light and thin flakes in this location (Figure 5.16). In reality, however, this is only a slight effect. The dispersed scatterplot of flake dimensions in Figure 5.8 suggests that this assemblage is in actually the product of more than one type reduction. Furthermore, the relatively large population of cores recorded in the field site ($n = 46$) are better candidates for the source of many of flakes than the much lower number of tools ($n = 20$). The characteristics of the core assemblage (see next section) probably explains the nature of the flakes recorded in MPM018, and raises the question of why, as shown in the RT index graph, many of these knapping products are so diminutive in size. If nothing else, this illustrates the importance of tempering "one size fits all" indices with contextual awareness of the associations that can be drawn out within whole assemblages, and whose importance certainly overrides any index (Shott and Nelson 2008, 38).

5.2.3 Tools

The artefacts recorded within the general category of tools are made up of a mix of unifacial and bifacially-flaked artefacts. The latter group consists mainly of roughouts, preforms and final stage curved cleavers (Riris and Romanowska 2014), as well as handaxe-like forms. Unifacial tools are even more heterogeneous, a problem added to when we consider that retouched flakes (see Figure 5.10) are a type of unifacial tool as well. Excluding retouched flakes, the quantity of artefacts in the tool category is small relative to the flake and core assemblages ($n = 70$) and is biased towards a small number of field sites. As the distribution of retouch in an assemblage can be an important indicator of the complexity and degree of investment in technological organization (Shott 2005; Blades 2008, 137), the analyses presented in this section will include many of the retouched flakes already discussed above. This presents 50 additions to the tool dataset, or approximately 12% of the flake assemblage. These will add more nuance to the picture of how lithic resources were made and used in the study area and are referred to as "utilized flakes" from here on. The basaltic raw material is a comparatively tough mineral, and edge modification in such a regular pattern is unlikely to occur by chance or accident. Finally, the small quantities of tools not accounted for in these groups consist of two polished stone artefacts and three hammer stones which are not included in the sample used for analysis.

The scatterplot of tool dimensions (Figure 5.17) displays marked differences in the horizontal dimensions of bifacial, utilized flakes, and unifacial tools. The difference between these last two groups hinges on the formality embodied in unifacial tool shape. Performing a one-way ANOVA on the lengths of unifacial tools, bifacial tools, and utilized flakes reveals that their means are significantly different ($F_{1,2} = 54.82,\ p < 0.01$), although a post-hoc significance test comparing groups pairwise shows that the unifacial-bifacial pair is non-significant. The differences in the widths of the same groups, while significant, do not differ to the same degree ($F_{1,2} = 5.846,\ p > 0.01$), which makes sense insofar as long edges were likely an important criterion for blank selection from a purely functional perspective. Unifacial tools are therefore significantly larger than utilized flakes, an important distinction to make, since this might indicate they stem from qualitatively different reduction sequences.

In the cases illustrated here, a key caveat that must be taken into account is the absence of small, bifacially flaked projectile points. Although their presence is reported anecdotally by local collectors, as well as in the archaeological literature of Misiones as part of the Umbu culture (Poujade 1992; Rodriguez 2001), finished forms do not feature in the PME project survey assemblage. A small quantity of flakes with total retouch ($n = 4$) might

Table 5.5: Summary statistics of metric measurements of all tools

	Minimum	Maximum	Mean	Standard deviation
Length	15	174	74.83	39.04
Width	17	147	48.96	19.68
Thickness	4	61	24.87	13.76
Mass	1	1275	162.55	191.95

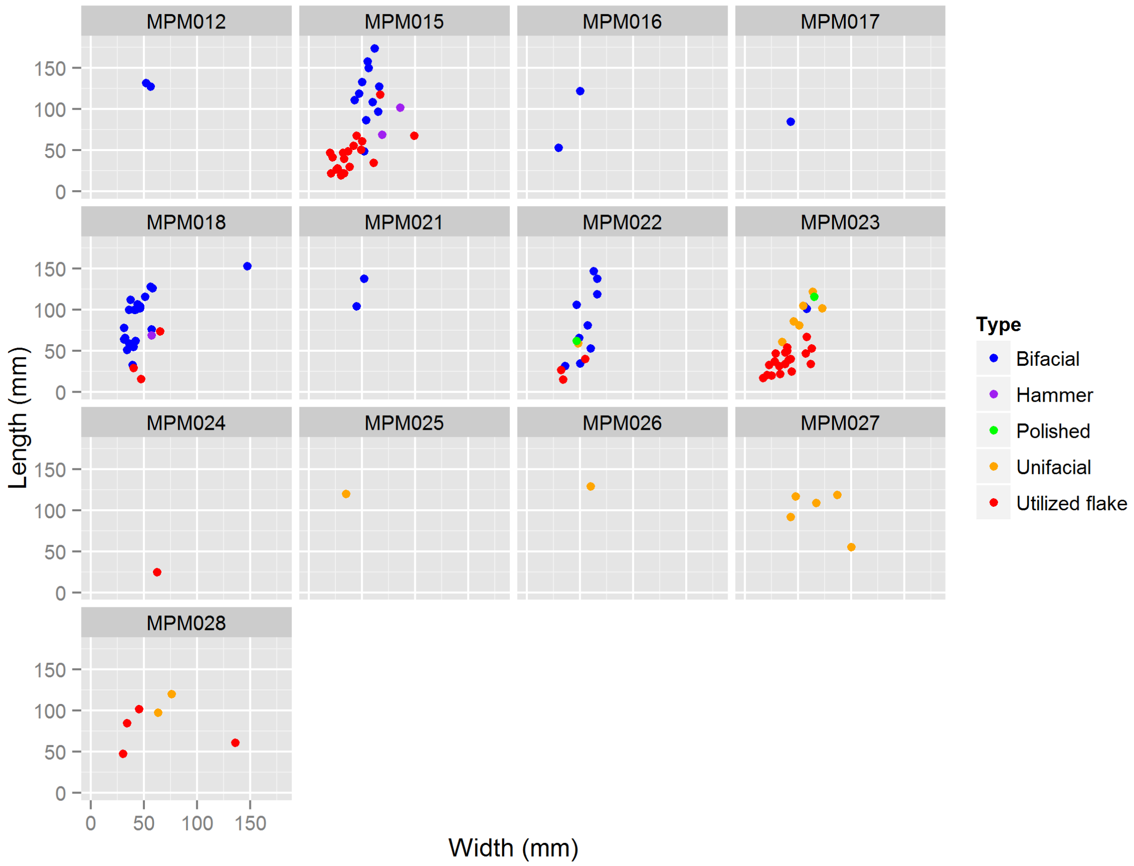


Figure 5.17: Scatterplot of tool dimensions by field site, symbolized by reduction type.

represent the rough-out stages of point blanks, but this cannot be tested with the data presently available. Projectile points would have very different reduction sequences to the larger and heavier handaxe-like artefacts evident in Figure 5.17. In other words, the differences within the tool assemblage that are shown here are an explicit comparison between the latter type of bifacial artefacts and utilized flakes.

Utilized flakes and unifacial tools

Comparing utilized flake length with the unretouched flakes using *t*-tests reveals no differences between the two sub-samples (Figure 5.18). Utilized flakes are very slightly larger and heavier on average, but not significantly so ($p > 0.05$ in both cases). It is

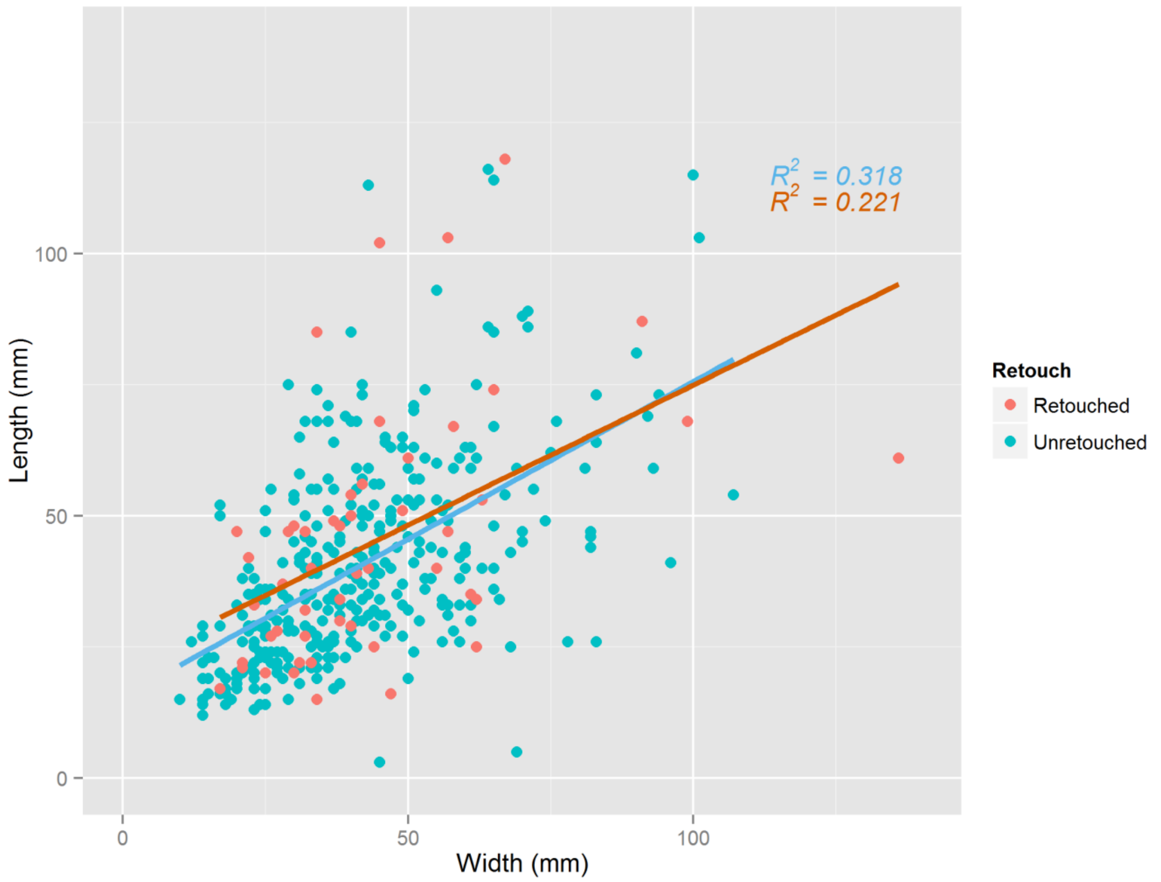


Figure 5.18: Scatterplot comparing dimensions of all utilized flakes (flake tools) with all unmodified flakes. Regression line and R^2 shown for each group.

therefore not possible to assert that specific size grades of flakes were selected for retouch by knappers in the study area. This agrees with the findings of the core analysis that the standard method of core exploitation was expedient rather than structured, but seems surprising given that, as a subtractive technology, retouched artefacts ought to be smaller due to increased reduction intensity. An alternative, depending on the amount of reduction that may have taken place, is that tool blanks were initially larger and were discarded at a size range roughly equivalent to unretouched flakes.

A truism in New World lithic studies is that bifacial tools may have functioned as sources of flakes in many contexts (see Kelly 1988; Holdaway and Douglass 2012). To this end, flake retouch does not appear to be solely present on flakes detached from cores, as 10% of the utilized flake assemblage (n = 5) are also candidates for bifacial thinning flakes. This number is unrepresentative of the assemblage as a whole, however, since only the flakes of MPM015 and MPM018 were examined for the traits of bifacial flaking. Adjusting the proportions of utilized flakes to these two sites, thinning flake candidates make up 21.7% of the flake tool assemblage. The type of retouch on these artefacts is universally discontinuous, while only one has any retouch whose extent is not short. Tentatively, the observed pattern of low retouch intensity may be related to the curation of bifacial tools as sources of flakes whose use and purpose was short-term.

Further to this, a count of retouch extent by type (Figure 5.19) clearly shows that the majority of retouch at the level of the total survey assemblage is both discontinuous and short. This is parsimonious with the overall conformity in size of the utilized flakes with the unretouched; the former is simply not modified enough to significantly change artefact shape. It is worth noting, furthermore, that the artefacts with retouch along a single edge have exclusively been subjected to short retouch. An example of this has already been illustrated above in Figure 5.10. It is possible that the widespread presence of short, discontinuous retouch (and, conversely, the lack of systematic, intensive retouch) is due to the functional need for cutting implements being fulfilled by simple flakes. The low frequency of invasive and absence of covering retouch extents is probably related to the lack of recognition of a point-producing industry (i.e. Umbu culture) in the total survey dataset.

Breaking the retouch patterns down further by analytical site (Table 5.6) shows the overall distribution of edge-shaping activity across the survey assemblages. In all the sites analysed, the frequency of retouch is notably low. Even in the MPM023 assemblage, which has proportionally received the largest amount of retouch, more than three quarters of the flakes are unmodified. Secondly, Discontinuous retouch is by far the dominant type; across all sites the retouched flakes in this category outnumber the other types. Artefacts with Single edge retouch (e.g. Figure 5.10) are the next most common category. Typologically, many of these could be termed side- or endscrapers. One specimen with a Single modified edge from MPM015 (#131) has retouch on its ventral surface too, making it technically a bifacially flaked flake and unique among the retouched flakes. Finally, Total coverage retouch is very rarely observed, with only four flakes in the entire PME dataset bearing it. Such a comprehensive pattern of retouch suggests the intent to create a preconceived shape on a flake, and as the four specimens are in a similar

Table 5.6: Summary table of retouch type and retouch extent on all flakes and flake tools in the analytical sites, showing an overall low rate of retouch and low degree of intensity.

		MPM015 *n* = 180	MPM018 *n* = 71	MPM022 *n* = 22	MPM023 *n* = 75	MPM028 *n* = 19
Retouch type	Discontinuous	7.8%	1.4%	4.5%	16%	21%
	Single	2.2%	1.4%	9.1%	6.7%	.0%
	Total	1.1%	1.4%	.0%	1.3%	.0%
	None	88.9%	95.8%	86.4%	76%	79%
	Sum	100%	100%	100%	100%	100%
Retouch extent	Short	9.4%	2.8%	9.1%	18.7%	10.5%
	Long	1.1%	1.4%	4.5%	4%	10.5%
	Invasive	0.6%	.0%	.0%	1.3%	.0%
	None	88.9%	95.8%	86.4%	76%	79%
	Sum	100%	100%	100%	100%	100%

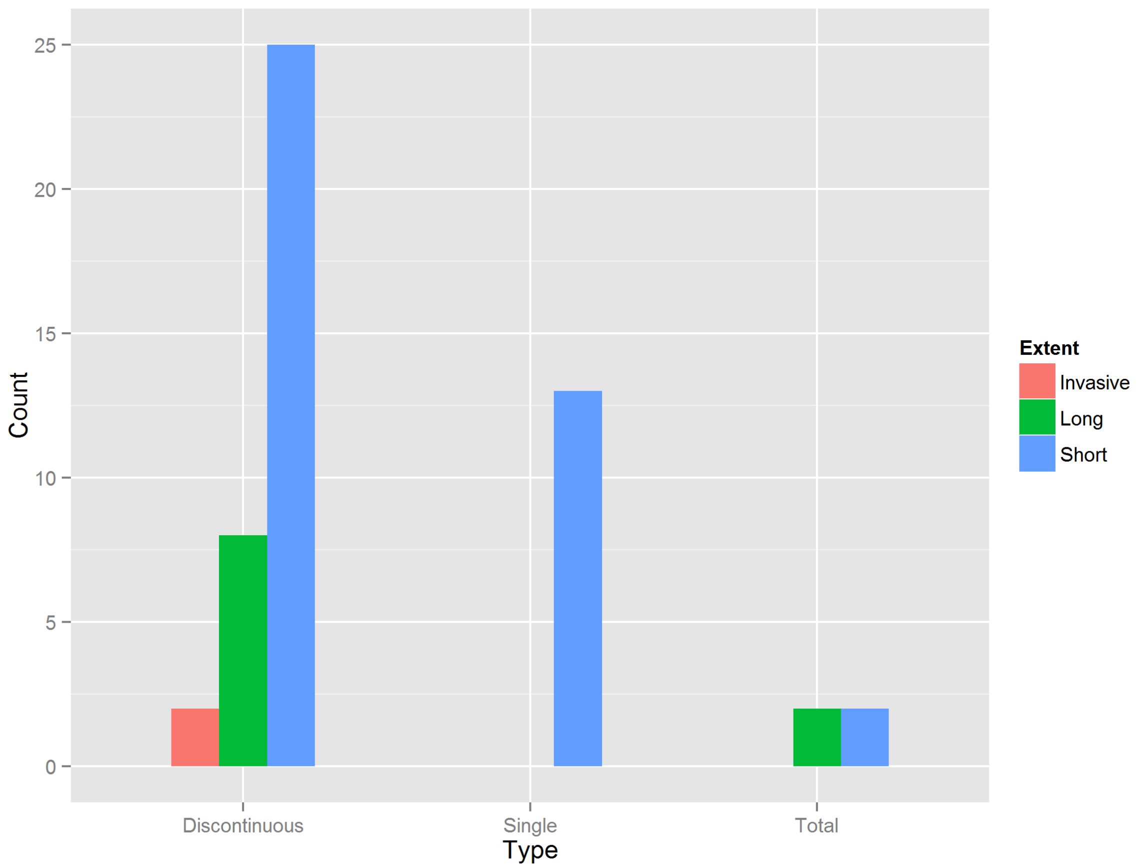


Figure 5.19: Distribution of retouch extent among retouch types. Covering retouch (see Chapter 3) was not recorded on any flakes in the total survey assemblage, and is not represented.

diminutive size range (5 – 10 on the relative thickness index), they might be technologically related too. Consequently, and although "finished" Umbu points are not present in the survey assemblage, flakes with Total retouch may be considered likely candidates for the preforms of this type of artefact. For lack of more detailed understandings of Umbu spatio-temporal distribution and technology in Misiones (as developed in, for instance, Okamura and Araujo 2014), this should be regarded as speculation.

Concerning retouch extent, Short is unambiguously the dominant form of edge modification. In effect, retouch of this nature only reshapes the very outer margins, resulting in few changes to flake morphology. This echoes the point illustrated in Figure 5.18 that modified and unmodified flakes have very similar morphologies. The Short and largely Discontinuous retouch that prevails across the field sites suggests strongly that the knappers in these areas practiced a technology that was expedient in response to situational, rather than anticipated, needs. As part of this system, flake edges were retouched only if necessary, evidenced by the limited modification of flake morphology and overall low retouch intensity distributed thinly across a large flake population.

Bifacial tools

The bifacial artefacts are a diverse group of lithics that ranges from specimens in the earliest stages of roughing out, through complete tools and ending with pieces recognizable as broken fragments (see also Figure 2.4). The latter category is unambiguous evidence of *in situ* artefact discard due to either failed attempts at shaping or from usage, and will be addressed in detail later. A study of bifacial tools was carried out in parallel to this research on the PME project assemblage, supplemented with older collections (Riris and Romanowska 2014) and the results are briefly summarized here. The study aimed to reconstruct the *chaîne opératoire* of so-called "curved cleavers", a distinctive type of bifacial artefact found throughout the eastern La Plata basin (Menghin 1955/56; De Masi and Artusi 1985; Schmitz 1987). In the cultural-historical view of the macro-region they belong to the Humaitá industry in Brazil and the Altoparanaense in Misiones, however, their temporal range is now known to vastly exceed the original estimates for both of these notional "cultures" (Dias and Hoeltz 2010). In its most exaggerated form during the latter stages of production, the shape of the tool can be very eccentric (Figure 5.20). Only a single preceding study (Nami 2006) has attempted to address the tools' reduction sequence and reconstruct the steps taken by the knappers that produced these tools. This experimental study was used as a baseline to understand the curved cleaver *chaîne opératoire* and generate meaningful comparisons with archaeological examples.

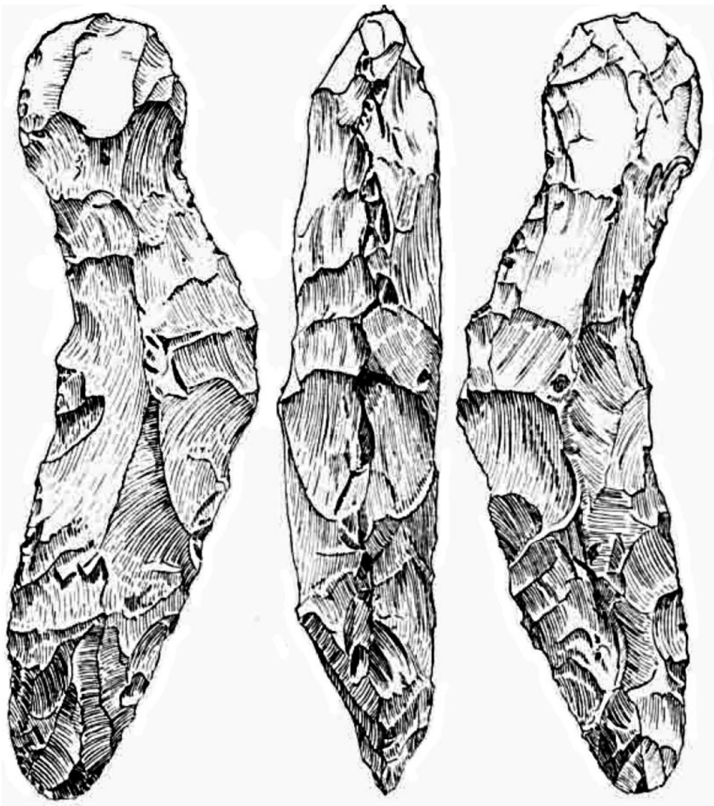


Figure 5.20: Curved cleaver collected in Yaguarazapá, Paraguay. Scale not known. After: Menghin 1955/56.

Supported by the qualitative *chaîne opératoire* analysis and statistical regression, the study concluded that curved cleavers were produced on either large flakes or elongated nodules. The distinctive asymmetrical curved profile is imposed comparatively late in the reduction sequence, while earlier forms do not possess the curve unless the raw material itself did (see Hoeltz 2007). Consequently, the symmetry of the "handaxe-like" forms of the earlier stages (see also Menghin 1957, 21-23) is masked by later modifications. Extending this finding, the study shows that the majority of bifacially-flaked artefacts found in Misiones are in reality preforms of curved cleavers that have gone unrecognized (Riris and Romanowska 2014). Using only typology as a basis for defining tools, preforms would be considered unrelated to the final form of the curved cleavers. For the purposes of this chapter, the study achieves two objectives. First, it has been possible to categorize bifacial tools into preforms, finished tools, and tool fragments (see Figures 5.21 and 5.22) throughout the total survey assemblage. As no other late-stage bifacial tool type was recorded by the PME project, the categories can be used with some confidence to represent curved cleavers at various points in their biographies. Second, new possibilities are opened for understanding the distribution of knapping activities and discard across the landscape of the study area.

The ratio of bifacial artefacts to flakes can be examined on a site-by-site basis to further explore the circumstances under which these tools moved around the landscape and contributed to the formation of assemblages. Following Magne (1989), the ratio can be set against the percentage of late-stage debitage (defined here as non-cortical flakes) in an assemblage to explore whether tool maintenance or tool manufacturing activities took place. These two variables, the score on the ratio and percentage of non-cortical flakes, interact to produce a set of possible interpretations from the data.

In brief, an increase in non-cortical flakes can be linked to tool maintenance activities, as these flakes may be struck off finished tools with little to no cortex. Alternatively, it could imply that pre-forms were introduced to the field site and thinned, shaped and finished. Tool manufacture, from raw material to blanks to preform to finished product, should be reflected in a greater proportion of earlier flakes in the assemblage. A high score on the flake-to-biface ratio, i.e. a large number of flakes and a smaller population of tools, indicates that tools were being curated and used in a given area. Conversely, a low score suggests a high rate of discard during production or use (Carr and Bradbury 2011, 314). This cannot, however, distinguish between cortical flakes produced from biface manufacture or core reduction, which must be taken into account.

It is useful to observe the distribution of the data to get an impression of how tool manufacture, use and discard unfolded in the study area. Figure 5.22 graphs the relationship of the two variables in the five analytical sites. As always with surface collected assemblages, the possibility exists that the occurrence of multiple processes and strategies in the same sampling unit through time has muddled the data and lead to a mixed picture of the activities that took place. As indicated previously, this has likely occurred in most, if not all, the analytical sites. Due to the caveats identified above, the results should not be

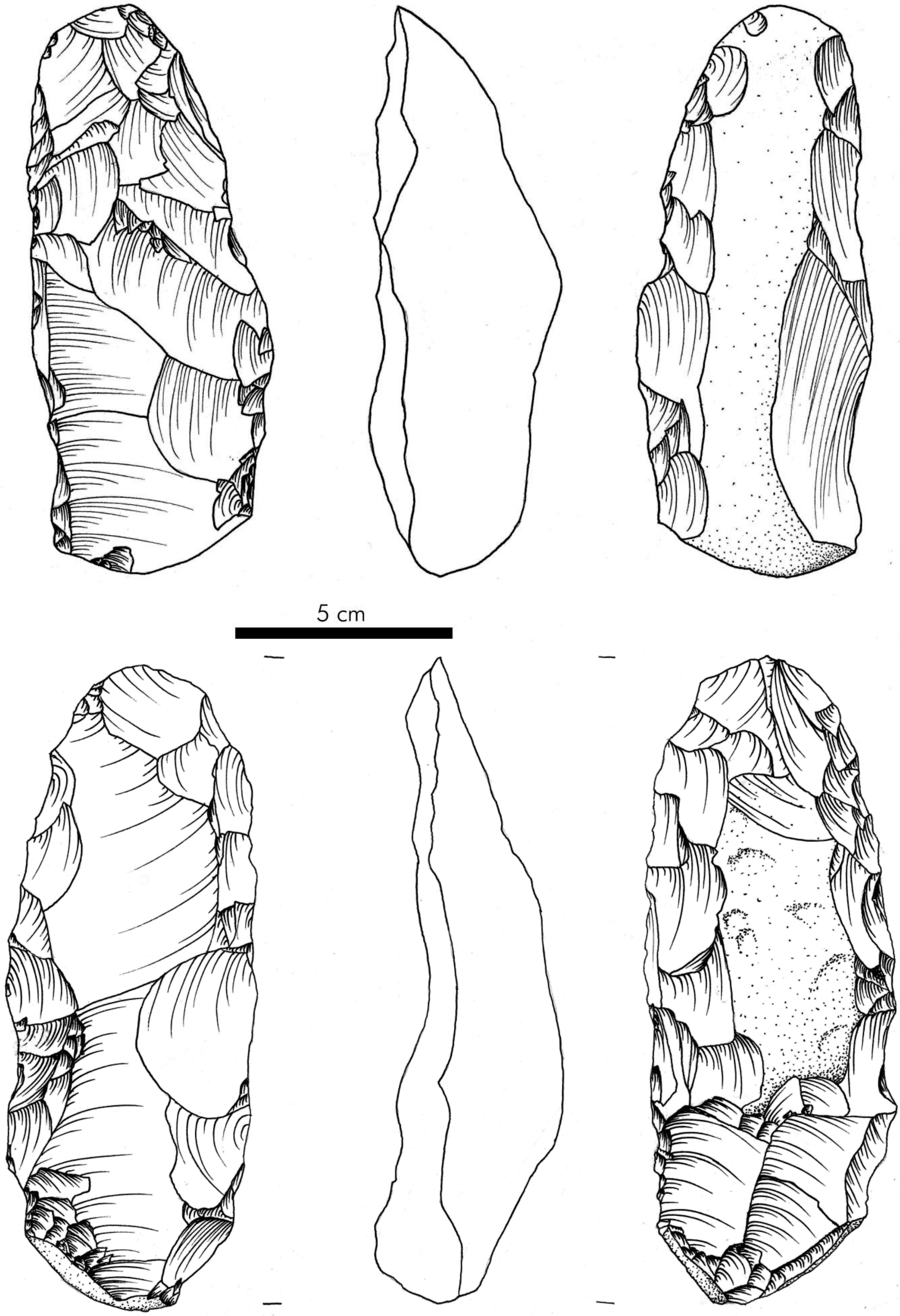


Figure 5.21: Top: Early stage preform of tool with bifacial reduction. Artefact #17. Bottom: Late stage preform of tool with bifacial reduction, lacking only the imposition of left-right asymmetry, Artefact #246 Drawings by I. Romanowska.

taken at face value, which somewhat limits the viability of this index for investigating assemblage formation. Consequently, late-stage debitage is conservatively defined as those with 0% cortical cover.

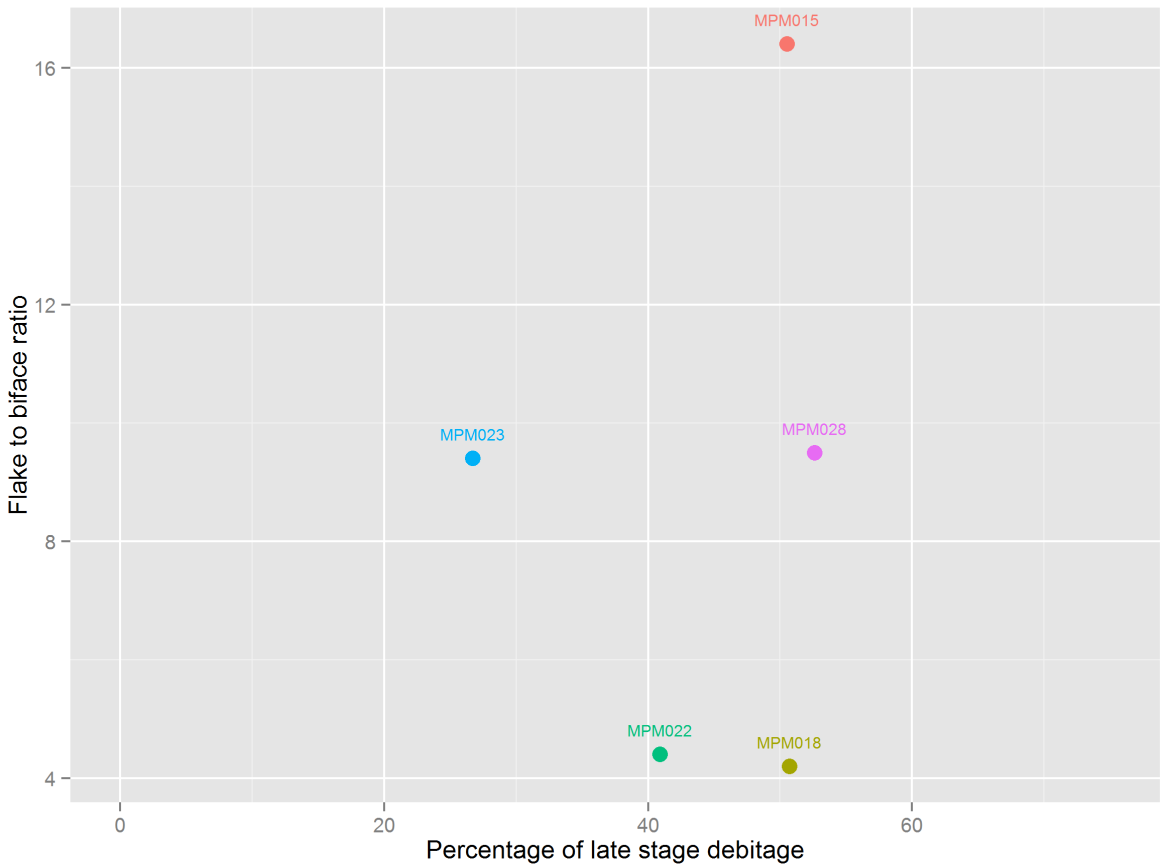


Figure 5.22: Scatterplot showing the flake to biface ratios and percentage of late stage flakes for each analytical site.

As with the flake relative-thickness index, the field sites can be divided into three groups, consisting of MPM018/MPM022, MPM023/MPM028 and MPM015. This last, solitary field site has the most easily interpreted relationship between the two variables. A high percentage of non-cortical flakes (maintenance) combined with a relatively small number of tools implies that bifacial tools were being used and discarded *in situ*, having initially been prepared elsewhere. Unfortunately, the fact that the majority of the bifacial tools (*n* = 12, 85.7%) are curved cleaver preforms undermines this interpretation to a certain degree. The high proportion of non-cortical flakes implies that the preforms were not produced in MPM015, but brought to this location. This would indicate that the bifaces had a degree of mobility in the landscape.

On the other hand, while MPM018 and MPM022 score similarly on the percentage of cortical flakes, the pattern of deposition is the opposite of MPM015. The comparatively high rates of discard implied by the ratio fits a material pattern; 40.9% of bifacial tools in these locations are recorded as broken, possibly from use or resharpening (Figure 5.23). The former is more likely than the latter, given the typical pattern of breakage across the transversal plane, and that a function as a digging tool has been suggested elsewhere (Nami 2006). Finally, the indices of MPM023 and MPM028 are more difficult to interpret. The sample of bifacial tools in MPM028 is very small (*n* = 2), making it impossible to make any defensible statements about knapping systems or their function. Assuming for a moment that bifacial tool manufacture occurred in MPM023, as suggested by the high proportion of cortical flakes and preforms, what do "middle of the road" ratio values imply for tool transport and discard? One possible interpretation is that blanks were being reduced into preforms, but that the rate of rejection and discard was approximately equal to the rate of transport for use in other contexts. It seems possible to, however tentatively, characterize the field site as a tool workshop where the initial preparation of bifacial tools occurred.

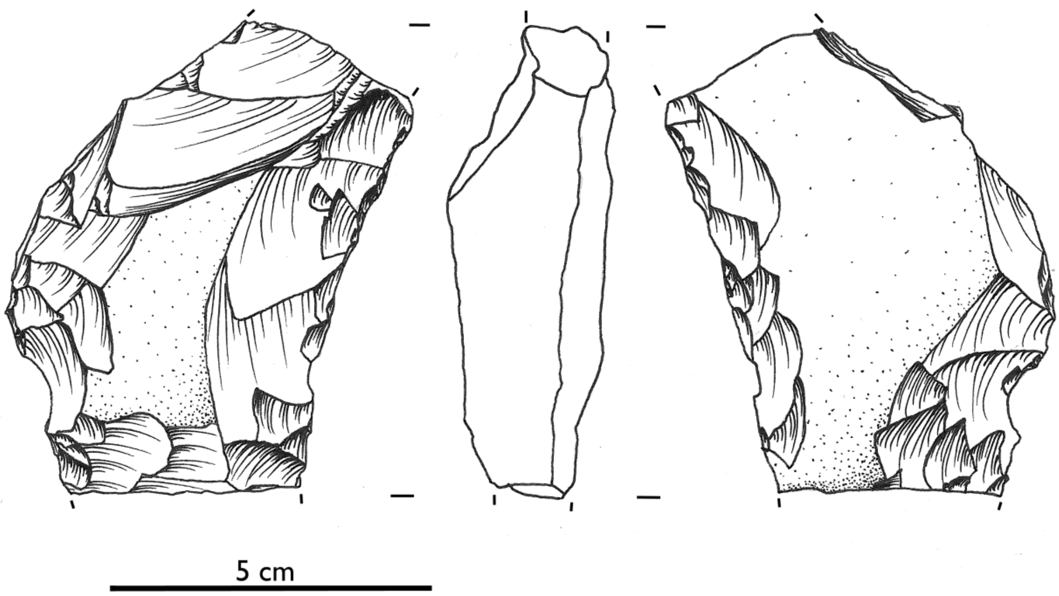


Figure 5.23: Broken curved cleaver collected from the roadside in a reconnaissance survey. Raw material is fine-grained black basalt. Transversal pattern of breakage is typical of this class of artefact. The high quantity of cortex present might imply manufacture breakage. Artefact #84. Drawing by I. Romanowska.

5.3 Concluding summary

The aim of this chapter was to analyze and interpret the lithics collected and recorded in the PME project survey in order to provide specific answers to questions about lithic technology in Misiones province. These sought to interrogate: *a)* the presence of different knapping systems, *b)* the role of retouch and reduction intensity in these, *c)* the influence of raw material management practices and *d)* the implications of the analyses in terms of land use. This was achieved by looking at the three defined classes of stone artefact in order to build up an impression of long-term patterning and variability in the surface record. The main area of interest was the core and flake technology that dominates the dataset. Consequently, the management of the basaltic raw material, the intensity of reduction and exploitation, and the distribution of retouch within knapping systems formed the focus of most of the chapter. Additionally, a consideration of tool production and discard sought to address how more complex artefacts with a greater degree of morphological formality were curated and used. This concluding section will attempt to summarize the major findings of the analyses and outline set of priorities for further exploration of the PME dataset by spatial analysis. It is structured by the technological systems that can be identified as a result of the above analyses and present a synthetic view of the work.

Core and flake exploitation systems

As discussed, core and flake reduction dominates the total survey assemblage. This system of reduction involved detaching large quantities of flakes from decortified river cobbles that received only a modicum of preparation in advance. Cores were flaked using a variety of techniques (unidirectional, alternating, multiplatform), but these do not appear to be linked to any particular exploitation strategy; reduction intensity is stable across these categories. The cultural significance of different techniques is an open question, since these are universal ways of knapping non-prepared cores. A very small quantity of cores in exotic grey basalt which display intensive, systematic reduction can only offer a tantalizing glimpse of differential treatment of raw material at this stage. On the whole, therefore, cores were not managed beyond the immediate needs of the knapper and were probably not curated to a large degree. Frequently, they appear to have been discarded after a very small number of removals. Their mobility in the landscape was probably relatively low, but low amounts of cortical cover in certain flake assemblages might speak to the extraction and preparation of raw material *ex situ*. Despite this and the variability of reduction intensity, core size is consistent across the field site assemblages. As discussed, this could be attributed to cultural selection of specific size grades of raw material, but is more likely simply related to its availability.

Expediency in core reduction should not be mistaken for opportunistic; "expedient" technology in the archaeological record represents the intent to extract quantities of material from informal cores, a behaviour which is implicitly planned (Nelson 1991). The abundant basaltic geology meant that river cobbles and nodules could rapidly be converted into a dependable source of flakes as required. In the majority of cases this activity was centred on generating amorphous flakes in the 25 – 50 mm size range, but there is reason to believe that much larger flakes were detached in certain cases. These may have been incorporated into the unifacial tool system, discussed further below. The majority of flakes appear to have never been used and are simply debitage that almost immediately entered the archaeological record. Retouch is the only direct evidence of flake usage in the dataset, and it is notably uncommon as well as varied (see Figure 5.24). Furthermore, the retouched artefacts display no dominant morphological pattern other than marginal retouch. The aim appears to have been to sharpen an edge rather than to reduce flake tools into specific shapes in a pre-conceived sequence. This makes sense insofar as, without a shortage of cores from which to detach flakes, there is little

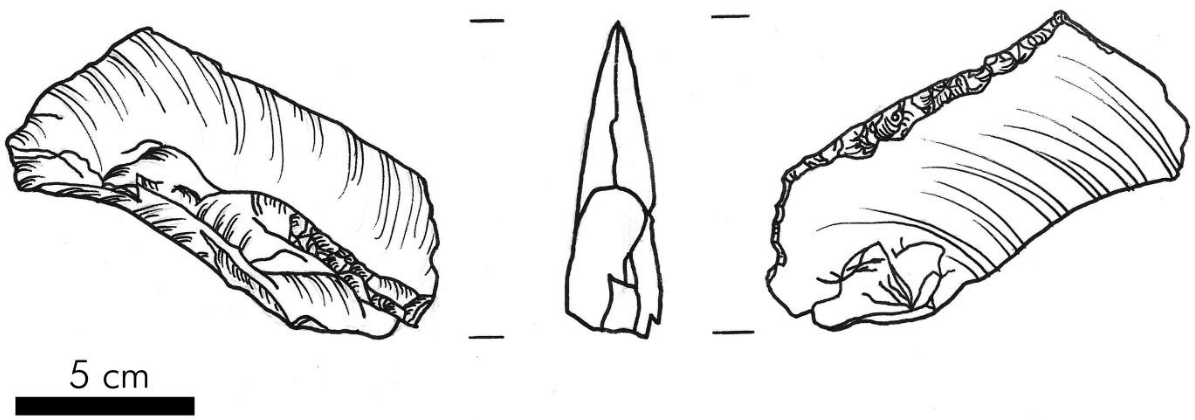


Figure 5.24: Retouch patterns are highly heterogeneous, although in absolute terms short retouch (as above) dominates the assemblages. This is a rare example of ventral surface retouch (R). Artefact #131, drawing by O. Martin.

compelling reason to either *a)* exert a lot of control over core shape and hence flake morphology or *b)* produce and select flakes conservatively to minimize "waste" (Hayden 1979, 92 in: Holdaway and Douglass 2012).

The analysis of the utilized flakes indicates that certain artefacts were curated more than others and, but in this case does not allow the quantification of occupation duration in the landscape (see Roth and Dibble 1998). Nonetheless, flakes were probably selected to meet anticipated needs because they are efficient tools (Kuhn 1994), but were retouched as needed on daily itineraries. This might reflect a technological response to shifting priorities. Cortical cover appears to not have had much impact on this choice, if at all. In contrast to unretouched flakes, therefore, utilized flakes were sharpened in order to continue serving a purpose, and were more likely to be transported away from their production context. Unretouched flakes, if they ever were used, reflect expedient *use* and were likely discarded on the spot. Although a non-site framework does not attempt to reconstruct individual activities or depositional events, the duration and intensity of occupation, as well as the spatial scale of these processes, are within the purview of this research. It is clear that neither the raw distributional data presented in the previous chapter, nor this technological analysis can furnish complete answers on their own and must be seen in a spatial analytical perspective. Unfortunately, it was not possible to establish independent controls for the RT index by relating it to the intensity of core reduction or to the reduction strategy.

Unifacial tool system

The unifacial tool system is, in effect, an offshoot of the core and flake system. There are two main distinguishing factors between a unifacial tool and a utilized flake. First, the size and mass of unifacial tools is consistently greater than utilized flakes (the latter illustrated in Figure 5.17). While the ultimate provenance of unifacial tool blanks is, of course, cores, the qualitative difference in size of these tools suggests a more careful selection and preparation of raw material than the bulk of the core and flake system. Hints of such a process are in the survey assemblages (notably Table 5.4), but cannot conclusively be demonstrated to exist with the presently available data. The existence of uncommonly large cores for the production of large blanks is conjectural, based on the presence of the end results of this system.

Second, the formality and intensity of retouch differs between unifacial tools and utilized flakes. While utilized flakes receive limited retouch (see Figure 5.7, bottom), in some cases seemingly at random, tools such as the one shown in Figure 5.10 show deliberate intent to modify an edge. In the latter case, the system is mainly composed of end- and side-scrapers with managed morphologies. The observed strategy of intensive, repetitious retouch on a single edge in these tools implies that blanks were chosen with the knowledge that their shape and volume would need to be adaptable to comparatively long use-lives. The time and labour invested in these tools might implicate them in curatorial practices that extended into roles beyond the tasks that utilized flakes were able to accomplish expediently. This interpretation, however, presumes that production effort translates directly into a long use-life. Only a series of these artefacts with clear evidence of resharpening would be able to decisively establish whether this is the case. In the present case, it is unfortunately equally plausible that scrapers were discarded after a single use. Overall, morphology was not a decisive aspect of unifacial tool systems, but ability to receive retouch likely was. Like the core and flake system, unifacial tools were geared towards provisioning people rather than places (Holdaway et al. 2010, 189) as part of a shifting and relatively mobile pattern of land use.

Bifacial tool system

The interpretation of the bifacial tool system leans heavily on the findings in Riris and Romanowska (2014), including the recognition of five distinct tool stages. In brief, this suggested that many, if not all, handaxe-like artefacts that were recorded the study area could be curved cleaver preforms, an aspect of technological organization that has hereto gone unnoticed in Misiones (see Menghin (1955/56; 1957). Preceding typological distinctions were not able to view bifacial artefacts as the product of a sequence of reduction. The recognition of the *chaîne opératoire* of curved cleavers opens a wealth of possibilities for understanding the spatial distribution of lithic practices (Riris and Romanowska 2014). Although various stages of bifacially reduced preforms may have functioned as tools at certain points, links can clearly be made between these and the "final stage" curved cleavers through the identified reduction sequence. In the distributional analysis of stone artefacts (see Chapter 6), this may inform the positive identification of tool use versus tool production and raw material extraction. Sites with the potential to be quarries or workshops have previously been located in Misiones (Iriarte et al. 2010b), and this would be the first time a formal spatial analysis of such locations takes place.

The full range of curved cleaver biographies is represented in the PME survey dataset. In certain contexts there appears to be direct evidence of deposition in either "final stage" or broken forms, implying usage *in situ*. Additionally, artefacts that can be identified as preforms on the basis of the study (Riris and Romanowska 2014) exist in abundances greater than the population of primary and bifacial thinning flakes would suggest on their own. In other words, there is a comparative lack of primary flakes resulting from the processing of nodules into blanks, meaning the very first stages in the bifacial system of production. Nonetheless, if these were present, surface collected data would not permit them to be specifically attributed to either bifacial tools *or* cores. In addition to the actual use and *in situ* discard of curved cleavers, locations were likely also provisioned with blanks and roughouts that had been prepared elsewhere, which could explain the lack of "classic" thinning flakes. This may indicate that locales such as MPM015 played host to places that were returned to regularly by pre-Columbian people in the knowledge that previous visits had left prepared material there. This implicates long-term occupational cycles in the production of bifacial tools, while the effort and care involved in shaping bifacial tools substantiates the view that these places were also occupied for some length of time. Archaeologically, however, provisioning would appear identical to discard in the initial stages of preparation, and cannot be conclusively proven as present.

In contrast to the core and flake reduction system, which expediently provided individuals with stone implements, from a technological perspective the bifacial tool system appears provision *places* with material that could later be shaped into curved cleavers. This is unexpected, in that it somewhat contradicts the most prevalent theoretical model for biface usage in the Americas (Kelly 1988), for which the formal biface is the archetypal mobile stone tool in the hunter-gatherer toolkit, while expedient technology is the adaptive response of more sedentary societies. In reality, the informal-formal and mobile-sedentary duality is too dichotomous on its own, in that raw material availability and social context will strongly affect how much effort is invested into producing tools with specific functional requirements (Holdaway and Douglass 2012). Evidence of curved cleaver usage is scant, with the possible exception of flake assemblages in two low-density field sites (MPM016 and MPM024) that could be related to retouch. If a tool was fulfilling its function, however, it would naturally be absent from the archaeological record, which represents discard. Therefore, low-density sites could be related to a genuine practice of occasional edge rejuvenation on curated bifacial tools during small-scale, infrequent visitation and re-use of a locale over the long term. This would lead to deposition that is spatially unstructured but which exhibits technological consistency. Nonetheless, the limited sample sizes preclude a strong conclusion to be made on the matter and this interpretation should be regarded as tentative at best.

The next chapter will adapt the findings of this chapter and their interpretation into the spatial analytical perspective that this research has been building towards. The lithic analysis will therefore be used to discuss and evaluate land use, spatial practices and record formation in the study area using novel techniques.

6. Distributional analysis

"You can make up a lot of stories about what inter-site variability means, but unless you have formulated hypotheses which can be tested, it's just science fiction."

Sally Binford (in: Clinger 2005, 195)

6.1 Introduction: spatial analysis and land use

In this chapter, the spatial structure of the lithic assemblages recorded in the Alto Paraná will be examined from a multi-scalar perspective. The intent of this is to interrogate potential long-term patterns in depositional behaviour in the surface record, and in doing so build up an impression of the variability in land use and spatialized practice by pre-Columbian groups in the study region. To achieve this objective, a family of spatial analytical methods are introduced and applied to the spatial point pattern data described in Chapter 4. As the correlation of surface data with patterns of land use from has until now relied on speculation without any rigorous definition of the boundaries within which indigenous cultures might have operated, these statistics can be seen as the cornerstone of developing a renewed understanding of settlement practices in the Alto Paraná. The spatial analyses build upon the findings of the technological analysis elaborated in the previous chapter. Several of the interpretations are employed as points of departure for generating hypotheses about the observed patterning in the survey assemblages. What follows therefore is a quantitative analysis the distribution of archaeological points in space. Each approach offers advantages which are identified in relation to the scale of the questions being pursued (Bevan et al. 2013). Understanding how our representations of archaeological data impact interpretation is necessary in order to characterize these phenomena, and truly appreciate what they can tell us about the past.

The distribution of archaeological remains in space has been a key focus of interpretation practically since the inception of the discipline (Trigger 2006, 289). Despite early programmatic interests within archaeological research (e.g. Whallon 1973; Hodder and Orton 1976; Clarke 1977), scholars in fields such as ecology and geography have generally made greater use of quantitative spatial methods and benefitted the most from the application of new methods as they are developed. Intuitive and simple density-based interpretations of spatial patterning persisted as the norm until fairly recently (Premo 2004, 865), when the ubiquitous adoption of spatial technologies in the 21st century (see

Wheatley and Gillings 2002; Conolly and Lake 2006; Bevan and Lake 2013) has reawakened an interest in more rigorous definition of how cultural behaviour varies spatially. Furthermore, the corresponding expansion of spatial data(-bases) places limits on the viability of prior practice. In other words, with the size, accuracy and precision of our datasets being augmented, the sophistication of our methods must improve to match them (Bevan 2012, 493). When surface material represents a time-averaged palimpsest of occupations with indeterminate spatio-temporal extents, as it certainly does here, inferring dynamic cultural process from a static archaeological pattern represents a clear challenge to quantitative methods.

To this end, the methods used in this chapter build upon the analysis of flaked stone from the preceding chapter. A number of reduction systems and technological attributes were identified in the survey assemblages, which were grouped under three principal systems of exploitation:

- *Core and flake reduction* dominates the majority of the field site assemblages. Despite the amorphous shapes of both artefact types, consistent size grades of raw material appear to have been selected, although flakes have greater variability. A small number of flakes show clear signs of use and informal retouch. Furthermore, cores were exploited in different ways, but there is no sign that this is directly related to the degree of exploitation. Producing large quantities of flakes, of which only a few were selected for further use, appears to have been the main outcome of this system.

- *Unifacial tool production*, which differs significantly from the predominant pattern of expedient flake removal in both labour investment and size. Unifacial tools exhibit a greater degree of management and maintenance of a useful edge (for cutting or scraping) than utilized flakes and are generally larger in all recorded dimensions. While morphology appears to have been largely uncontrolled, based on the appearance of the available sample, unifacial tool systems met variety of functional requirements.

- *Bifacial tool production*, which consists entirely of large bifacial "curved cleavers" and "hand axe-like" preforms. From a cultural-historical point of view, these artefacts would be linked to Altoparanaense (Humaitá) land use. Although each stage of this artefact is represented in the survey assemblage (Riris and Romanowska 2014), linking their production to specific types of debitage is more problematic, as so-called bifacial thinning flakes are rarely encountered and ambiguously defined. This system likely involved curatorial practices to a greater degree than the previous two systems.

The identification of these reduction systems in Chapter 5 must be considered alongside the observation made in Chapter 4 that the assemblages are far from uniformly distributed across the study area. The methods presented in this chapter attempt to unify the conclusions drawn from the preceding chapters in a quantitative spatial framework. The detection of differential patterns of deposition, mediated through record formation processes, implies that flaked stone was organized spatially as well as technologically. It is argued that understanding the interface of these two aspects of land use have an important contribution to make regarding the scale of pre-Columbian society in Misiones province.

The notion of "land use", as discussed previously, is used as a shorthand term for the landscape-level palimpsest of unfolding events, occupations and biographies that contributed to the emergence of persistent places in the material record (Schlanger 1992; Ebert 1992). To the advantage of the research objectives, the survey succeeded in recording archaeological material in a variety of topographical settings within the study area. Planes and the channels of rivers indicated by the landform classification in Chapter 4 constitute the main bulk of the field site areas, but ridgetop locations also feature in a significant quantity. If land use varies with the features encountered in these different settings and the tasks they afford, this inclusive sample increases the likelihood that a variety of practices will be reflected in the material record. In terms of local relief, the areas surveyed were mostly flat to gently undulating, which likely ameliorates the severity of erosional processes in comparison to steeper hillside locations.

With this understanding of the Piray Mini Exploration project dataset, the potential of applied spatial statistical methods for archaeological data analysis will be explored following the themes defined by this research.

6.1.1 *Representational thought and spatial data*

As a brief aside, it is useful to reflect on the nature of spatial data representation and the epistemology of cartography in archaeological research. Spatial data are a type of information with a component that links to a real geographical location, which are usually represented as simple geometric entities such as points, lines, and polygons. These spatial objects are fundamentally *representations* of some realized spatial process, whether the growth of trees in a stand, the route of a traveller or the municipal boundaries of a city (Haining 2010). They are convenient devices for managing the complexities lying behind the data gathered by archaeologists (Conolly and Lake 2006, 162; McCoy and Ladefoged 2009, 267). A point to emphasize is that the data presented here is only a single view of the material record in a handful of "analytical sites" covered by the PME project in 2013. Although this is to some degree unavoidable, insofar as quantitative spatial methods are implicated in the production of hegemonic discourses (Griffiths 2012, 156), the archaeological as well as statistical significance of the findings will be evaluated in due course. Other projects, using different methods and visiting at another time, would likely encounter artefacts that could tell a story wholly unlike the one advanced here. This is not a problem; current practice in the archaeology of landscapes encourages the multivocality of different spatial narratives (Llobera 2012; Bevan et al. 2013; Wheatley 2014; c.f. Thomas 2004). Acknowledging this point strengthens the ability of the project to connect the surface record with the dynamic processes within past cultures that produced it. Within the limitations imposed by the epistemology and data structure of spatial thinking and digital cartography, a wealth of options are available for appropriately characterizing the properties of spatial point patterns in this chapter (Conolly and Lake 2006, 31-32; Goodchild and Janelle 2010; Lock 2010, 105).

6.1.2 *Characteristics of spatial point processes and patterns*

In advance of examining the PME project assemblages with spatial analytical methods, some elements of point process theory are introduced in order to understand the assumptions they make about spatial structure and hence how they function as indicators of statistical significance. Formally, a spatial point process is defined as:

"[…] a stochastic mechanism which generates a countable set of events x_i in the plane" (Diggle 2003, 43).

Following from this, empirical point patterns are empirically observed "realizations" or outcomes of such a process. They can be generically described as a series of points ($p_1, p_2 \ldots p_n$) distributed in a region R and optionally "marked" with additional attributes taking the form of $m_1, m_2 \ldots m_n$ (Perry et al. 2006, 60; Diggle 2003). Spatial patterns can be realizations of one or several theoretical point process models (Figure 6.1; Orton 2004, 299; Shekhar et al. 2011, 196). All point processes possess a variable termed intensity, denoted as λ, which describes the expected number of points per unit of area. An example of commonsensical usage of intensity in archaeological discourse are estimations of artefacts/m^3 and derivatives such as isolines or shaded density plots (e.g. Araujo 2001). Although potentially useful as visualization tools, their output is highly scale-dependent and they are therefore limited as an inferential device (Ebert 1992). Conversely, to build statistical inferences, the point of departure for most exploratory spatial analysis is comparing the empirical distribution of data to a distribution drawn from a spatial Poisson process. A Poisson process is functionally analogous to complete spatial randomness or CSR, in which points are independently distributed in space (Cressie 1993) and is the most common null hypothesis.

Naturally, archaeologists would very rarely expect data to follow a random distribution, since randomness implies that behaviour is absent or that the data quality is not sufficient. Furthermore, it is obvious that archaeological point patterns are generated by processes that take place over time as well as in space. The strength of employing CSR as a null hypothesis, however, stems from the fact that it affords the ability to assess at *what scale* and *where* a pattern can be distinguished from "random noise" (Fortin et al. 2002, 2051). In the case of this research, the analyses substitute the attribute data gleaned from the lithics for temporal information, as is commensurate with the non-site questions being pursued (Dunnell 1992; Ebert 1992; Sullivan 1998; Law et al. 2009, 618). In archaeological terms, this has the potential to enable inference about the nature of long-term land use (Bevan and Connolly 2006). Furthermore, in the absence of preceding archaeological research of this nature in Misiones province, the presumption of a non-Poisson null model might obfuscate the detection of significant patterns more than it can help infer process. Departures from CSR, i.e. non-random patterns, are typically described as aggregated when points display attraction or segregated when they are inhibited, respectively (Bevan et al. 2013, 29). These types of behaviour are otherwise known as clustered or dispersed (see Figure 6.1), which are the predominant terms used from here on out. The notions of "random", "dispersed" or "clustered" patterns as discrete, well-defined descriptors needs to be qualified, as these categories can simplify and gloss over a great deal of complexity when taken uncritically in isolation (Haining 2010, 214).

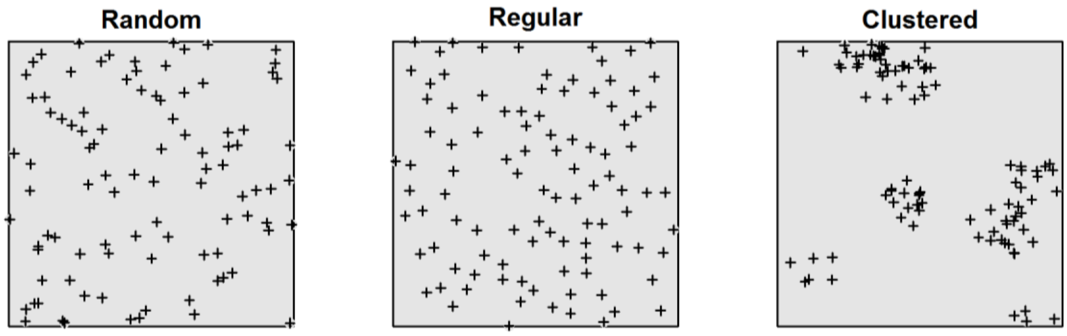


Figure 6.1: Point patterns generated from three theoretical point processes: (L-R) Poisson, Simple Sequential Inhibition, and Matern Cluster, illustrating idealized random, regular and clustered patterns, respectively.

When analyzing spatial structure, it is important to distinguish between the first-order and second-order characteristics of a point pattern. First-order characteristics are global, large-scale trends in a point pattern directly related to the intensity of the point process (Table 4.1; Couteron and Kokou 1997, 214; Diggle 2003; Wiegand and Molony 2004, 210). The spatial relationships between points caused by first-order effects are also known as *induced* dependence, meaning the pattern is related to external phenomena affecting its distribution (Fortin et al. 2002; Bevan and Conolly 2009, 959). A good archaeological example may be the tendency for European early Neolithic settlements to cluster on the best loess soils. Second-order characteristics, conversely, describe the interactions between the points themselves (Aldstadt 2010, 287), meaning the propensity for the locations of points to be attracted or inhibited by the locations of others (Bevan et al. 2013, 31). The properties of these processes are also termed *inherent* spatial dependence (Fortin et al. 2002, 2051; Bevan and Conolly 2009, 959). In the classic "complete radius leapfrog pattern" of hunter-gatherer camp distribution (Binford 1982, 10), the establishment of new camps is strongly conditioned by the locations of previous camps. To avoid overexploiting a range, new camps will ideally be established at a distance so there is no overlap between previous camps' foraging radii, in spatial terms a process of inhibition. Exploring the properties of spatial data is accomplished through first- and second-order statistics (Wiegand and Molony 2004). The latter is not commonly tackled until the former has been identified.

In practice, most empirical spatial data is autocorrelated (it exhibits interaction) in some way (Shekhar et al. 2011, 197). While best practice is to progress logically first through visualization, then first-order and onto second-order analyses in order to describe patterning (Perry et al. 2002, 597), such a critical understanding of spatial data implies that hypotheses should be generated in advance of deploying specific forms of analysis. Detecting spatial patterning is a comparatively simple task when compared to inferring the process(es) which resulted in the pattern. This is because observed patterns can often be satisfactorily explained by several processes or a combination thereof, the long-standing problem of equifinality (De Luis et al. 2008, 626). Also, specifically to archaeology, it is well known that observed data is an imperfect sample from a largely unknown sampling universe (Nance 1983; Orton 2000), an issue dealt with previously in this research. Careful formulations therefore allow stronger statements to be made on the nature of the cultural and natural mechanisms that caused the surface record to appear as recorded (Perry et al. 2006, 80). With an emphasis on exploration and building towards inference, an "artefact's-eye view" (*sensu* Purves and Law 2002) of the field site assemblages is developed through a suite of statistical methods designed for these purposes. The rejection of the Poisson null hypothesis is, on its own, not enough to ensure the recovery of meaningful information about the past, and comparative analyses must be undertaken where possible (Aldstadt 2010, 286). The methods described below attempt to understand the variability between field sites and their assemblages with an eye to preserving the nuance of the surface material record and its underlying cultural information.

6.2 Method and analysis

Most foundational and early applied texts on surface archaeology tend to use aggregate measures of spatial patterning to characterize their data (Thomas 1975; Foley 1981b; Schofield 1987; Ebert 1992), that is, artefact counts in quadrats and their variance around the mean. If this is considered the "expansion" phase of surface archaeology (Lewarch and O'Brien 1981), then the present may be thought of as a formalization phase in both a theoretical (Harrison 2011) and technical sense. In terms of the latter, with the increased availability and accuracy of spatial technology there has been a shift towards using point locations (Bevan and Conolly 2009) or in some cases points simulated from an archaeological distribution fitted to a model (Crema and Bianchi 2013) instead of aggregate measures.

The analyses carried out in this section make use of the empirical point data from the analytical sites that were collected during the PME project survey. As discussed in Chapter 4, these data have a horizontal error of up to 10 meters from where the artefacts were actually encountered. In reality, this displacement was actually much less (no more than 4 m). Furthermore, in a holistic view, the cumulative effect this random error is likely to be minimized by the large number observations in the analytical sites. At most, patterns detected at spatial scales below 10 m should be treated with a degree of caution to avoid over-interpreting short-range spatial structure.

The equations of the spatial statistics used in this section are presented separately in Appendix A.

6.2.1 A broad view: general spatial trends

Before the implementation of the formal spatial statistical analysis, some brief considerations of the spatial structure of the analytical sites are carried out. Although artefact density plots as an interpretative device are limited in many ways (Ebert 1992, 173-175), visual inspection of the point pattern data is usually a useful first step. Indeed, some aspects of this were already touched upon in Chapter 4. Two additional quantitative measures also feature here: the distribution of nearest neighbour distances and kernel density estimates of point pattern intensities. These are useful for characterizing any broad trends in the data and highlighting areas of interest for subsequent formal analyses to investigate.

Nearest Neighbour analysis

The Clark-Evans test (Clark and Evans 1954) has a venerable history of application to spatial questions in archaeology (see Hodder and Orton 1976; Clarke 1977). The test fell out of use with the adoption of new methods such as variance-to-mean ratios (Ebert 1992), kernel density estimates (Baxter et al. 1997) and k-means clustering (Kintigh and Ammerman 1982), but with support from additional methods it can function as a point of departure. The basic spatial structure of a point pattern is observed by producing an index R, which is the ratio of the observed mean nearest neighbour distance to the expected distance under CSR. Values of $R < 1$ indicate the presence of clustering, while those >1 indicate regularity (Baddeley and Turner 2005, 164). The Clark-Evans test was calculated for the total assemblage of each site and compared with a distribution of the test scores under multiple realizations of CSR (Table 6.1). The alternative hypothesis for these tests in the case of $R \neq 1$ was two-sided (i.e. the test was for the presence of both clustering and regularity). It is not surprising, based on the observed distribution of archaeological material, that the test indicates statistically significant departures from CSR in all field sites bar Gruber IV. The value of R on its own would indicate a very slightly clustered pattern for this site, but comparison with the values obtained from simulation indicates that such an interpretation would be untenable.

Table 6.1: Nearest Neighbour values (Clark-Evans *R* statistic), with edge correction using cdf method and 999 simulations of CSR with an intensity equal to the empirical point pattern to calculate the *p*-value. All field sites exhibit clustered distributions according to *R*, except for Gruber IV, which is randomly distributed.

Field site	*n*	*R*	*p*-score	Mean NN (m)
Aumer I	228	0.4449	<.01	6.145
Ziegler II	137	0.621	<.01	11.739
Ziegler III	45	0.5154	<.01	16.462
Ziegler IV	114	0.5934	<.01	10.165
Gruber IV	29	0.9573	>.5	10.245

Although the mean distance to the first nearest neighbour was calculated for each assemblage under investigation, the test does not indicate the overall distribution of distances with respect to the spatially random point patterns. In order to explore this characteristic, the distance of each point to its nearest neighbour was calculated and binned by 1 m of separation in a probability distribution (Figure 6.2 and Figure 6.3). Additionally, this analysis was performed on 999 realizations of CSR for each field site, and is displayed as a curve of expected values in the probability distribution. These graphs show that the probability of a point having a close neighbour (approximately <10 m away) is much higher than expected in all field sites. Interestingly, this value follows the curve above 10 m until about 25 m in Ziegler II and until about 40 m in Ziegler IV. Much lower values are found in the 10-30 m range for Aumer I, while a mixture of high and low exist in Ziegler III and Gruber IV. Finally, Ziegler III exhibits several spikes above 50 m.

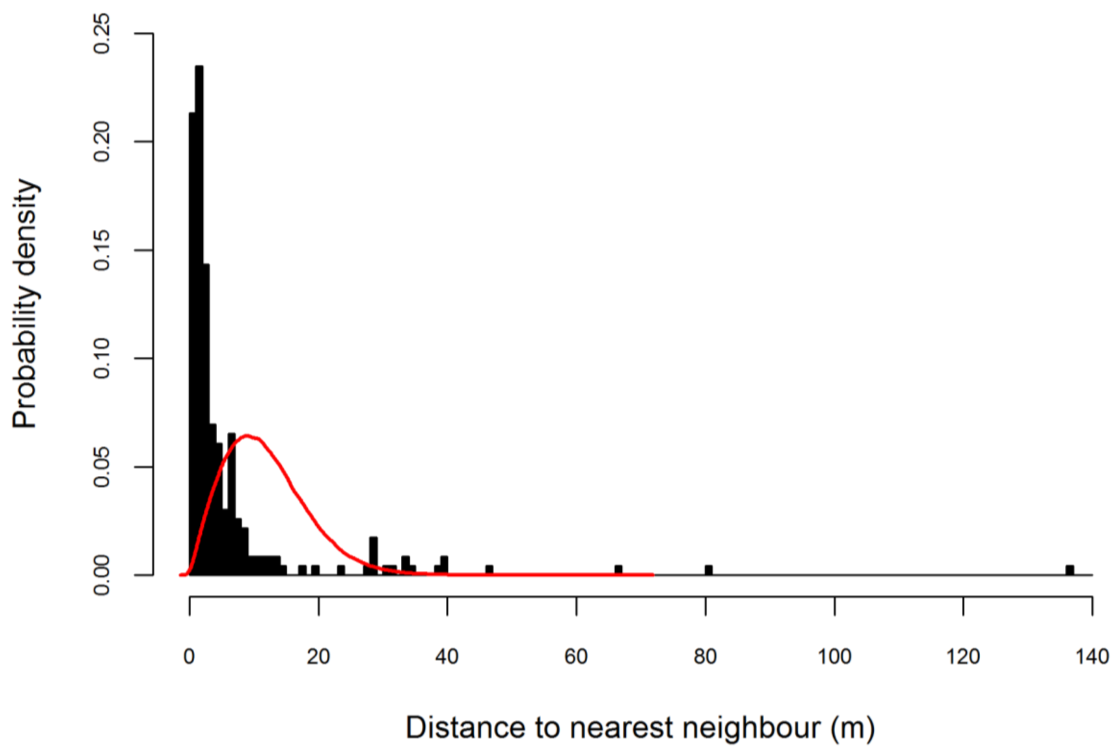


Figure 6.2: Probability density distribution of NN distances for Aumer I in bins of 1 m. Red curve indicates expected distribution of values derived from 999 realizations of CSR with an equal intensity.

Altogether, these results that a high degree of clustering is present in the PME project survey data and that a null hypothesis of CSR can be categorically rejected. This is a relatively shallow result, for two reasons. First, clustering is readily apparent in the density distribution alone and because of this, second, the probability distribution only gives an idea of clustering at fixed scales. Potential interactions between points and evidence of changing behaviour at different scales cannot be directly accessed with the Clark-Evans test. The version performed above is a first-order (meaning the first nearest neighbour is identified, rather than in the sense defined in section 6.1.2). Although it is possible to carry out *n*th-order analyses, the results become more problematic to interpret as the number of neighbouring points increases (Perry et al. 2006, 67). While the NN statistic has been

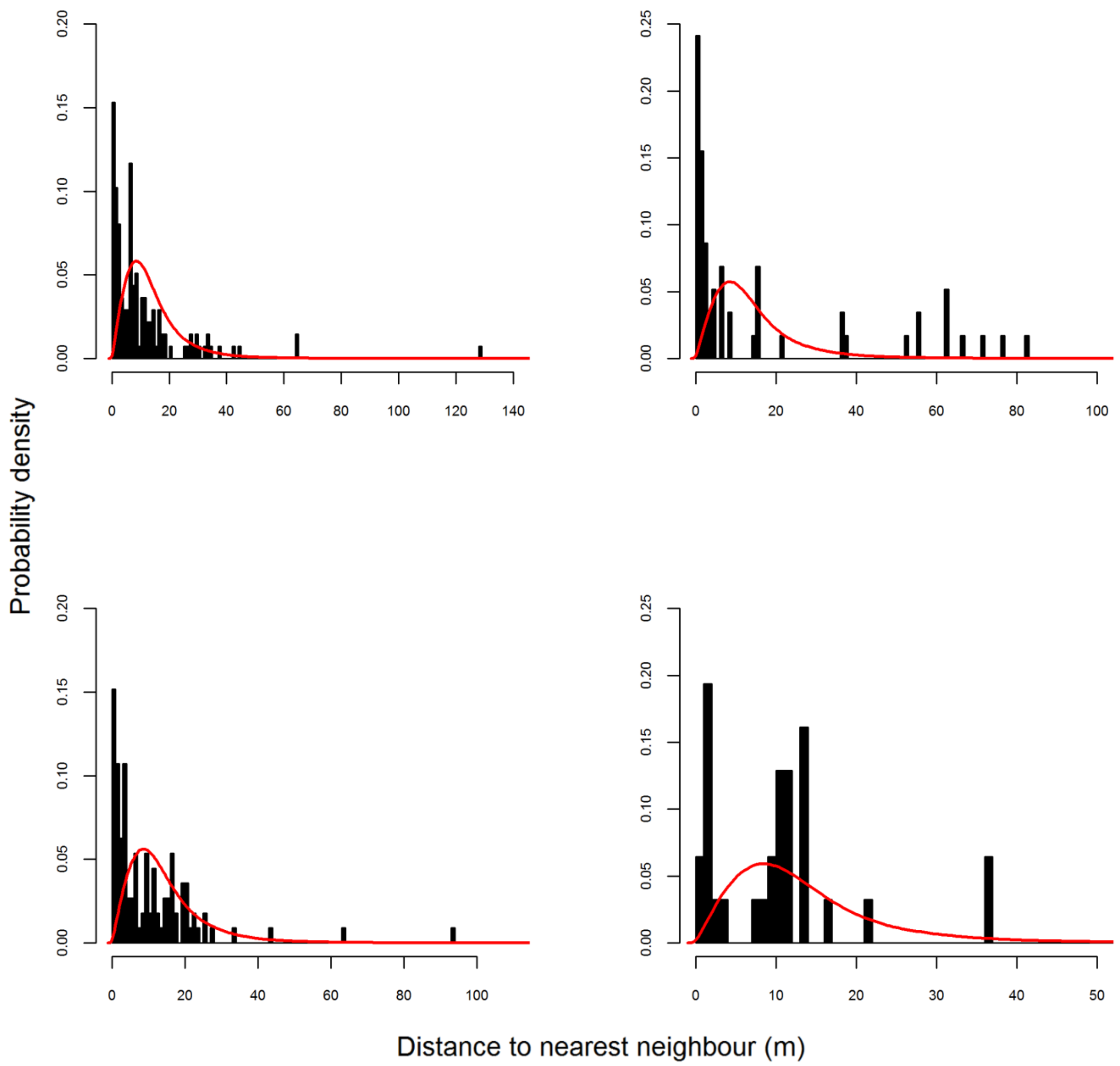


Figure 6.3: Probability density distributions for NN distance in 1 m bins for (clockwise from top left): Ziegler II, Ziegler III, Gruber IV and Ziegler IV. Red lines indicate expected distributions of NN values derived from 999 realizations of CSR with an equal intensity to that of the individual field site.

useful in a preliminary sense, characterizing spatial structure at multiple scales requires getting to grips with the spatial data using second-order exploratory methods.

6.2.2 Scalar complexity: second-order spatial trends

Second-order statistics have the ability to characterize the structure of point patterns over a range of spatial scales. Ripley's K statistic (Ripley 1976) is widely deployed to this task in landscape ecology. Several archaeological applications are also published (Bevan and Conolly 2006; Crema and Bianchi 2013; Eve and Crema 2014; Markofsky 2014), point to its flexibility in dealing with point patterns of different origins and natures. The function $K(r)$ describes the observed number of points in a circle of radius r around a point divided by the overall intensity of the pattern, displayed with an approximation of the statistic under CSR (Pélissier and Goreaud 2001, 101-102; Wiegand and Moloney 2004, 210). A modification of Ripley's K proposed by Besag (1977) is used here on the field site assemblages, termed the L statistic. This version is generally considered more robust and easier to interpret (Fortin et al. 2002, 2053), and has seen some use in archaeological applications (Bevan et al. 2013). The result of this statistic indicates whether a distribution can be considered clustered or regular at multiple scales simultaneously, with respect to the benchmark of CSR. At larger radii, however, the accumulation of values can bias the results (Getis 1984, 178) and overestimate the degree of clustering in a given pattern. A complementary method is necessary to ameliorate this issue.

The O-ring statistic (otherwise the pair correlation function or neighbourhood density function) $g(r)$ provides a second, related measure of the field site point patterns. In this statistic, the radii of the circles in Ripley's K are replaced by rings with outer and inner boundaries, allowing for clearer perception at patterning at distinct spatial scales (Stoyan and Stoyan 1994). In other words, structure is measured *between* the distance bands of r_1 and r_2 rather than *within* r_1 first and up to r_n. Due to the fact that the function does not accumulate like the K statistic, it also provides a more intuitive output (Jacquemyn et al. 2007, 451) and a closer look at the "critical scales" where spatial structure is present (Wiegand and Moloney 2004, 225).

As established previously, empirical point patterns will usually deviate from realizations of CSR in some way. This curtails the ability of the spatial analyst to correctly reject a null hypothesis without additional benchmarks for the significance of the observed variation in the spatial behaviour of a pattern (Crema and Bianchi 2013, 387). In order mitigate the odds of an incorrect rejection, tests of significance were also carried out via a Monte Carlo simulation. For each application of $L(r)$ and $g(r)$, 99 realizations of CSR with the same intensity as the empirical point pattern were generated and analyzed alongside it. The results of this procedure were used to create envelopes at the minima and maxima of the simulated point patterns (Stoyan and Stoyan 1994; Diggle 2003). Simulation envelopes emphatically cannot be interpreted as confidence intervals, however (Baddeley and Turner 2005; Jacquemyn et al. 2007, 451). They are significance bands for critical values of the functions, which for the parameters given above are at the level of $\alpha = \mathbf{0.02}$. This corresponds to a 2% chance of incorrectly rejecting the null hypothesis. In the context of the exploratory nature of these procedures, this is acceptable.

Finally, the procedures apply a correction for edge effects to the point patterns. As noted above, the spatial statistics used in this section employ area measures of intensity for each point in a given distribution. Without a factor of correction for artefacts located near the edges of the field sites, the intensity in these locations can easily be underestimated by including the empty space of non-sampled locations in the calculations (Bevan and Conolly 2006, 221). Ripley's isotropic correction (Goreaud and Pélissier 1999) was applied to all the cases discussed here. The statistical properties of this correction are the most parsimonious with respect to the data structure and the chapter aims (Perry et al. 2006, 62).

The results of these analyses are shown in Figure 6.4 and Figure 6.5 below. The results of the L statistic reinforce the Clark-Evans test, demonstrating significant spatial clustering across all scales. A notable exception is Gruber IV, whose point pattern appears random across no matter the scale, save for at a very small distance band (2-3 m) where clustering is detected. This is within the margin of error of the survey equipment, and, given the nature of the identified trend as only slightly above CSR, this result must be regarded as of limited utility for interpreting spatial structure even at the calculated level of significance.

More subtle variation in the point patterns can be seen through the results of *g(r)*, however. In Ziegler II, the pattern actually descends to spatial randomness at distances of approximately 45 m, while the same is true in Ziegler IV at 60 m. At the corresponding ranges in the L statistic there are near-imperceptible dips in the curve. The lack of accumulation in the former statistic is, in these cases, key to identifying scales of potential

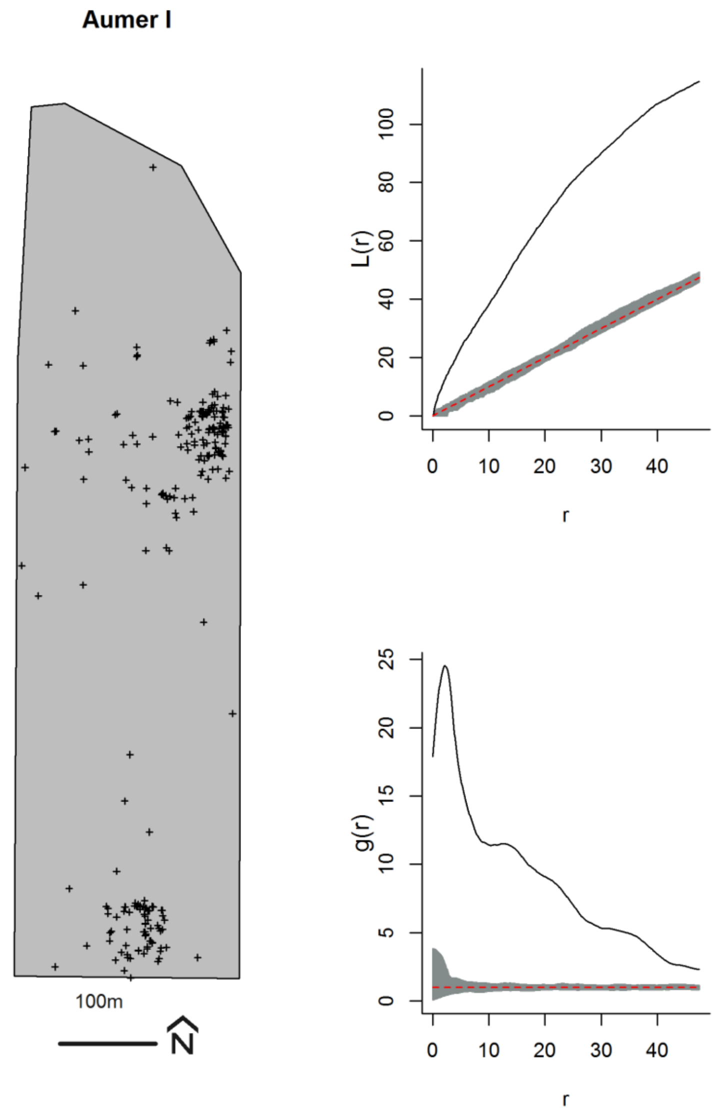


Figure 6.4: L(r) (top) and O-ring statistic (bottom) for all points in Aumer I, with simulation envelopes in dark grey and the statistic under CSR in red.

interest. The short-range clustering pattern in Gruber IV persists. At a range of approximately 24 m, however, $g(r)$ succeeds in detecting the only possible instance of spatial inhibition in all the analytical sites. The effect is very slight and might be spurious. Again, this cannot be blindly accepted at the computed significance level. At present, it can serve to cement the possibility that Gruber IV might be qualitatively different from the remainder of the sites in other ways too.

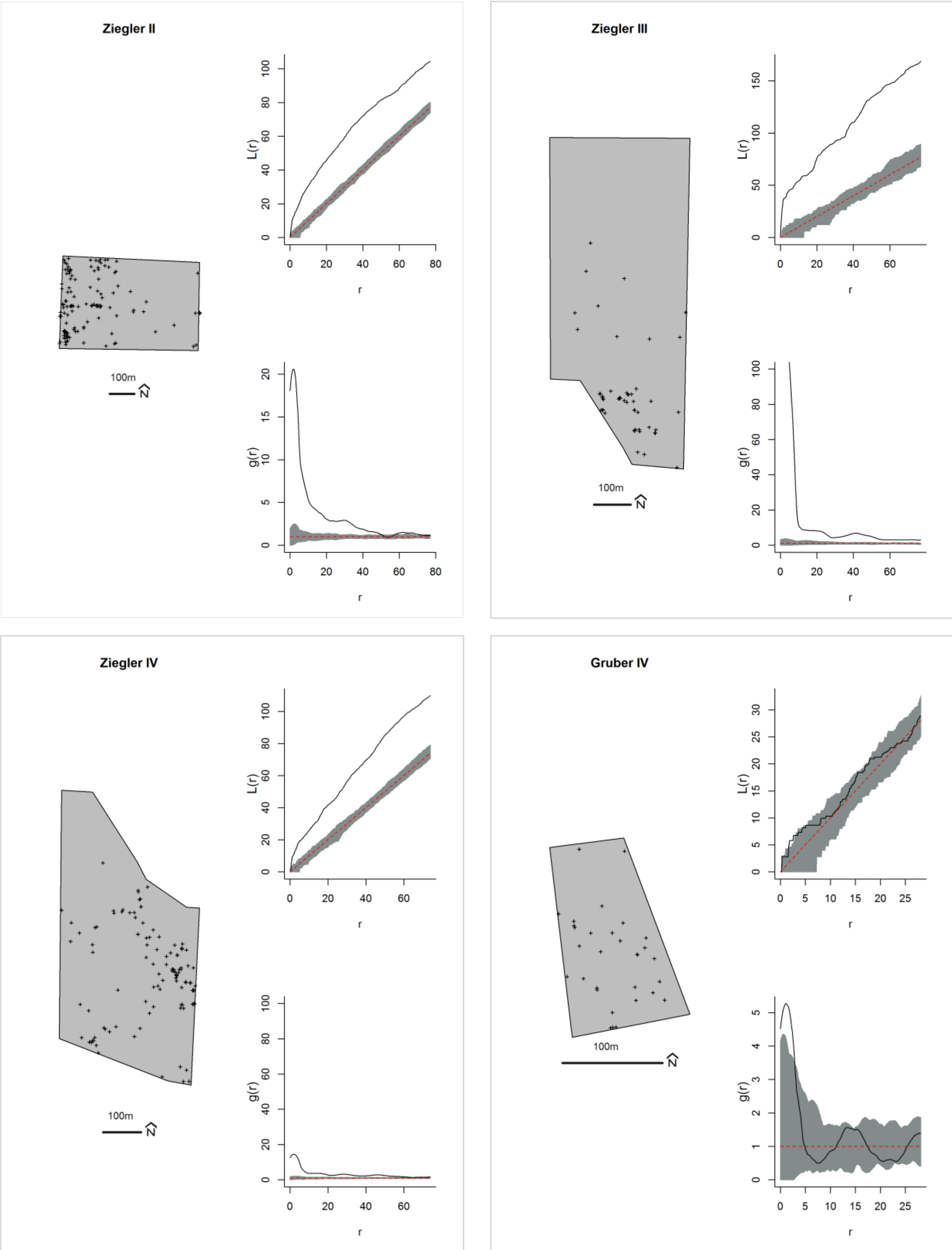


Figure 6.5: L(r) and O-ring statistic for analytical sites Ziegler II - IV and Gruber IV with simulation envelopes.

Both of the statistics discussed in this section are subject to a few limitations. First, whole survey assemblages served as the input data. The previous chapter established the variability of the lithic material record and indicated how subsets of this data ought to be conceptualized as technologically, if not culturally, distinct. The global spatial statistics hereto discussed have glossed over this variability in favour of the "big picture" of spatial structure within field sites. Consequently, much of the nuance of how the assemblages may relate to each other (or not) is lost in this narrative. Second, the O-ring statistic helped to identify trends within field sites that can be described as anomalous with respect to the overall pattern of clustering. This is the first robust evidence of spatial heterogeneity in what has thus far been statistically assumed to be the result of homogenous point processes. Indeed, the operation of different technological systems in the past also provided tentative evidence that spatial inhomogeneity (multiple processes operating at different scales) should be expected from the PME survey data. Unlike homogenous processes, the intensity of an inhomogeneous process varies according to spatial location (Orton 2004, 299), which has an impact on how the data should be handled analytically and interpreted. Pélissier and Goreaud (2001) advocate identifying homogenous sub-regions of the study areas and analyzing them separately. This is an unattractive prospect in the first instance due to the treatment of the assemblages as a unified palimpsest of depositional information. Second, most of the strength of non-site archaeology stems from the holistic treatment of surface remains (Ebert 1992).

In lieu of the above, the next section employs a dual strategy to solve the issue of how to make use of the technological attributes in a spatial framework and delve into the local, heterogeneous patterning of the field site assemblages. The analyses performed in this section offer hints as to how this may be achieved. In univariate point patterns, there is evidence to suggest that maxima in the L function correspond to cluster sizes while the first maximum in $g(r)$ indicates the average inter-point distance (Getis and Franklin 1987, 474; Strand et al. 2007, 168). These characteristics possess a direct relationship to the spatial structure of an assemblage, and hence which elements of lithic technology might be associated through a pattern of land use. A variant on the L function, called simply the "local L", is capable of providing deeper insights into inferred patterns of spatial heterogeneity (Markofsky 2014). Before employing this tool, however, additional links between defined subsets of the empirical point patterns will be subjected to further analysis with bivariate correlation functions. Both these and the local L are discussed next.

6.2.3 *Putting stones to the test: bivariate interactions*

Patterning is assessed at multiple spatial scales by the $L(r)$ and $g(r)$ functions, although they operate globally on the points. While it has been possible to observe the scales at which there is significant clustering through the exploratory analysis, these methods are incapable of demonstrating *which types of artefacts* interact and *where* they are located. This information can enable interpretations of the plausible cultural dynamics which produced the observed structure of the surface record. To this end, two variants on the previous multiscalar functions are applied here to tackle specific systemic issues in the spatial behaviour of lithics in the study area: the bivariate $g(r)$ and the local L function.

The bivariate statistic measures the relationship between two marked subsets of points, i and j, in a pattern. It can be thought of as another extension of the K statistic which tests for spatial independence (Getis and Franklin 1987; Jacquemyn et al. 2007, 452). With respect to other marks, results above the significance envelope are spatially associated while those below are segregated at those specific ranges, independent of any patterning within each subset (Wiegand and Moloney 2004, 218). The formulation of a null hypothesis can take one of two forms in the bivariate statistic, termed population independence and random labelling (Goreaud and Pélissier 2003). For reasons that will become clear, the former is used here; a rejection of the null hypothesis is equivalent to the marked points being independent realizations of two different processes (Crema and Bianchi 2013, 388). In effect, this analysis seeks to characterize whether two distinct subsets of the survey assemblages can be considered part of the same discard process or not. The same edge correction and simulation parameters were used as with its univariate siblings.

It is generally cautioned to have a developed understanding of the significance of point attributes before constructing hypotheses (Bevan and Conolly 2006, 229; Perry et al. 2006, 74). In the case of this research, the technological analysis in Chapter 5 established several trends of interest in the lithic assemblages, which were summarized in section 6.1. Clearly, certain lithics are always technologically related in some way. For instance, flakes must by their nature originate from larger pieces such as tools or cores. In other cases, the analysis made it clear that bifacially reduced tools were the outcome of a very different sequence of reduction to unifacial tools and utilized flakes. Culturally, segregated or random patterning in the discard of technologically distinctive sets of artefacts could stem from differential use of space. Clustering could be the result of related systems of land use causing successive occupations at similar scales. In reality, due to the overall clustered nature of the assemblages (see above), the degree of interaction between technologically-distinct should be a question of degree and scale rather than a binary true/false. These types of spatial relationships are amenable to testing through the bivariate O-ring statistic. The sample sizes involved in several of these are small (<30 points).

The discussion in the previous chapter stated that cores in the PME survey assemblage were reduced *in situ* with the aim of producing large quantities of flakes, only a few of which fulfilled subsequent functional needs in other locations. A test of the first clause is shown in Figure 6.6, examining the relationship between cores and flakes. If the null hypothesis of CSR between the two patterns is rejected, the strict interpretation of the alternative hypothesis is that they are clustered or inhibited. Based on the prior knowledge that exists on flintknapping practices, the expectation should be that flakes and cores are highly associated in space.

The alternative hypothesis is largely confirmed by the bivariate analyses: flakes cluster highly significantly with cores. At distances of *up to* 20 m (Ziegler III), 30 m (Aumer I, Ziegler II) and 40 m (Ziegler IV) all exhibit this quality. Beyond these ranges the patterns descend to spatial randomness. Further to this, since the maxima in each statistic are close to zero, the average distances between flakes and core can be inferred to be very short within these four sites. This is commensurate with the established technological knowledge of how cores were treated in the study area. As with the above attempts, the bivariate O-ring statistic has failed to find any statistically significant patterns of deviation from CSR in Gruber IV. Despite the presence of several cores (possibly used for producing unifacial

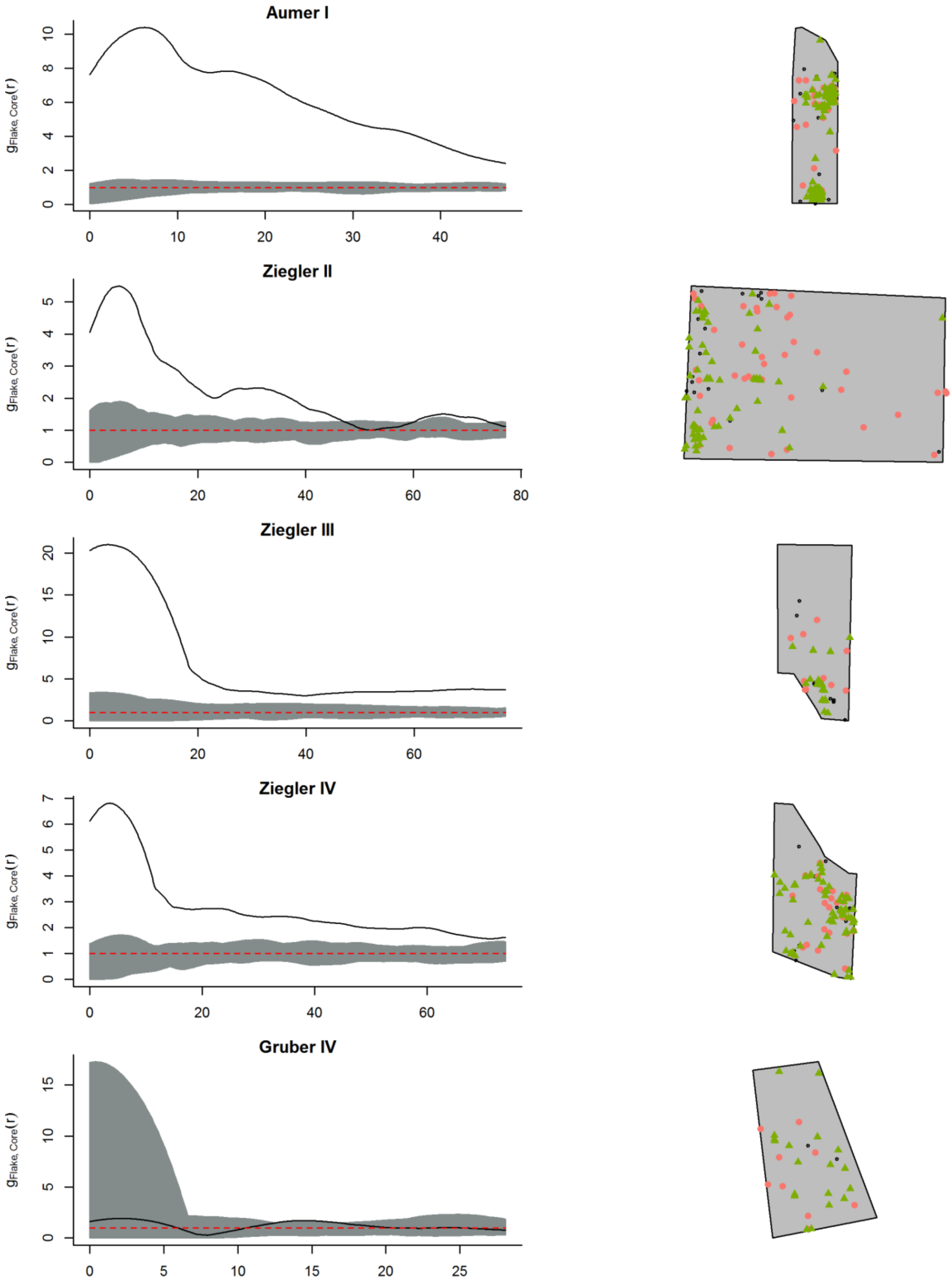


Figure 6.6: Results of bivariate *g(r)* on flakes (green) and cores (red). Points not analyzed displayed as hollow circles.

tool blanks, see Chapter 5), flakes do not appear in expected quantities, meaning the pattern must be accounted for by other means.

For present purposes, however, the core-flake reduction system can be considered as a confirmed spatial relationship at least preliminarily. The next association of potential interest is between cores and bifacial tools. These artefacts represent the outcome of two very different systems of reduction and, in the chrono-typological perspective on the pre-Columbian past of Misiones, the products of different cultures. The latter point is not the topic of enquiry in this case, but nonetheless, the spatial behaviour of the lithics with respect to one another has a contribution to make towards the research questions being

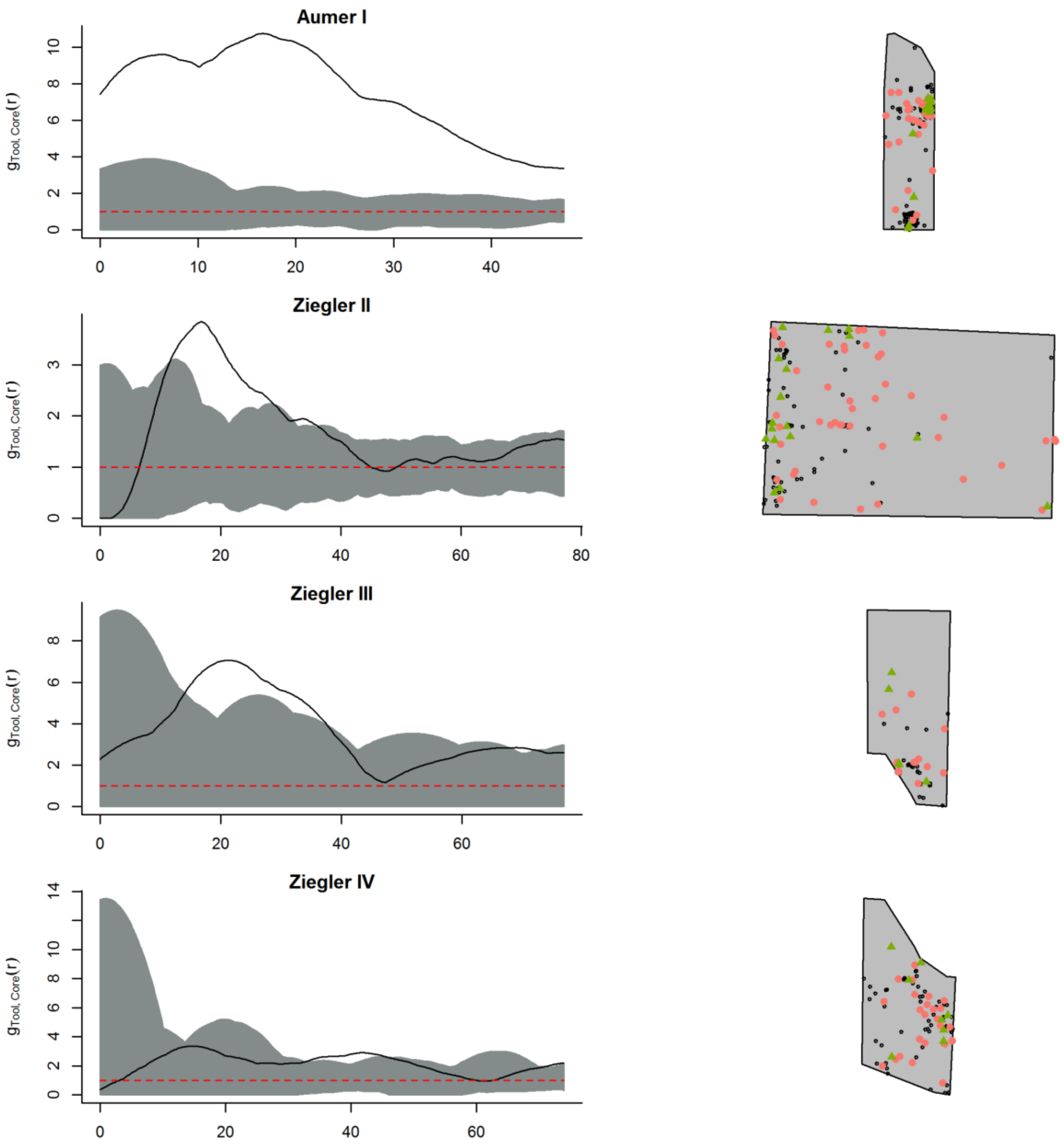


Figure 6.7: Bivariate g(r) for cores and bifacial tools (preforms and final-stage). Points not analyzed symbolized as hollow circles.

pursued. Neither class of artefact exists in sufficient quantities for a robust analysis in Gruber IV, and in this instance the site is excluded from the sample.

The result is shown in Figure 6.7. Unlike cores and flakes, there is no association between cores and bifacial tools at very close ranges (<5 m). On the other hand, at middle ranges the artefacts form significant aggregations in the first three field sites which differ in size and duration (meaning the distances over which the relationship is sustained). Notably, the statistics in these sites all have maxima at the range of approximately 20 m indicating where the pattern is strongest and what the average distance between the two artefact classes is. The association between the patterns in Aumer I only appears random again at quite large ranges (>40 m). Similarly, this occurs in Ziegler II and III around the 30 m mark. Due to the large differences in function, technology and morphology between these artefacts, the significance of cores and bifacial tools associating in greater numbers than expected at these distances is difficult to assess directly. Lastly, Ziegler IV reveals no spatial interactions at any scale between its core assemblage and bifacial tools. There is some indication that there are associations around 15 m (the only maximum), which appears to be supported by the empirical distribution, but the statistic lies just inside the significance envelope at this range too. As the sample size is sufficient in this case, the result can be taken as robust. If the spatial behaviour of bifacial tools is to be understood, their interactions alongside other classes of artefacts must be explored as well.

To this end, the bivariate O-ring statistic was extended to bifacial thinning flakes and their interactions with the tools themselves. In the data collection strategy and during the lab analysis, the identification of diagnostic traits linked to the thinning of bifacial tools was not initially a priority. Consequently, candidates for flakes of this type were only identified in Aumer I (MPM015) on a preliminary basis and thus provide the only case study for this statistic. The limited sampling universe of bifacial thinning flakes must be borne in mind for any subsequent interpretation. Furthermore, preceding analyses repeatedly demonstrated how the distribution of artefacts in the site clusters significantly in two broadly circular scatters (see also Chapter 4). Due to the fact that the majority of material stems from these two locations in an otherwise diffuse distribution, clustering of both cores and bifacial tools with the thinning flake candidates can be expected. In light of this, any interpretation is an interrogation of the relative degree of clustering to a much greater extent than the comparisons made between different field site assemblages.

Figure 6.8 displays the bivariate *g(r)* for bifacial thinning flakes in Aumer I. The first point to note is that at very short (<1 m) and long ranges (>40 m), cores and thinning flakes are randomly distributed with respect to one another. Conversely, bifacial tools were found to always be associated with thinning flakes in this field site, and always to a greater degree than cores. This is particularly evident when comparing the curves up to a range of 10 m. This is an interesting finding given that cores are present in greater numbers than bifacial tools and might be found in association with thinning flake candidates by sheer weight of numbers. In a comparative view of the three classes of artefacts, it appears to be warranted to consider the thinning flake candidates to be legitimate by-products of tool production, at least in this specific scenario.

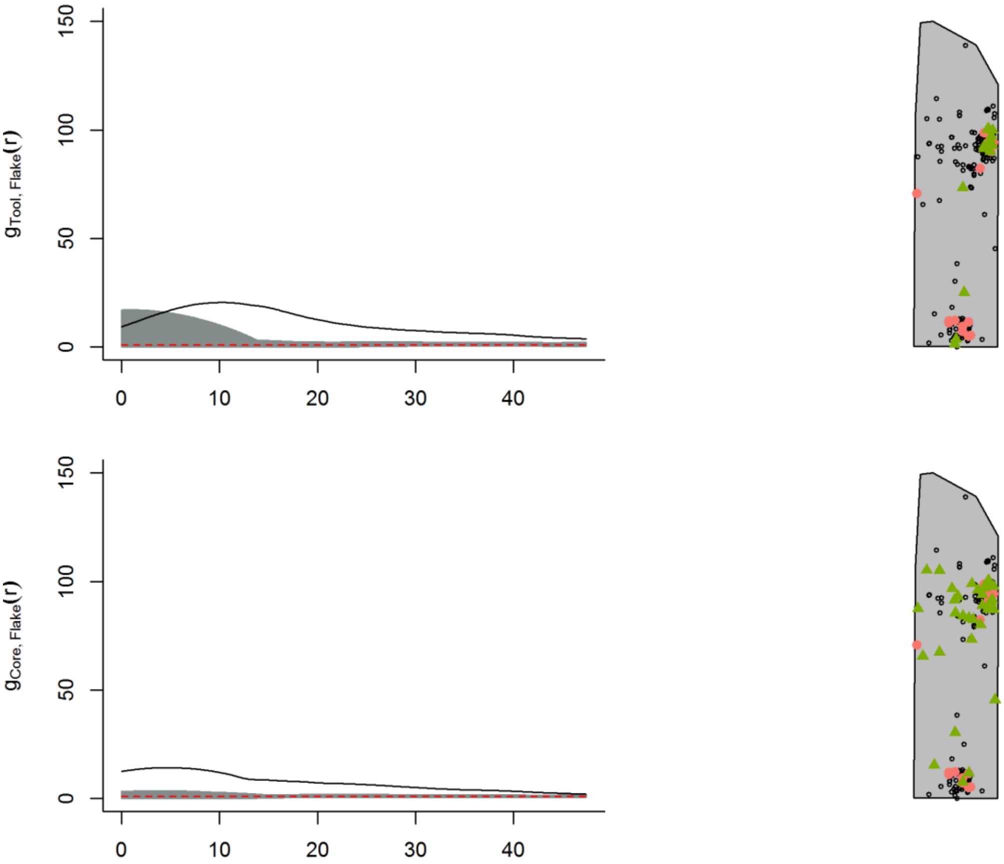


Figure 6.8: Bivariate *g(r)* on bifacial thinning flake candidates (red circles). Top: bifacial tools (green). Bottom: cores (green). Other artefacts visualized as hollow circles. Y- and X-axis are plotted as identical to facilitate comparison.

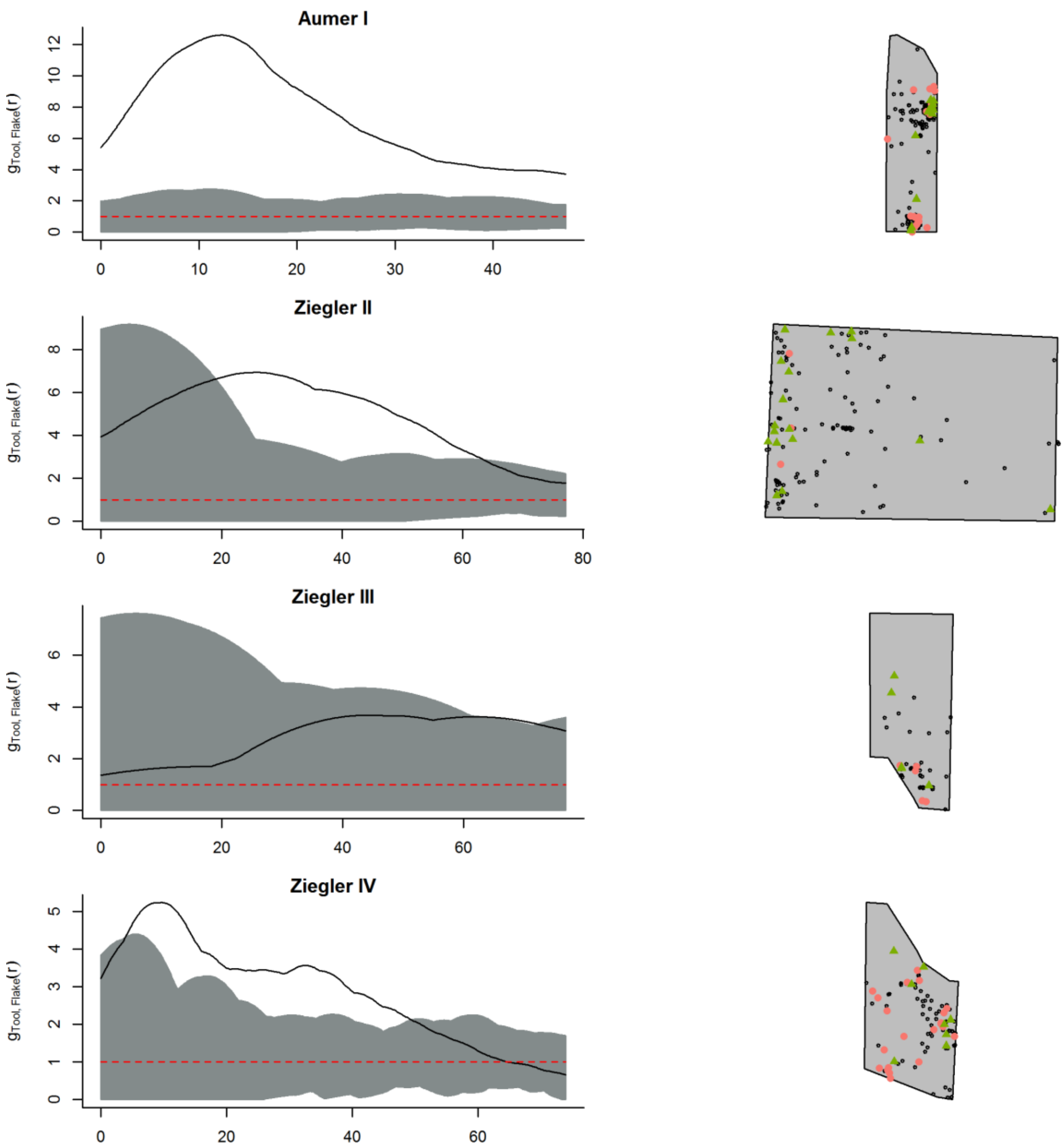


Figure 6.9: Bivariate g(r) for unifacial tools/utilized flakes (red) and bifacial tools (green).

The lithic analysis also singled out a unifacial tool system within the survey assemblages, which was considered a more formal offshoot of the more generalized core and flake reduction system, which was mostly used for expedient mass flake production. Although unifacial tools and utilized flakes differ with regards to their method of reduction, intensity of use and morphology, in functional terms they are implicated in similar tasks. More importantly, despite a few bifacial thinning flakes exhibiting evidence of subsequent use, the tasks to which utilized flakes and unifacial were put would not overlap significantly with heavy-duty bifacial tools. The last test using the bivariate O-ring statistic is therefore between unifacial tools and utilized flakes (Group 1) and bifacial tools (Group 2). Gruber IV is excluded from this analysis again due to lack of sufficient material from the latter group. The results are shown below in Figure 6.9.

In two out four cases (Ziegler III and IV), the relationship between the groups of artefacts is almost totally random save for a slight tendency to cluster at a range of 24-25 m in the latter field site. The point pattern of Aumer I, already known to be very significantly clustered, shows association between the groups *up to* 30 m, beyond which no association can be detected. Observing the distribution of material in the field site, this makes sense; both groups are found almost exclusively in the two main scatters of material to the north and south of each other. The small quantity of artefacts between these areas would not contribute to any clustering up to the ranges analyzed by the statistic (50 m). Ziegler II displays very slight association between approximately 3 and 40 m, which is difficult to interpret given that only three flakes with signs of edge modification are located in this site. This illustrates the likely effect that the size of the sample has on assemblage composition more than the distribution of technological variation itself.

6.2.4 With a fine-toothed comb: local indicators of spatial autocorrelation

From a technical standpoint, bivariate functions above are global methods of spatial exploration in the same vein as their univariate counterparts, as they fundamentally describe an average trend of all (marked) points within a region of interest (Crema and Bianchi 2013, 388). While they also permit a degree of inference about the nature of the underlying point processes which the univariate $L(r)$ and $g(r)$ have difficulty achieving, nonetheless, inferring local interactions and intensities within complex, multivariate datasets is not often made possible by the output. The local L function (Getis and Franklin 1987) is identical to the transformed Ripley's K, but instead calculates the local neighbourhood density for each point separately. Unfortunately, performing the analysis on individual points for an assemblage potentially made up of hundreds more does not yield readily interpreted summary graphs as with the global functions. Furthermore, extracting single points from the analysis does not give a sense of how the local intensity of the pattern as a whole varies in space. Instead of summary graphs therefore, this section applies the local L function and a bivariate version of the local K function and visualizes the results as trend surfaces in the former case, and as marked point patterns in the latter. In summary, these final sets of analyses

Local L function

The local L permits another approach to visualization and detection of mixed patterns of dispersal and clustering within field sites. The spatial structure of the dataset can be computed for each defined distance band r of potential interest in a point pattern (Pélissier and Goreaud 2001) and passed to a kernel smoothing function. This would produce a shaded visual output of local spatial interactions at the scales of interest. The output differs from related forms of point pattern visualization in that the areas displayed indicate statistically significant relationships, rather than the intensity of the pattern in terms of numerical averages (e.g. artefacts/m^3) which can be misleading (Ebert 1992, 175). As with the previous statistics, the local L function indicates the degree of aggregation where $r > L(r)$ (Perry et al. 2006, 71). In summary, the local function builds upon exploratory analyses and allows more detailed inferences to be made about the characteristics of the processes behind the patterns. It also allows an assessment to be made on which subsets of the assemblages contribute the most to the patterns picked up on by the preceding analyses (Markofsky 2014). A step-wise approach was taken to the scale of the analysis, from short- to medium- and large-scale patterning.

The smoothed local L surface for Aumer I is shown in Figure 6.10. A point of particular interest in this case is how relationships can be observed to change as the scale increases. While the z-axes of the images are different between each iteration of the function, visual comparisons are simple to make based on the locations of the artefacts that have been plotted. Note the pattern of relatively weak aggregation to the north of the main northern cluster of material at $r = 2.5$, which gradually loses its significance until the final step when it becomes reincorporated into a very large scatter of artefacts. Despite these very large search radii in the last two iterations (80 m is almost half the width of the field site) there are still notable statistical outliers which do not aggregate to any particular pattern. This could be an indication of distinctive formation processes contributing to the formation of spatial heterogeneity in the surface record. Although significant clustering is generally

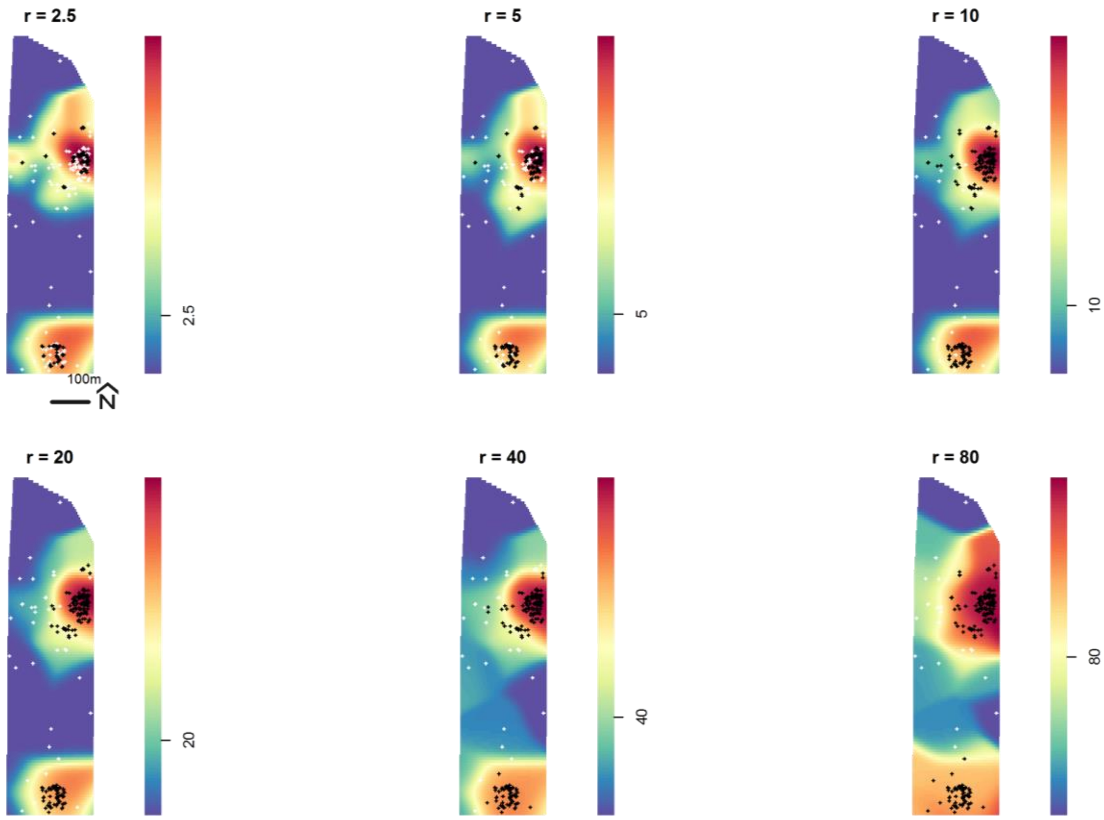


Figure 6.10: Local *L* function for Aumer I at six spatial scales. Tick marks on the legend indicate cut-off point of *L(r)* between clustering (red) and randomness/dispersal (blue). Non-aggregated artefacts are rendered in white and clustered in black at each scale of the function.

assumed to be the target of interest in the analysis of archaeological point patterns (Orton 2004), the *lack* of any interaction to such a degree is also of interest from a non-site perspective. This is further demonstrated by taking a look a local patterning in Ziegler II (Figure 6.11).

For the run of the local L function on this field site, the linear arrangement of artefacts that was identified as a direct outcome of gullying (see Chapter 4) was kept in the analysis. As a result, a notable presence of clustering was made apparent in its location in the site until $r = 20$. Furthermore, other areas of equal or greater significance do not appear until this range. Since short-range clustering was readily detected across the whole field site at these short ranges by the global *L* function, the natural processes that caused the surface record to appear this way poses some interpretative issues. On the other hand, this serves as an excellent illustration of how the local statistic can be used to meaningfully identify local areas of spatial homogeneity. Most commonly in ecological point pattern analysis,

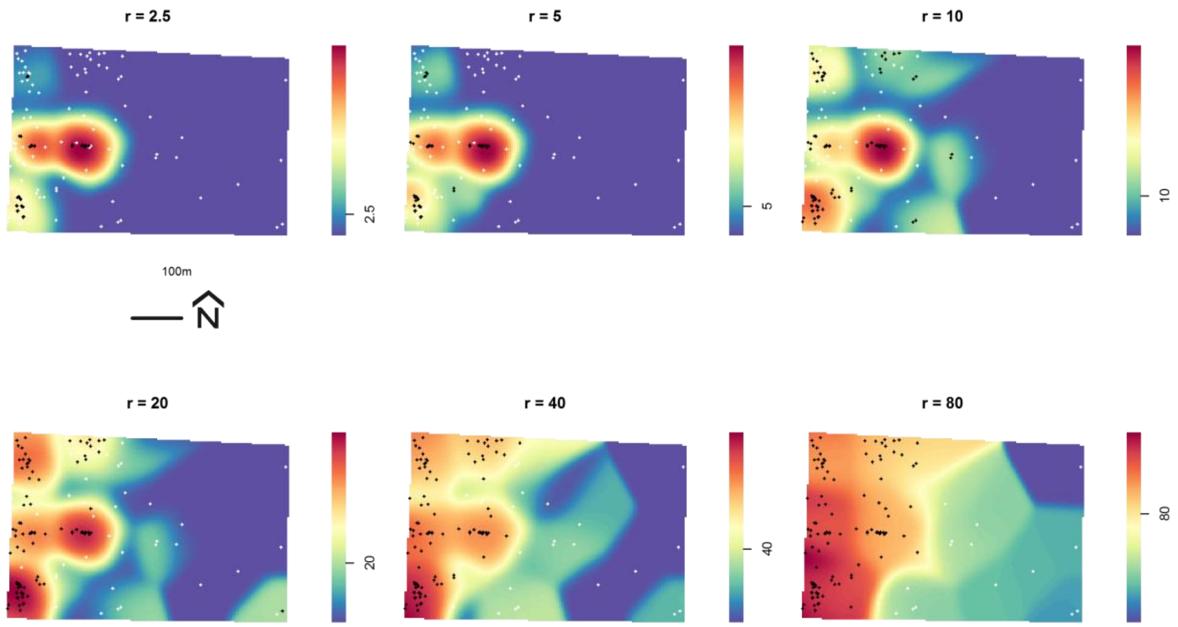


Figure 6.11: Local L for Ziegler II. Note importance and isolation of cluster to the centre-left until *r* = 20, when it becomes subsumed into larger-scale patterns.

the goal of such a procedure would be to extract these identified areas and analyze them separately as an independent point pattern (Perry et al. 2006, 71). A further use in this case, however, would be to eliminate spurious data from a sample. Since this particular subset of the data is known to be less useful for the purposes of this research and problematic to interpret in archaeological terms, this is also a valid function of the statistic. Despite the presence of this strong clustering, three to four independent signals of aggregation establish their own spheres of influence up to a range of 10 m. After this midway point, the individual clusters to the west and their constituent points amalgamate into a single large cluster, while the eastern portion of the field site remains significantly dispersed until the final iteration. Some visual artefacts of the smoothing algorithm begin to appear at longer ranges in the north-eastern corner, however, there is little reason to doubt that points in these regions are anything except extremely dispersed from other points in the dataset.

As the field sites Ziegler III and IV adjoin at their southern and northern margins, respectively (see Figure 4.1), they are shown together in Figure 6.12, although their calculations were carried out separately. In the former site, there appears to be an intractable difference in spatial structure between the southern quarter and the remaining three quarters of the coverage to the north. Despite some apparent internal heterogeneity

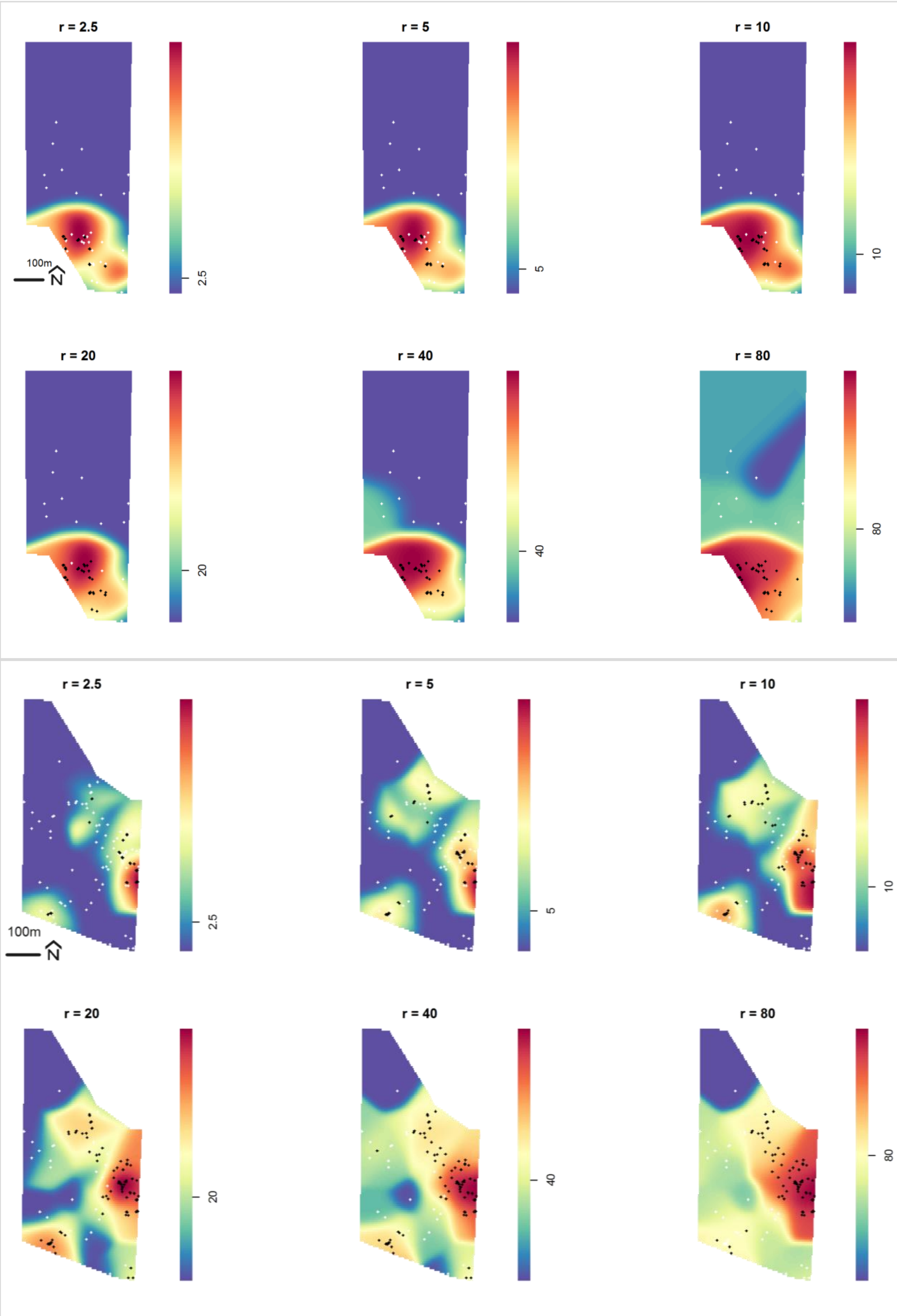


Figure 6.12: Local L function for Ziegler III (top) and Ziegler IV (bottom) at six spatial scales with clustered and unclustered points plotted on top.

at the shorter ranges, the divide between the large aggregation containing the majority of the cultural material to the south and the dispersed scatter of material to the north appears to be robust. Possible reasons are explored in the concluding summary.

Conversely, Ziegler IV displays multiple pockets of aggregation and segregation that ebb and flow as analytical scale changes. At the shortest ranges, only a small quantity of the total field site assemblage (separated into three sub-regions) actually cluster significantly, in spite of what Figure 6.5 would seem to suggest for this field site. The first two increases in scale lead to the aggregated sub-regions becoming more sharply defined in relation to each other, as well as to the wider distribution of dispersed artefacts. Even within the clusters of aggregation, however, pockets of dispersal can be observed at these short ranges. This trend is eliminated in the larger scales, although a separation persists between the south-western sector of the site and the scatters of clustered material to the east and north of it. At all three of the largest analytical scales, there is a very clearly defined band of dispersion running south-east to north-west in Ziegler IV. It is most obvious and its membership largest at $r = 80$.

The archaeological point pattern in Gruber IV was almost unequivocally characterized by the preceding spatial analytical methods as random. Slight exceptions were found at very narrow ranges, but on the whole the global methods offered little insight into any significant spatial relationships within the assemblage. To this end, the application of the local L has the potential to uncover if these findings stand up to scrutiny in all cases (Figure 6.13).

The first point to note is the fluid membership of points in each subset of the assemblage as the analytical scale changes. This characteristic was also observed in the other field sites, but it much more apparent in this relatively small parcel of space. The final iteration at $r = 80$ can discarded for present purposes, as this number far exceeds the effective scale for an analytical frame of the size of Gruber IV. Nonetheless, the case of Gruber IV is illustrative of the importance of statistically verifying associations (or lack thereof) in spatial datasets instead of relying on "expert judgement" to divide the surface record into meaningful units. For this field site, the most that can be stated with confidence is that a

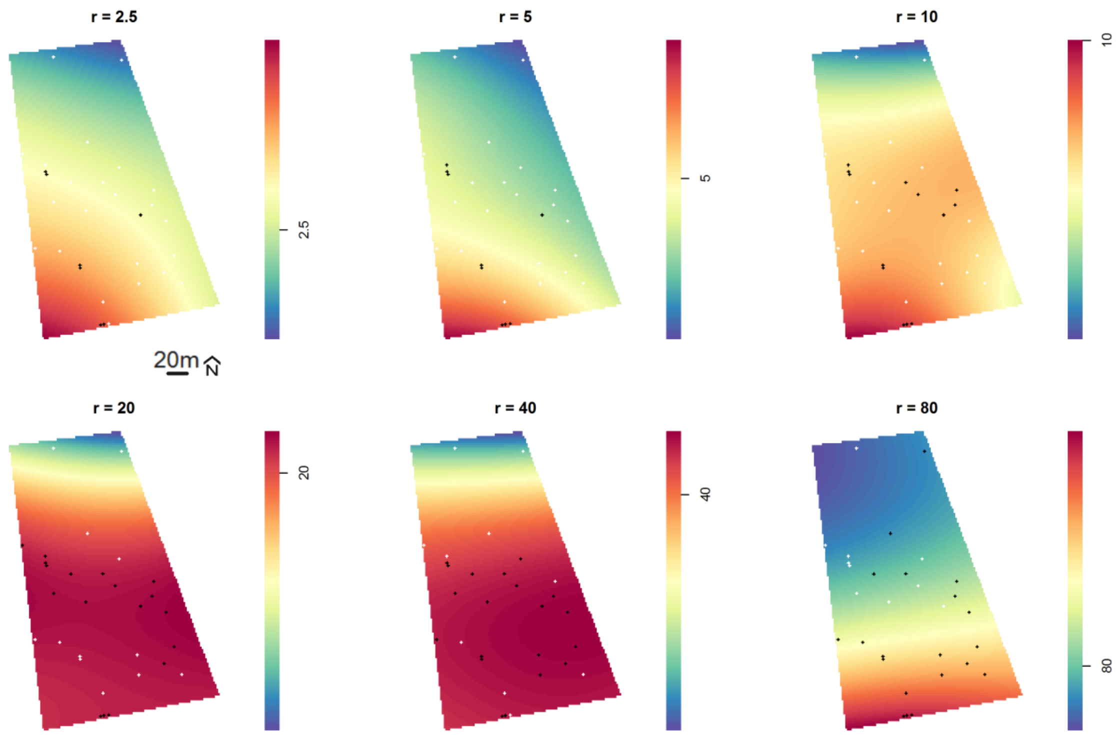


Figure 6.13: Local *L* function for Gruber IV. Note generally shifting adherence of points to the clustered (black) and unaggregated (white) groups.

clustered pattern to be somewhat persistent in the central portion of its coverage, although membership appears to change a lot at different scales. This zone appears most clearly starting at $r = 10$ and is flanked to the north and south by dispersed scatters of material at $r = 20$ and $r = 40$. The finding that the interplay of aggregated and dispersed groups of artefacts in Gruber IV experiences regular shifts at different analytical scales gives indirect support of the results of the global statistics deployed in section 6.2.1 and 6.2.2. In other words, there are few strongly obtrusive or reliably robust spatial patterns that can be sifted from the point pattern of this field site. Using local autocorrelation statistics in this manner permits a partial confirmation of results seen elsewhere.

Local bivariate K function

Bivariate transformations of the local K function can also be implemented to show where the most significant variations occur in the bivariate spatial relationships (Crema and Bianchi 2013, 391; E. Crema 2014, personal communication). For the purposes of assessing precisely which elements of the site assemblages are significantly associated (since no bivariate patterns were found to be dispersed below the computed CSR envelopes), the implementations of this function presented below deal with the critical scales of *clustering* that were identified for the various bivariate point patterns in section 6.2.3. This is reflected in Figure 6.14 to Figure 6.17, which each show a single scale of interest based on the output of the global functions. The emphasis on this type of spatial structure does not preclude subsets of the bivariate datasets from displaying significant dispersal. Going on the results of the global bivariate analysis, however, would suggest that these artefacts are in a vanishingly small minority. Furthermore, examining the short-

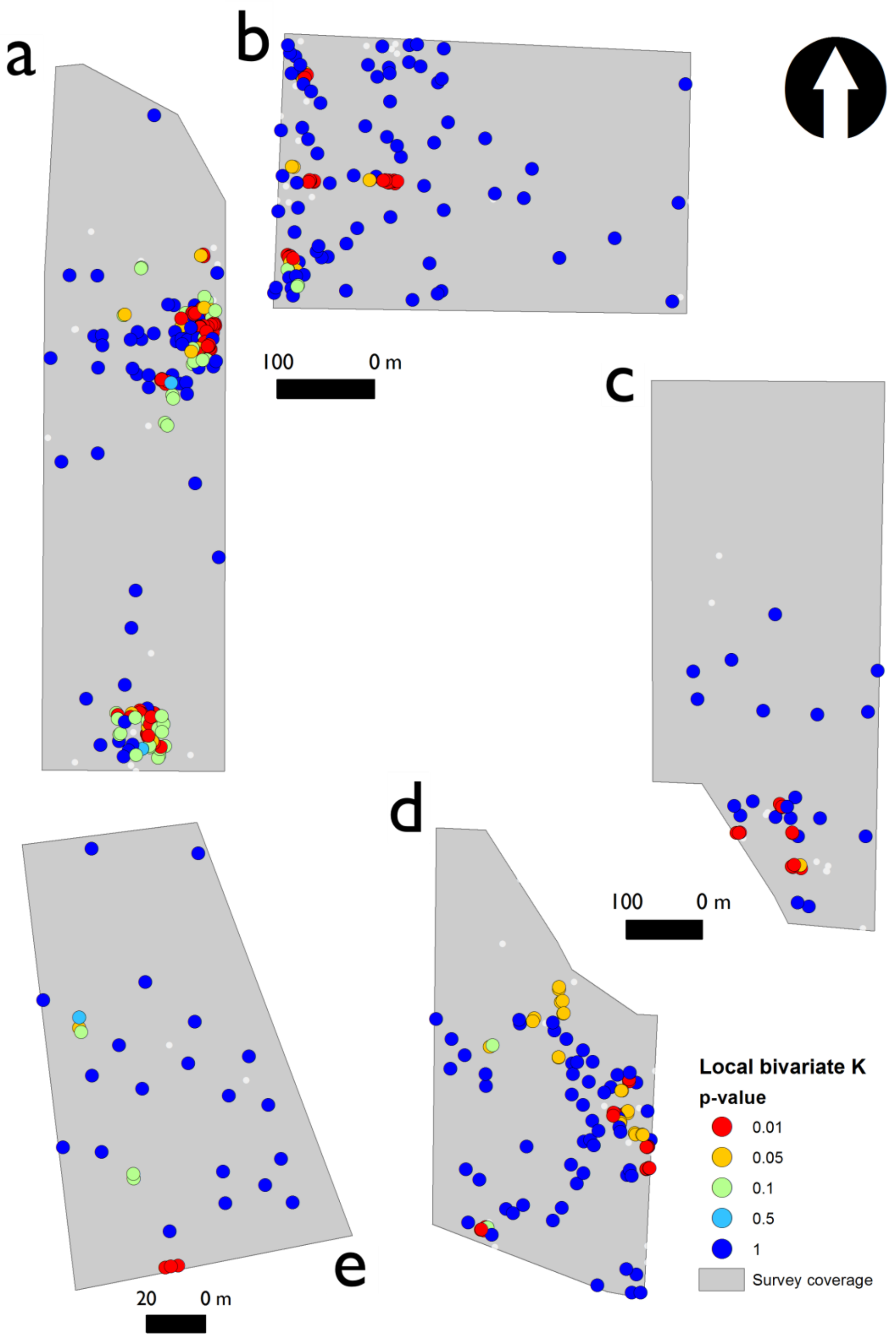


Figure 6.14: Local bivariate K between cores and flakes in all analytical sites at r = 5. Results are displayed at increasing levels of significance, indicating exactly which artefacts display the strongest spatial relationships and where they are located in relation to the remaining assemblage (symbolized as smaller white points). Only the significance for clustering is displayed, as no significant dispersal was indicated by the global function at any range.

Common display scales set for: a) Aumer I and b) Ziegler II, for: c) Ziegler III and d) Ziegler IV and for: e) Gruber IV range spatial behaviour of the artefacts in question has the ability to yield more information about structure *within* already highly clustered data. In the analysis of the material which exhibited strong short-range spatial autocorrelation, the shortest range considered in the local bivariate K was 5 meters. Below this threshold, the uncontrolled variation in the accuracy of the data recording limits the utility of any statistic despite the relatively large number of data points available in some cases.

Two examples of within-cluster heterogeneity stem from the relatively dense scatters of material in Aumer I, which are composed predominantly of cores and knapping products from both cores and bifacial tools (Figure 6.14). The local bivariate K at $r = 5$ reveals that major sub-groups of spatially autocorrelated material can be detected, adding another level of detail for these artefacts. The same observation can be extended the dense scatter in the south-western corner of Ziegler II. The cases of strong spatial clustering in the centre of this site can be disregarded. As discussed above in the context of roadside gullying, this linear arrangement of artefacts clearly appears to be due to modern land use practices affecting the ploughzone. Interestingly, the three "main" clusters that were identified in Ziegler IV up to $r = 20$ (see Figure 6.12) also appear in the local bivariate analysis. In the case of Gruber IV, the limited concentrations of clustered artefacts at this scale further reinforce previous observations on the absence of a defined spatial structure for this field site.

In the case of flake tool and bifacial tool interaction, several peaks in the global bivariate analysis were shown at a range of approximately 25 m (with small deviations from this trend between the sites examined). Using this subset of the assemblages reveals substantially different trends at this scale in comparison to the short range core/flake analysis. Aumer I and potentially Ziegler III show relatively tight groups of highly autocorrelated artefacts of these two types, with almost no points of unconfirmed or potentially ambiguous membership. Ziegler II and IV on the other hand, reveal only one "principal" clustered group at $p = 0.01$, while the majority of the artefacts do not actually cluster in any significant way. For Ziegler IV this is in line with expectations (see Figure 6.9), but somewhat contradicts the preceding bivariate analysis, underlining additional heterogeneity in this subset of the data.

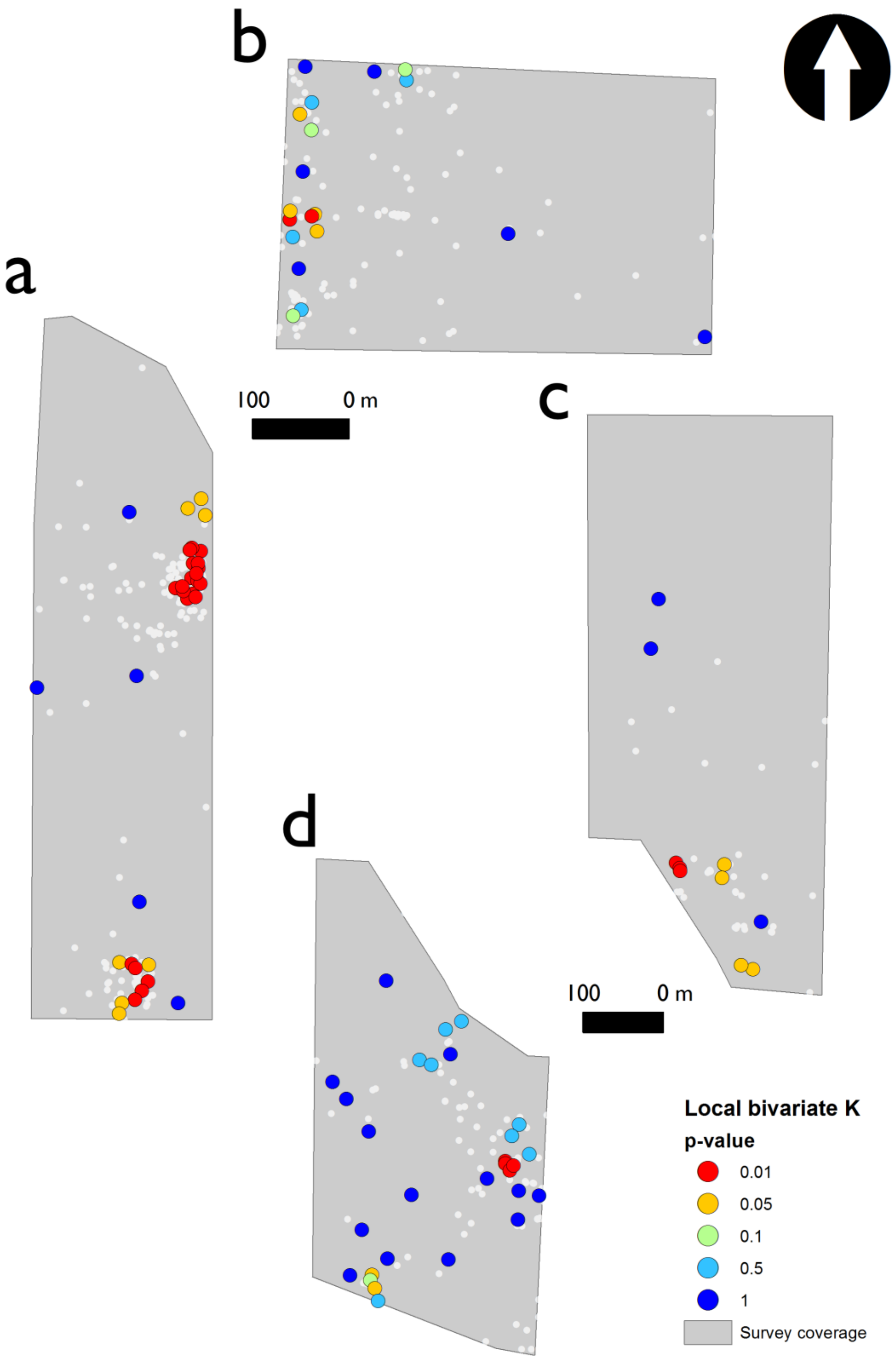


Figure 6.15: Local bivariate K for clustering between flake tools (unifacial tools and utilized flakes) and bifacial tools in all analytical sites at r = 25. The remaining elements of the assemblages are symbolized as smaller white points.

Same display scale for a) Aumer I, b) Ziegler II and c) Ziegler III, d) Ziegler IV

Much like the global variety of the statistic, the local bivariate K also lends itself to comparative analysis between two or more groups of artefacts. Documenting variability in the spatial behaviour of radically different lithic reduction systems, including any potential interaction, is central to this research. For $r = 5$, Figure 6.16a shows where bifacial thinning flake candidates cluster with bifacial tools, while Figure 6.16b displays the same for thinning flakes and cores. Although strong patterning was demonstrated at practically all scales in Aumer I between these artefacts, it is at its strongest below 10 meters. Stronger and more numerous clustered relationships can be observed between bifacial tools and thinning flakes than between cores and thinning flakes in the denser northern cluster, confirming on the whole what the global analysis already indicated. In the southern cluster, however, the situation is more ambiguous. Despite exhibiting strong clustering in both cases, in terms of absolute figures, the more numerous bifacial tools

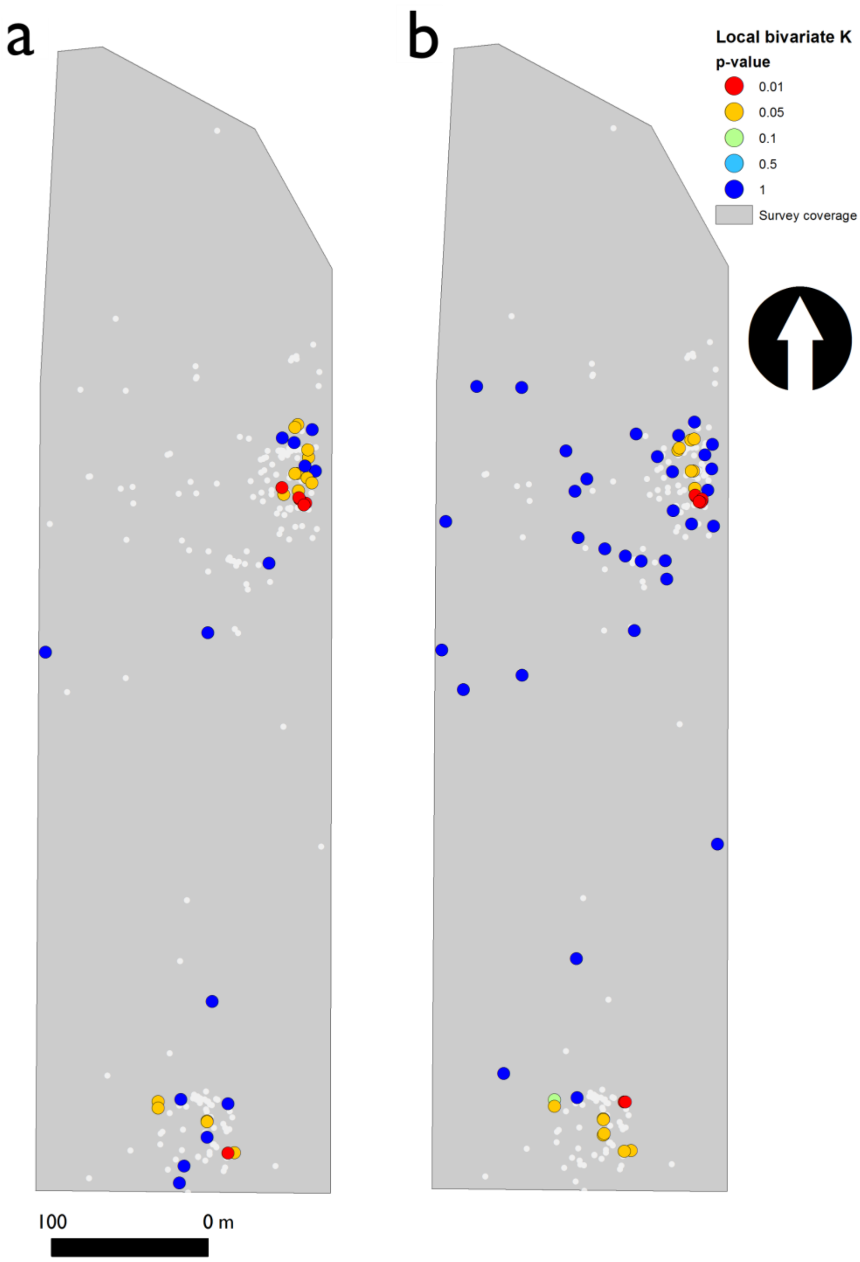


Figure 6.16: Bivariate local K for Aumer I showing significance of clustering between a) thinning flakes and bifacial tools and b) thinning flakes and cores at r = 5. The remaining elements of the assemblages are symbolized as smaller white points.

nonetheless interact with thinning flakes in fewer cases than the less abundant cores. In retrospect, the lithic analysis noted that thinning flake candidates were simply that:

candidates for a signature of an outcome of technological organization. At best, these artefacts are difficult to reliably identify and without additional experimental or archaeological data to draw upon for bifacial tool production in Misiones (c.f. Nami 2006), the spatial analysis shown in these figures cannot confirm which reduction system the thinning flake candidates "belong" to. This is an aspect of local spatial behaviour which summary graphs of global functions can fail to fully characterize.

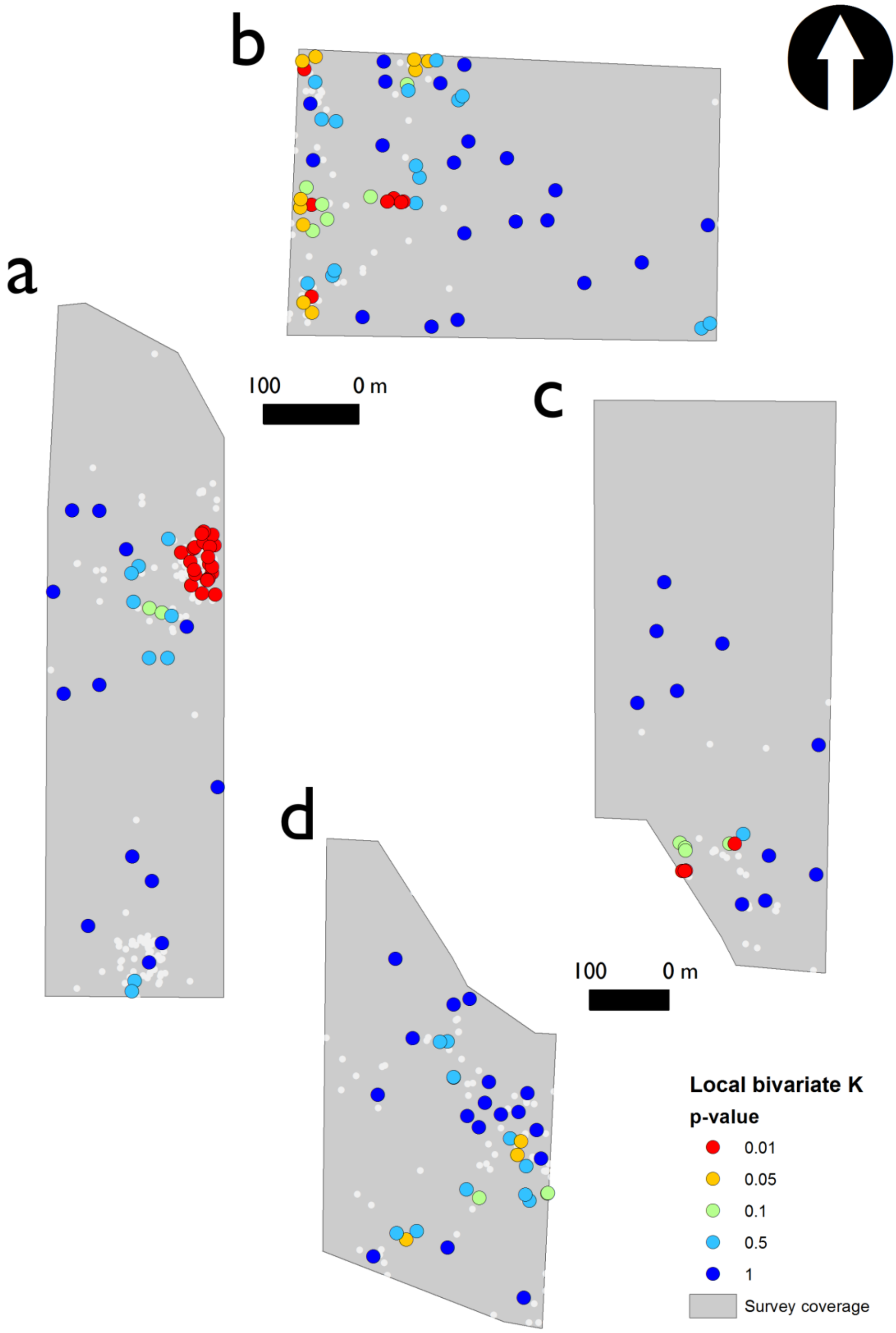


Figure 6.17: Local bivariate K cores and bifacial tools in Aumer I and Ziegler II - IV at r = 20 with significance levels for clustering. The remaining elements of the assemblages (not analyzed) are symbolized as small white points.

As it is not possible to reliably attribute flakes to a given set of flake sources, Figure 6.17 instead shows an attempt to examine the degree and location of clustering between the cores and bifacial tools themselves at $r = 20$. The patterning between these subsets in Ziegler II, III, and IV appears to be reflected in multiple small groups of artefacts that do not interact with each other. The clusters in Ziegler II and IV are also surrounded by artefacts with a low estimated probability of membership in a larger cluster of material, at least at this scale. At $r = 40$, or likely much before this arbitrary point, these same artefacts would be autocorrelated in a wider scatter of material, which could lead to alternative interpretations. Aumer I, on the other hand, is dominated by a single large and tightly-knit cluster in the northern sector of Aumer I, surrounded by a halo of artefacts less likely to be autocorrelated, at least at this scale. Interestingly, cores and bifacial tools located in the southern scatter do not exhibit interaction at all, despite both groups in this area of the field site being strongly autocorrelated with bifacial thinning flake candidates specifically and (in the case of cores) knapping products in general (see Figure 6.14 and Figure 6.16).

6.3 Overview and summary

The results presented in this chapter represent the culmination of a drive to integrate spatial point pattern analysis with a technological analysis of stone tools. Developing this interface permitted the synthesis of two mutually-reinforcing lines of evidence on how pre-Columbian patterns of land use led to the creation of the archaeological surface record. By furnishing the spatial statistical approach with a technological dimension (see Chapter 5), multiscalar patterns were disentangled from the highly heterogeneous raw distributional data (see Chapter 4). Beyond the obvious visual presence of short-range clustering, the results indicate that certain classes of artefact such as relatively highly reduced cores were discarded alone, forming much larger (and visually unintuitive) clusters several tens of meters across. Conversely, bifacial tools have a tendency to be deposited in close association with other types of artefacts, notably flakes, but especially thinning flakes. This raises interesting questions about the mobility regimes involved in the transport and use of certain functional artefact types, including the assumptions typically made about their behavioural significance (see Kelly 1988). Against this backdrop, local statistics provided further critical insight into the spatial behaviour of stone tools in Eldorado department.

The local L statistic served to underline that the archaeological data is the product of potentially millennia of gradual, infrequent accumulation of cultural material. It provided a valuable counterpart to analyses such as Nearest Neighbour (Clark-Evans test) or the global second-order statistics, demonstrating that "clusters", much like the site, is a heuristic that breaks down under rigorous examination. This does not fully preclude the possibility that areas of aggregation on some level represent the occupation and use of a specific parcel of space in a relatively short time span (Sullivan 1995). Consequently, the principal outcome of this chapter has been to repeatedly demonstrate the nested nature of many of the relationships that can be drawn out of the surface record. The methods in this chapter succeeded in identifying multiscalar spatial patterns in the survey data, as well as between technologically significant subsets of the site assemblages. A strong point of the combinations of these methods is that many patterns appear to be both statistically robust and meaningful in systemic terms. In terms of interpreting the analytical sites as palimpsests, it should be clear that they represent a range of aggregations and dispersals whose significance, numbers and size shifts along with the scale of investigation. Importantly, these changes shift the emphasis of interpretation these patterns towards an emphasis on the meaning of variability in *scale* rather than unsupported (as shown here) inferences of cultural units from surface data. The hierarchical approach taken here from general trends, to interaction, and finally local interaction permitted the variability of the surface record in these location to be dissected in a way that side-steps the commonsensical and arbitrary assignation of artefacts into "sites" and "non-sites" that belong to specific cultural-historical entities. Instead, a wide range of spatial practices and different types of patterning can be observed.

While the PME project dataset, like all archaeological data, is fragmentary and partial at best, the analytical emphasis in this chapter has been to deploy exploratory methods with the built-in capability to critically assess statistical significance in the output. The inference of process from pattern is notoriously difficult to achieve using only exploratory spatial analysis, due to the established problem of equifinality (Wiegand et al. 2003; De Luis et al.

2008, 626). While there is no way to tell from the statistics *alone* how an empirical distribution may have formed into patterns of aggregation or dispersal (or indeed, randomness) at different scales. Alternative models to the Poisson process could potentially model the distributions in the field sites and offer additional insight (see Vanzetti et al. 2010; Bevan et al. 2013; Eve and Crema 2014). The foremost reason to object to this in the present case is the utter lack of preceding work on this topic for the places and cultures under investigation.

Finally, it should be recalled that the analytical sites number five out of a total of 18 sites surveyed. The goal to detect and examine spatial patterning at a landscape level was attained at the conceptual micro- and meso-scales, i.e. the investigation of patterns within field sites and extending to comparisons between them. As a result, the distribution maps presented at face value in Chapter 4 can furnish a wider sense of the variety of discard processes that occurred in the pre-Columbian Alto Paraná. Taking this into account, the norm appears to be a very low intensity of land use, which will be taken into account in the final discussion.

7. Modelling pre-Columbian landscape structure

7.1 Introduction

The previous chapter investigated spatial patterning in the pre-Columbian surface archaeology of Misiones province through multiscalar point pattern analysis, in order to characterize land use in the study area through the lens of long term place history. These analyses took place within two principal frames of reference: the micro- (intra-field site) and meso- (between-field site) scales, in a well-defined study area. This data cannot, at present, provide insight into macro-scale patterns in landscape structure, and how distinct cultural responses to the environment may have emerged. To this end, the objective of the following chapter is to seek an understanding of how wider patterns of pre-Columbian landscape structure emerged from new types of social organization within a specific time period. This is carried out as a focused case study on cultural locations identified by preceding programs of research in the eastern La Plata basin. The precepts of non-site archaeology established in Chapter 2 are suspended for present purposes. The merit of this is to illustrate how site-based approaches can complement strictly distributional analysis.

The simplification of artefacts to one-dimensional point data was acceptable at the scale of analysis and the questions being pursued in the previous chapter (see section 6.1.1). This case study seeks to understand southern proto-Jê mound and enclosure complexes (MECs) from the perspective of territoriality as a function of structured patterns of movement. This type of corporate architecture emerged across the eastern La Plata basin circa 1000 years BP as part of a broader process of long term intensification in land use (see Chapter 2). At the scale of landscapes, the representation of these cultural locations as point data can also be considered relatively unproblematic. The main subject of this enquiry is a funerary monument located a short distance from the city of Eldorado (PM01) within the study area (Iriarte et al. 2008; 2010a).

Human movement, as a social process (Close 2000; Frello 2008), is fundamentally embedded in land use (Binford 1980; Kelly 1992; Whallon 2006). The investigation of movement patterns among non-hunter-gatherer-pastoralist societies tends focus on "state-like" formations that left behind direct material evidence. Outstanding examples include the Inka road network, Maya *sacbeob* and the Roman *viae* (Hyslop 1984; Keller 2009; Verhagen and Jeneson 2012). In the present case, the study of movement is undertaken on the broader landscape-level context of PM01 with a geospatial model, in order to develop hypotheses about the role of territoriality (as considered through differentiated mobility patterns) among the southern proto-Jê before European contact in Misiones province. PM01 is, at time of writing, the best known pre-Columbian archaeological site in the entirety of Misiones province. First identified by Menghin (1955/56; 1957) as a possible village enclosure with a central plaza and funerary mound, later investigators (Iriarte et al. 2008; 2010a) have interpreted it as a ceremonial enclosure where people gathered regularly to enact rites of feasting to commemorate and solidify ties to a venerated ancestor. Several other enclosures, some with mounds, were documented in close proximity (Figure 7.1), but later destroyed by modern development (Wachnitz 1984). The roles played by these monuments in the societies who built and used them for centuries are the focus of continuing archaeological investigation (see

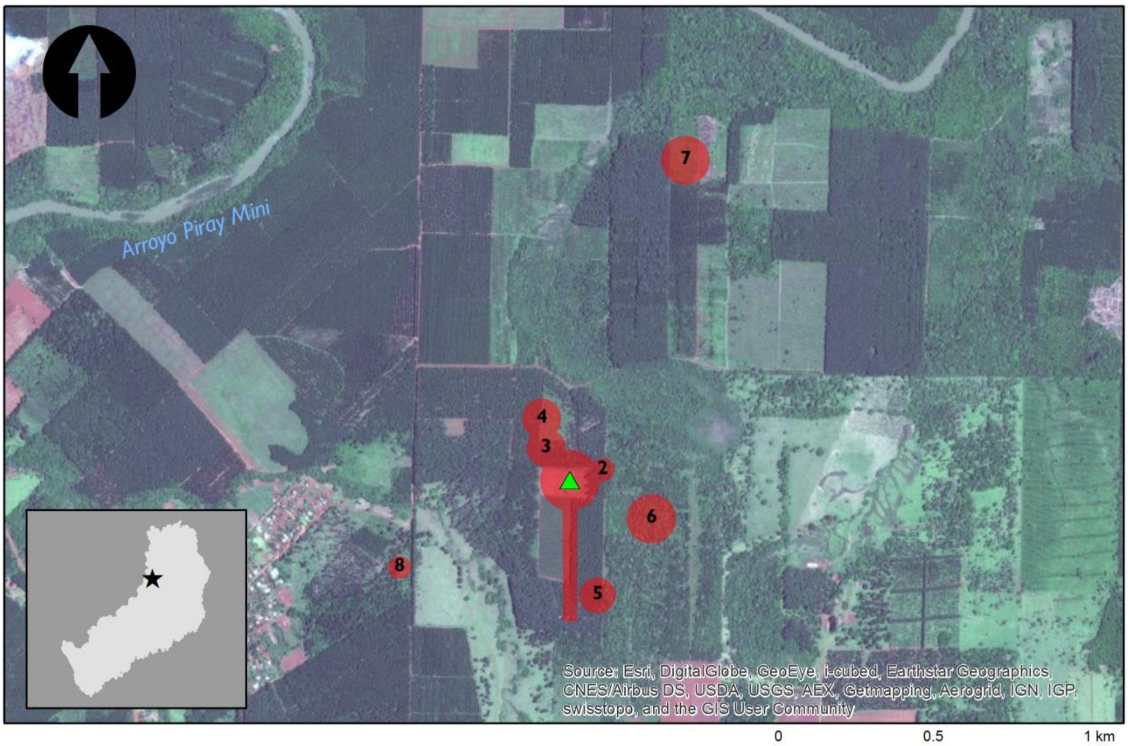


Figure 7.1: Eight southern proto-Je enclosures formerly located near Eldorado, Misiones. PM01 is the central feature with a causeway indicated by the green triangle, with the other features numbered from two to eight. PM01 had two mound features, while Circle 8 was recorded with one. After: Wachnitz (1984).

Iriarte et al. 2013 for a summary of current scholarship). The present case study aims to contribute to this effort by questioning how mound and enclosure complexes structured their social and physical environments. More specifically, it can be asked: how did the performance of ritual activity at monuments in the study area impact the development of territoriality among the pre-Columbian southern proto-Jê?

As noted in Chapter 2, the term southern proto-Jê denotes an ethnolinguistic group that had entered the eastern La Plata basin from Amazonia by the second century CE (Prous 1992; Beber 2005) and possibly earlier (De Masi 2005), following an earlier separation around 3000 yr BP from Jê people residing in central Brazil (Noelli 2005; Callegari-Jacques et al. 2011). Members of the southern proto-Jê formerly extended across the Brazilian states of Rio Grande do Sul, Santa Catarina, Paraná, and parts of São Paulo, as well as the Argentinean province of Misiones. They are noteworthy for introducing ceramic technology (Taquara/Itararé tradition pottery), domestic pit house dwellings and possibly cultivars to the material record of the macro-study region (Menghin 1957; Rizzo 1968; Schmitz 1991; Noelli 1999-2000; Beber 2005; Araujo 2007; Iriarte et al. 2008). Consequently, although this chapter expands the spatial scale, the time period under investigation is much narrower than up to this point in this research. Before proceeding with the case study, the place of MECs in relation to broadly contemporaneous changes in other lowland pre-Columbian societies during the late Holocene will be outlined.

7.1.1 Movement, earthworks and social structure in late Holocene lowland South America

It is relevant to again emphasize the deep history of Amerindian societies and their trajectories of development. Over the past thirty years, archaeology and allied disciplines have gradually rejected the so-called "Standard Model" of lowland prehistory (see Meggers 1954; Meggers and Evans 1957; Evans and Meggers 1961; Meggers et al. 1965; Meggers 1985; 2010) that was backed for several decades by Betty Meggers and Clifford Evans across South America. Simplifying the scenario, the revisionist view stresses time depth, the reciprocal nature of human-environmental interactions, and the distinctiveness of Amerindian cultural trajectories in Amazonia and beyond (Viveiros de Castro 1996; Neves 1999; Heckenberger et al. 1999; Stahl 2002; Heckenberger and

Neves 2009; Denevan 2012). With this comes the understanding that patterns seen in the archaeological records of later periods ultimately stem from complex, long term engagement of past cultures with the wider socio-cultural and physical environments which unfolded in parallel.

Bearing this in mind, southern proto-Jê MECs should be viewed alongside other traditions of large-scale intervention in the natural landscape that other lowland Amerindian societies engaged in. Indeed, mound-building cultures have traditionally figured heavily in discussions of socio-political complexity in lowland South America (Roosevelt 1993, 273; Heckenberger 2005, 124; Walker 2012). Examples abound in the later Holocene material record: habitation mounds are widespread in the Orinoco basin (Zucchi 1973; Gassón 2002), the Llanos de Moxos (Denevan 1966; Walker 2011), the Paraná delta (Politis et al. 2011; Bonomo et al. 2011b), and eastern Uruguay (López Mazz 2001), to name only a few. Other examples, such as wetland mound complexes in Uruguay (Iriarte et al. 2004; Iriarte 2006) and sambaquis of the south Brazilian coast (Gaspar et al. 2008; Wagner et al. 2011) are even more ancient. More to the point for this case study, however, other types of pre-Columbian earthworks of monumental dimensions are also implicated in facilitating the movement of people at a landscape level. Erickson (2008) noted recently that all pre-Columbian lowland groups maintained networks of paths to some degree. The role of movement in the appropriation of space into cultural frameworks has a direct bearing on how territoriality is negotiated by groups inhabiting their environments (Murrieta-Flores 2009, 16-17). Two examples are highlighted here to explore how the concept of directed movement, meaning pedestrian locomotion towards a pre-defined destination of cultural importance, creates order in a landscape (*sensu* Llobera et al. 2011).

The first is from the Upper Xingu in the Brazilian Amazon. Archaeological research in this region (Nimuendajú 1952; Heckenberger 1996; Heckenberger et al. 1999; Heckenberger 2005) revealed evidence of a regionally-organized indigenous polity whose apex was during a “Galactic Period” that began, at the latest, around 1250 CE. A centuries-long developmental phase preceded this, during which populations merged into formalized plaza villages that became organized in a spatial and symbolic hierarchy linked through a radial network of roads. These roads in the Upper Xingu were up to 10 metres wide and set between linear mounds that flanked them for their entire run, connecting villages several kilometres apart. Roads provided access to ritual and economic resources in the environment, while also directing between-settlement movement (Heckenberger 2005, 118-124). While the status of village clusters is primarily reflected in their degree of architectural elaboration, their relative importance (centrality) in the overall settlement hierarchy is also closely related to how symbolic capital was distributed via the networks of movement engendered by the roads (Heckenberger 2005, 127-129). The role of such routes of transit in structuring the Amazonian landscape at a regional scale is therefore likely to be nontrivial (Erickson 2008, 173).

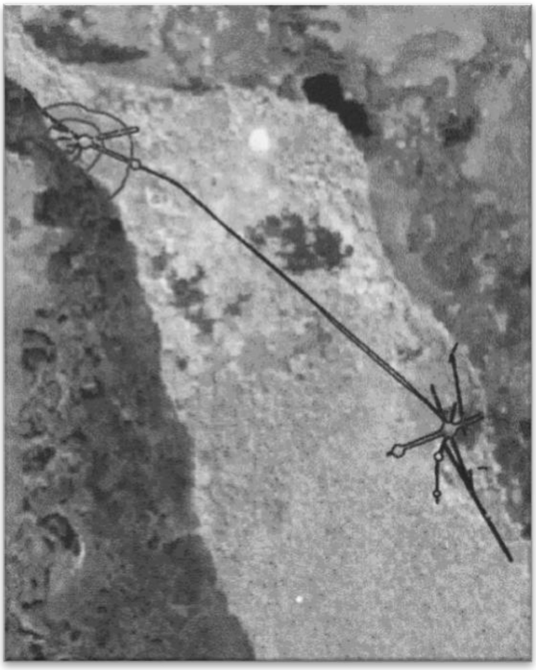


Figure 7.2: Pre-Columbian Upper Xingu villages X6 (R) and X13 (L), connected through a radial road network. Source: Heckenberger 2005, 81.

The second example is located in the Llanos de Moxos of Bolivian Amazonia. This vast, seasonally-flooded savannah bears extensive marks of pre-Columbian anthropogenic intervention, including habitation mounds (terminal occupation circa 1400 CE), raised fields, and weirs (Nordenskiöld 1916; Erickson and Balée 2006, 200). The main features of interest at present are dense networks of Causeway-canals, which exist in Major and Minor size classes. These groups are distinct in terms of elaboration and scale, and had multiple functions as water-retention features, boundary markers, and forest/wetland resource hot-spots (Erickson and Balée 2006, 220; Walker 2011, 12). Following the descriptions of Erickson (2009, 212-213), the first are linear raised earthen banks up to 10 metres wide and 3 metres high, flanked by water-retaining canals on both sides. They enabled movement between forest islands kilometres apart both on foot and in canoes, and were large-scale constructions undertaken by an organized labour force. Minor causeway-canals, single linear canals flanked by two relatively low causeways, are far more numerous. They are probably the result of repeated canoe journeys creating grooves and depressions in the naturally low-lying Llanos to connect neighbouring islands. Primarily, however, they were routes of transit across the savannah that enabled relative ease of access between different communities and resources, as well as to periodic social events which are documented well into the colonial period. The landscapes of movement (Erickson 2001; Erickson 2009) in the Llanos were produced, on one hand, by deliberate, communal mobilizations and on the other as a by-product of repeated, intensive patterns of inter-forest island movement and interaction.

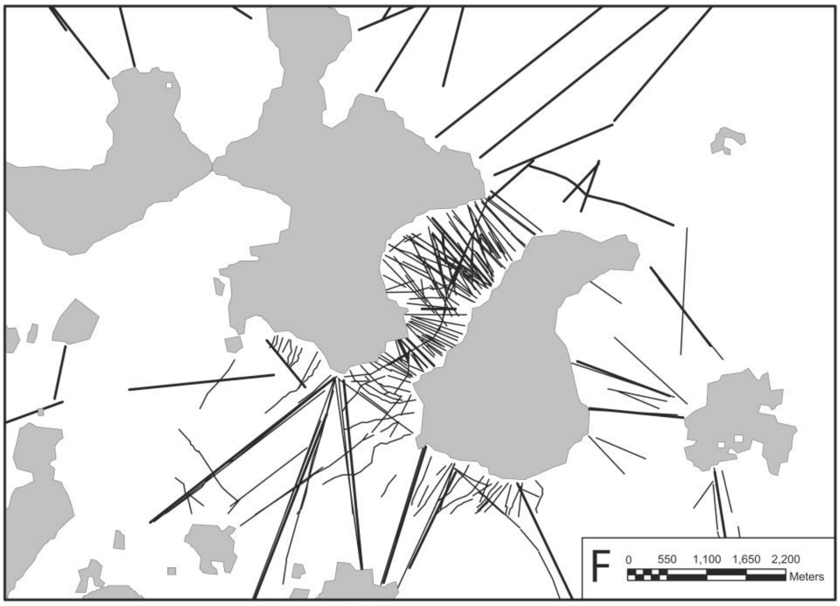


Figure 7.3: San Martin forest island complex, showing major and minor Causeway-canals in Baures, Bolivia. Source: Erickson 2009, 216.

These two examples illustrate some key theoretical points that bear on the geospatial model. The Upper Xingu road network and Major Causeway-canals reveal that significant communal effort was invested by pre-Contact societies in structuring social interaction via the determination of movement in space (Hillier and Hanson 1984; Bourdieu 1985, 724; Lefebvre 1991, 411). The collective mobilization of labour is conspicuous in the scale of these earthworks, representing significant anthropogenic modifications to the physical environment. As status indicators and facilitators of movements, the desire to structure mobility regimes in specific ways is implicit in their design. In other words, the flows of people and objects across these landscapes follow a particular vision of the socio-political order (Ingold 2000, 219; Bevan 2011; Llobera 2012, 503-504). Simply defining destinations (as in these examples, most obviously through architectural form) affects the spatial structure of the landscape, providing a physical and social framework for the development and constitution of the societies in question (Giddens 1984; Pred 1984, 282; Lawrence and Low 1990; Frello 2008, 29; Llobera et al. 2011). Second, Minor Causeway-canals also demonstrate how the establishment and repetitive use of routes in the long term causes spatial and social patterns to emerge from interrelated sets of practices (Pred 1981, 6), and their presence need not be conspicuous nor an intentional outcome of the social process of movement.

7.1.2 The archaeology and interpretation of mound and enclosure complexes

To this end, the archaeology and interpretation of MECs will be elaborated upon next. If MECs can be said to occur in a standardized form, the most basic would be a low circular earthen bank, less than 50 cm high and up to several tens of meters in diameter, which encircles a funerary mound a few meters in diameter and up to 2.5 m high (Iriarte et al. 2008). This generalizes the archaeology of MECs heavily. Indeed, mounds do not always occur with enclosures (Métraux 1946; Chmyz and Sauner 1971) and vice versa (Wachnitz 1984; Schmitz and Becker 1991). A recent review of the archaeology of mound and enclosure complexes has indeed highlighted the striking diversity among these monuments (Iriarte et al. 2013), which the following section draws upon extensively. For the purposes of the present study, PM01 must be viewed alongside the growing body of evidence still emerging from Brazil in order to understand its overall place in the spectrum of MEC forms.

Typically, the enclosure is circular or slightly sub-circular. Enclosures can, however, also occur as rectangles that form so-called “keyhole” shapes when combined with circular, abutting or overlying preceding enclosures. The implication is that layouts were actively manipulated during their lives. In the case of PM01, at least two smaller enclosures adjoined the main circle to the east and northwest. Furthermore, not all enclosures are fully “closed”, as gaps in the banks evoke a possible function as processional entranceways to the central plaza area hosting the mound. This interpretation is supported by the rare presence of linear embankments leading towards the gaps (e.g. Menghin

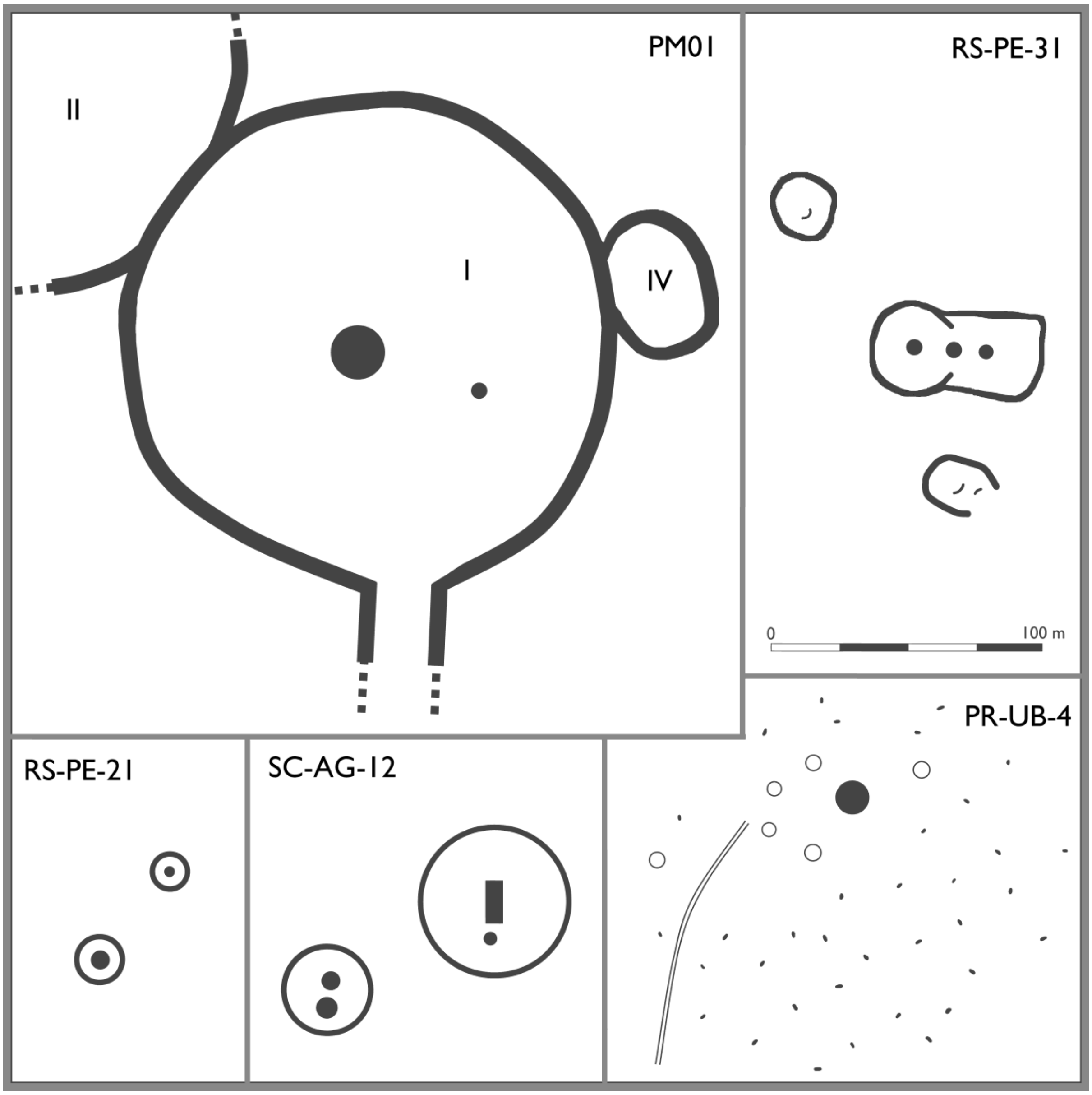


Figure 7.4: Plans of the MECs used in this study (PM01, RS-PE-21, SC-AG-12 and PR-UB-4), and a "keyhole-shaped enclosure" (RS-PE-31). Note paired enclosures and mounds, entryways, and association of a group of pit-houses and a trail with the mounds in the case of PR-UB-4 (hollow shapes). After: Chmyz and Sauner 1971, 13; Wachnitz 1984; De Masi 2005, 234-235; Iriarte et al. 2008, 954; 2013, 88.

1957; Wachnitz 1984) or trackways towards the site itself (Chmyz and Sauner 1971), which may have functioned as processional causeways (Iriarte et al. 2008). Where enclosures occur in pairs, the larger of the two is usually in a more elevated position and to the west of the smaller enclosure. Regarding overall positioning in the landscape, MECs are topographically prominent, typically close to (but not quite on) the summits of hills and ridges overlooking settlement areas. The reverse pattern is observed in Urubici (Santa Catarina), however, with MECs instead located on river floodplains in association with pit houses (Corteletti 2012).

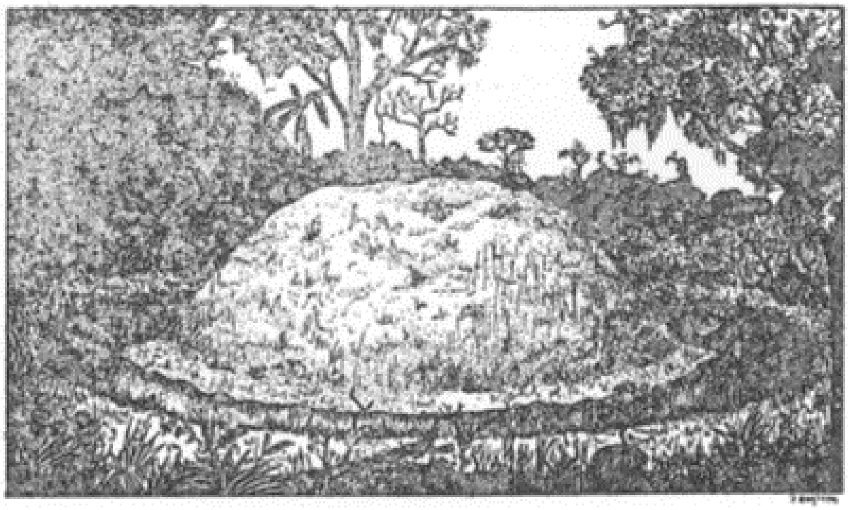


Figure 7.5: Drawing of a historical period mound and enclosure complex documented among the Kaingang. Source: Métraux 1946, 466.

Mounds typically occur within enclosures, although as noted above, late examples from Paraná present only a peripheral ditch, while ethnographic data on Jê groups would suggest that enclosures were a less common feature among post-contact MECs (Mabilde 1983 [1897-1899]; Métraux 1946). If a single mound is present within an enclosure, it will be located centrally, yet paired mounds can be erected significantly off-centre within a single enclosure. As with enclosures, the larger mound is usually the westernmost. Excavations in mounds (e.g. Menghin 1957; Chmyz and Sauner 1971; Copé and Saldanha 2002; Iriarte et al. 2013) have repeatedly confirmed their funerary nature, with layers containing ash, burnt earth and fragmented bone typically located at the base of these features. Burials took place through both cremation and inhumation, are often singular within mounds, and were reserved for high status individuals (Iriarte et al. 2008). Nonetheless, SC-AG-12, a pair of MECs located in Santa Catarina, has yielded multiple burials interred collectively in the mound (De Masi 2005; 2009). There is, furthermore, strong osteological and taphonomic evidence to suggest that certain burials were secondary (Müller 2008; De Souza and Copé 2010; Iriarte et al. 2013, 90). Mounds, although clearly the focal points of the activities hosted by MECs, appear to have functioned in a variety of ways according to the needs of the communities involved.

Interpretations of MECs have been put forward that stress that their presence reflects the contestation of terrain, and possibly the beginnings of control over areas of habitation and resources within defined territories (De Souza and Copé 2010). MECs often possess direct lines of sight to neighbouring groups of monuments, but have more restricted views of the surrounding landscape, focusing on areas containing settlements. This finding has been used to suggest the deliberate evocation of "visual dominance" by certain MECs over other monuments, as well as specific settled areas, possibly reflecting an emergent power structure within southern proto-Jê societies (Saldanha 2005, 146; Copé 2007). Exploratory spatial analyses have bolstered this interpretation by suggesting that monuments are closely aligned with "nodes" of transit in their respective landscapes (Saldanha 2005, 137), based on the application of simple least-cost pathway models (see also Corteletti 2012).

Recent research (De Masi 2006; De Souza and Copé 2010; Iriarte et al. 2013) builds on this work to suggest that MECs occur in two distinct size grades. Minor monuments are small (15 – 20 m in diameter) and likely served the ritual needs of "local groups" (Iriarte et al. 2013, 93). The minority of MECs are in a larger size grade, between 65 and 180 m in diameter, and are interpreted as ritual facilities used by larger, pan-regional groups (De Masi 2006; De Souza and Copé 2010). Evidence of feasting, as well as more elaborate architectural features (such as causeways and plaza entrances), are hereto only attested in larger monuments. This would imply that different types of MEC are implicated in practices that took place at a variety of spatial scales, which raises the issue of how much terrain was contested in different contexts and by different types of monument (Copé 2007, 18). What was the spatial scale of territorial control exerted over the landscape in intensively occupied regions, such as Pinhal da Serra or the Upper Canoas valley?

The case in question, PM01, is problematic, since direct evidence of contemporaneous settlements in the vicinity is lacking, except for the few fragments Taquara/Itararé tradition pottery recovered during the project survey of this research. In the absence of additional settlement data or MECs, a deeper understanding of pre-Columbian cultural landscapes in Misiones province hinges on being able to make robust comparisons with more well-studied contexts and set them within a landscape-level framework. As discussed, Misiones is located in an ecologically diverse subtropical setting, forming part of the border between the Interior Atlantic Forest, the Pampas and the southern Brazilian highlands, in addition to being embraced by two of the principal watersheds of the eastern La Plata basin (Iriarte et al. 2008; 2010; Riris 2010a). Understanding how the cultural responses of southern proto-Jê groups in this environment came to be distinctive can help solve some of the questions on how these societies began to diversify into regional polities and asserted their territoriality. The case study of PM01 will therefore rely on using evidence from additional sites located in southern Brazil to provide comparative studies and shed additional light on MEC diversity.

7.1.3 Territorial models and modelling territoriality

The study of territoriality in the social sciences and humanities is deeply bound up with the notion of physical control over space, stemming from long-term cumulative land use by particular groups (Soja 1971; Sack 1986; Ingold 1987, 141; Zedeño 1997, 69). The implication is that territories, although the outcome of social process, have real geographic dimensions which are made explicit by tangible material signifiers (Sack 1983, 59; Sack 1986, 19; Paasi 1998, 72) or "boundary objects" (Lamont and Molnar 2002, 180). Territories thus function as a means to differentiate access to resources or phenomena, be they literal or abstracted, by the maintenance of objects that denote ownership, restricting or enabling access to the territorial unit (Sack 1983, 57; Lamont and Molnar 2002, 168). Extending this to the present case, in settings heightened by ritual activity such as (post-)mortuary rites, the sensation of being included in a social world to the exclusion of non-participants may be especially keen (DeMarrais et al. 1996, 19; Iriarte et al. 2008; Mantha 2009, 160). These heuristic categories of included/excluded are dynamic, and dependent upon the fluid relationships of the actors involved in the boundary maintenance practices differentiating access to space. Indeed, social exclusion can function as a form of inclusion for the excluders (Barth 1966; 1969; Paasi 1998, 79; Silver 2007, 1).

The complexity of how accessibility was shaped in the past means that there is no single correct interpretation of "territory" to be found in the material record (Ingold 1987, 136). The archaeological study of territoriality should be concerned with exploring broad envelopes of possibilities that past territorial strategies may have encompassed. As discussed in section 7.1.1, movement is central to appropriating landscapes as culturally-cognized entities. The approach adopted here considers territoriality an outcome of differential access, itself a function of *ordered* or *structured* movement (Llobera et al. 2011), by employing computational modelling to explore the core dynamics at play between the act of moving, specific places and differential access.

The model discussed in detail in the next section to examine the accessibility of MECs in their environments is both geospatial and has a simulated component. That is, the scenarios take place on a canvass representing real geographical space as opposed to synthetic landscapes. If MECs are to be understood as territorial markers, as argued in the wider literature on southern proto-Jê monumentality, then territoriality can be expressed as the outcome of differing levels of accessibility (i.e. structure in landscape-level patterns of movement) to the activities and spaces that MECs afforded. The next section is concerned with formalizing this argument.

7.2 Modelling framework

The following section will detail how the geospatial model was specified, including the acquisition of the MEC data, the calculation of environmental factors (the friction surface), and the parameters that constrain the model. Associated information is also provided to enable independent evaluations of the model or any other method in the future. The Eldorado monument (PM01) in Misiones is the key subject of enquiry, and will be used for illustrative purposes throughout, although MECs culled from the Brazilian literature also feature as a basis for comparison.

7.2.1 Archaeological and simulated data

Four MECs were chosen to provide comparative case studies to the PM01 monument located in Misiones. The criteria for selection were:

a) Environmental setting. The study aimed to capture MECs in a variety of ecological and environmental settings. In addition to PM01 in Misiones, MECs in all three states of the south region of Brazil are represented in the sample. As a result, the subtropical interior forests, the highlands of southern Brazil, and examples from the basins of both the upper Paraná and upper Uruguay are included. The topographies of these areas differ majorly from one another.

b) History of investigation. References to dozens of MECs can be found in the southern Brazilian archaeological literature (PM01 and its associated monuments being the only published examples from Argentina). Only a small number of these are associated with reliable radiometric dates, plans, and coordinate data. Where two of these conditions, and preferably three, were present, the MEC was

Table 7.1: Descriptive data of the mound and enclosure complexes used in the geospatial model.

Designation (Earthwork)	Region (state, country)	Location (Decimal degrees)	^{14}C age (BP)	Reference(s)
PM01 (Circle I)	Misiones, Argentina	-26.382203 -54.549676	760 ± 60 760 ± 40 720 ± 40 480 ± 60	Menghin 1957; Iriarte et al. 2008
PR-UB-4	Paraná, Brazil	-24.414048 -53.113751	855 ± 95 470 ± 95	Chmyz and Sauner 1971; Chmyz et al. 2003
SC-AG-12 (Circle I)	Santa Catarina, Brazil	-27.660153 -51.023208	690 ± 40 600 ± 40 470 ± 40 430 ± 40	De Masi 2005; 2007; 2009
RS-PE-21	Rio Grande do Sul, Brazil	-27.821117 -51.181023	350 ± 40	Saldanha 2005; Iriarte et al. 2013
Urubici 21	Santa Catarina, Brazil	-27.979175 -49.576735	n.d.	Rohr 1971; Corteletti 2012

considered a candidate for inclusion.

c) Publication record. Grey literature sources were not considered when searching for candidates. All the MECs in the sample appear in at least one peer-reviewed journal article or monograph.

The results of using these selection criteria are shown in Table 7.1 and their regional distribution in Figure 7.6. Monument locations for PR-UB-4, SC-AG-12, and RS-PE-21

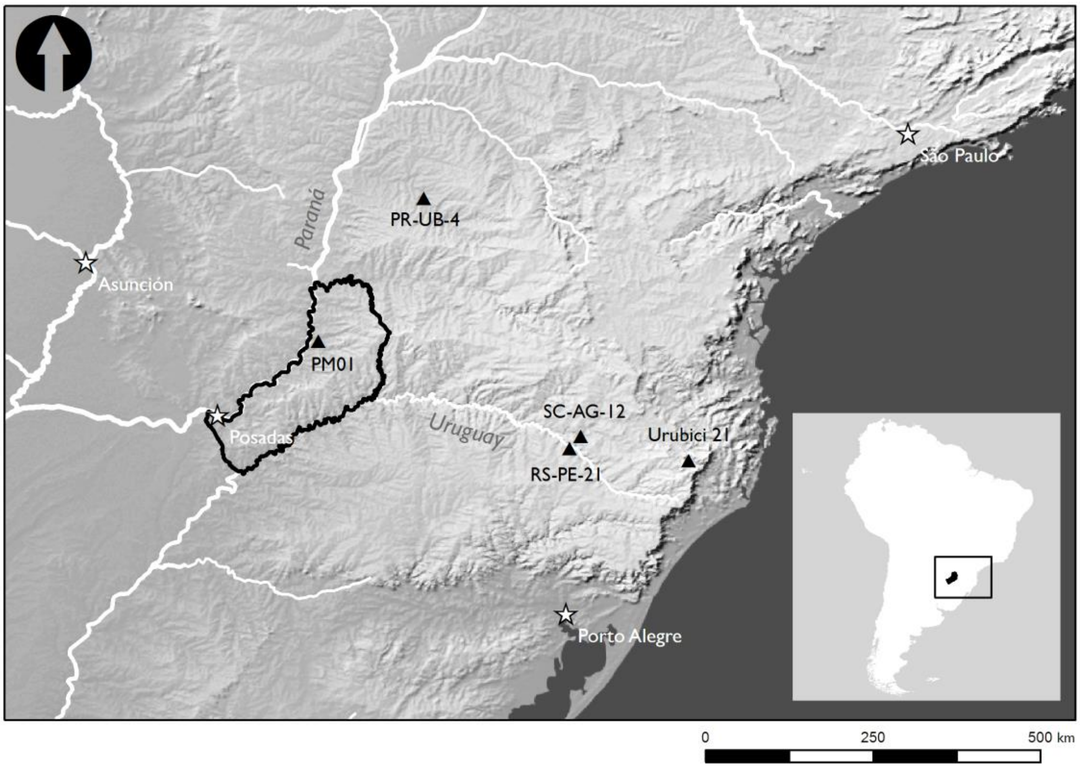


Figure 7.6: Distribution map of the archaeological sample used for the case studies in relation to PM01 and Misiones province. Inset: Location in South America.

were collected from georeferenced maps in the indicated publications, although unfortunately no dates are available for Urubici 21 (see Corteletti 2012). PM01 was visited during the Piray Mini Exploration project fieldwork (see Chapter 4) to record its location. It ought to be noted that these monuments are not isolated; several (e.g. SC-AG-12 and RS-PE-21) exist in close proximity to other MECs, settlements, and other site-types identified as belonging the southern proto-Jê.

For the geospatial analysis described below, buffers were created around each archaeological point equal to the radius of the MEC outer enclosures. This mirrors the area covered by each monument on the ground. Circular study areas around each MEC were defined with an arbitrary radius of 25 km. This figure was determined to be sufficient for capturing macro-scale patterning in the spatial structure of the landscape. Additionally, to mitigate the possibility of edge effects affecting the modelling procedure, the study areas were enlarged by an additional 25% to a radius of 31.25 km. This creates an "extended" study area of approximately 3067.96 km^2 within which all calculations and modelling took place.

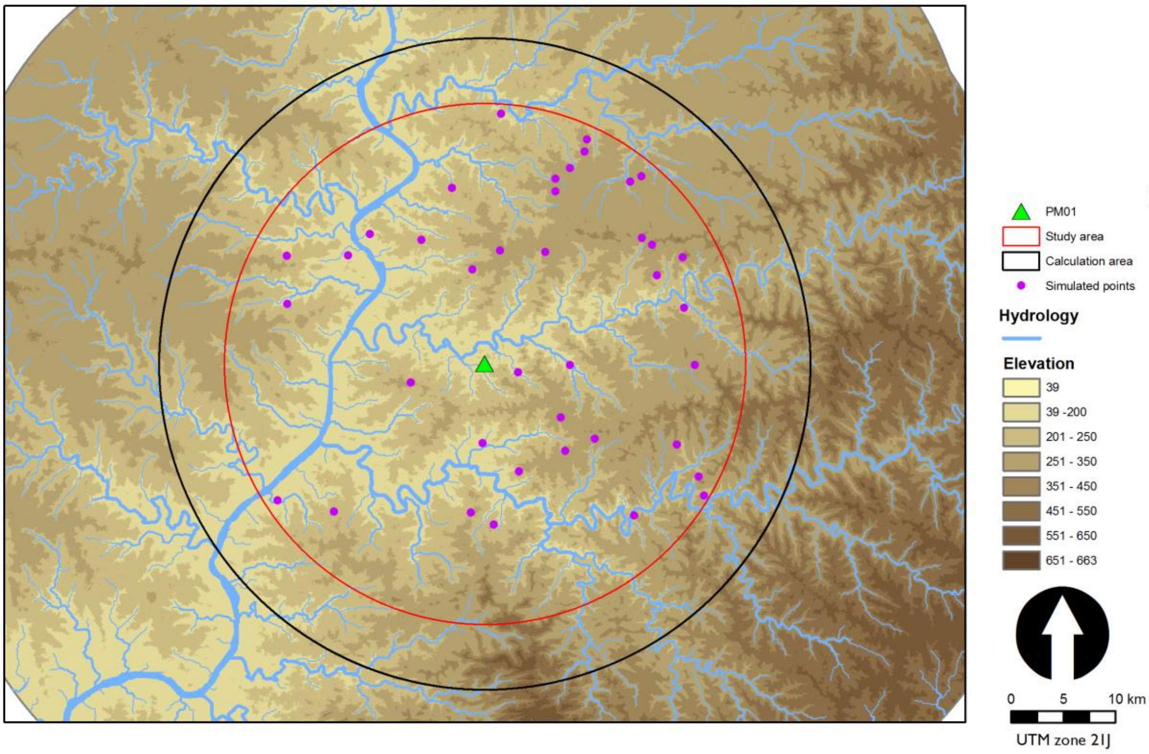


Figure 7.7: PM01 in its study area, showing the main topographical features of the environment, the study area (radius = 25 km), the extended area of calculation (radius = 31.25 km) and simulated random points (n = 39).

A focal mobility network (Llobera et al. 2011) examines the structure of movement in a single area of interest at a time by accumulating the "flow" of cells in a friction surface (cost raster) towards a focal point. One possible critique of this approach is the absence of comparative data for the focal point(s), meaning that the interpretation of each set of results is an exercise in subjectivity. Building a model does not indicate how it fits into an overarching system or give any metric by which its adequacy can be evaluated (Barth 1966, 28). To remedy this, the study at hand presents a solution by developing a baseline understanding of the structure of movement in the MEC study areas. This makes use of "null points" to run the model on, which complement the real archaeological site in each study area. The approach is closely related to Monte Carlo methods in numerical modelling, which repeatedly apply permutations of an analysis in order to obtain probability distributions of the phenomenon being modelled. In this case, 39 points within each of the MEC study areas were generated by drawing from a bivariate distribution, with no inhibition either between points or the central archaeological feature (Beyer 2012), in other words a random point process. Naturally, without exhaustive ground truthing there is no way of knowing whether any MECs already exist at the simulated point locations. For present purposes, however, they serve as adequate "null" points.

In summary, this modelling exercise considers the accessibility signatures of four MECs in addition to the PM01 monument. Due to these examples being widely separated in time and space, random simulated points are used as additional inputs within the MEC study areas to contextualize the accessibility signatures of individual monuments in their broader landscapes of movement. Structured movement, in this case, is a product of the affordances for movement in a given environment *combined* with the defined points of interest towards which past actors were directed (Llobera et al 2011, 843). As such, the modelling effort ought to encapsulate the main physiological effect of the environment on movement: the energetic cost of traversing the terrain and any other topographical features that could impact pedestrian movement. This is discussed in detail below.

7.2.2 Environmental factors

Friction surfaces (or cost surfaces) are at the core of most forms of cost-surface analysis in archaeology (Wheatley and Gillings 2002, 137; Herzog 2010). It can be derived in a variety of ways, typically estimated in terms of energy expenditure, although travel time instead of energetic cost is also common (Tobler 1993; Wheatley and Gillings 2002, 138; Herzog 2010). In both cases, the mathematical slope derived from a DEM is presumed to be the main determinant of "cost" to travel in a given parcel of space (Llobera and Sluckin 2007). Taking this as a point of departure, the topography of each study area provides the geospatial model with the data needed to approximate the cost of movement in each study area through a friction surface. Digital elevation models (DEM) were acquired from database of ASTER imagery and used for all subsequent calculations involving topography. Additionally, elevation was used as a vertical factor in the calculations to alter the magnitude of travel cost according to whether a traveller moves perpendicular to, up, or down a slope.

The relationship between topography and the cost of traversal is not linear (Llobera and Sluckin 2007). Complex polynomial functions have been developed to model this relationship, which provide a closer match to actual caloric expenditure than simpler approximations (see Minetti et al. 2002). Nonetheless, the modest improvement that complex equations (see Herzog 2010) afford over a simple calculation is still subject to the choice of the individual modeller. In the following model, therefore, the widely applied cost function developed by Bell and Lock (2000, 88) is used to reclassify the slope of the terrain to a cost surface:

$$Cost = \frac{\tan(slope)}{\tan(1°)} \tag{1}$$

The curve of the function is plotted in Figure 7.8. As a result of using this function, energetic cost increases dramatically with slope; cells with a slope >60° will be highly unlikely to be considered viable for transit if an easier alternative exists nearby.

An additional factor was used to generate a more inclusive view of the choices faced by travellers moving towards the focal points: the hydrological network of each study area. The runoff characteristics of each study area are simple to derive using standard GIS procedures. A threshold value of 200 cells was used to define the hydrological network, and the streams ranked following Strahler (1957). The rank scores were then assigned costs relative to their ranking in the stream network. This permitted it to be integrated with the basic friction surface based on slope (Table 7.2). Streams with a high order in the hierarchy were assigned a value of 20 in the friction surface, indicative of watercourses which pose significant barriers to pedestrian movement. These are commonly major rivers and their principal tributaries, which are conceivably fordable under optimal conditions, for instance after a period of low rainfall, during the formation of temporary upstream barriers, or where these rivers have rapids that could allow pedestrian crossings to form. Furthermore, the construction of temporary wooden bridges across smaller rivers has been documented among modern Jê groups in southern Brazil (Henry 1964, 171), which would provide greater affordances for crossing. Although these rivers would exert a considerable influence on the structure of movement possibilities, they are not impediments to the extent of being completely impermeable. Headwaters of rivers and smaller creeks or streams were considered to be easily crossable under most conditions, and were assigned values of 5 or 10 dependent on their order in the stream network, reflecting their minor role in

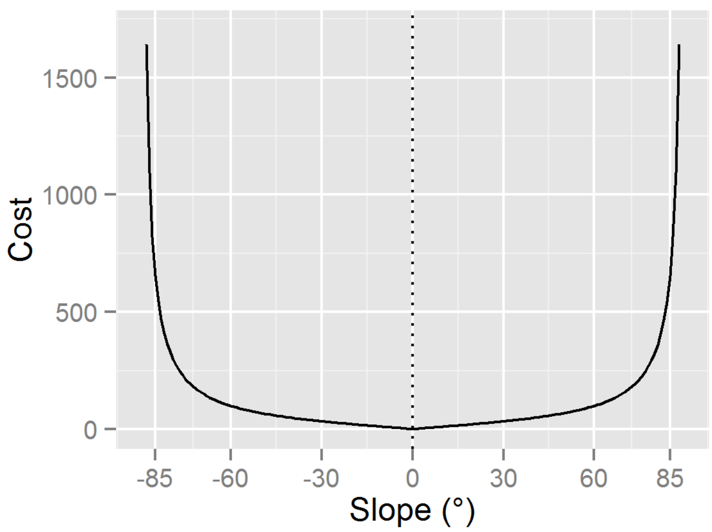


Figure 7.8: Plot of cost function used to calculate a friction surface of energetic cost from a slope raster after Bell and Lock (2000).

Table 7.2: Cost assigned to each rank in the stream network of the study areas

Rank order (Strahler 1957)	Cost
1	5
2	5
3	10
4	10
5	20
6	20

the overall structure of mobility.

The Río Paraná, which only features in the PM01 study area, is an exceptionally large watercourse out of the cases considered. The coverage of this river was manually digitized from satellite imagery and converted to a raster extent with the same resolution as the ASTER imagery. For all intents and purposes, it was assumed to be a strong limiting factor for transit in the cost-distance algorithms. This is modelled by allocating it a relatively high value of 100 in the friction surface. It is worth noting that other major rivers, such as the Piquiri, Canoas, and Pelotas are located in other MEC study areas. These have been extensively dammed in the modern era, however, and their widths in the present are not representative of the past. As such, they have been left as stream rasters with an extent of one cell as calculated by the hydrology toolset (ESRI 2012).

Although rivers have functioned as major facilitators of interaction and movement in the pre-Columbian history of South America (Lathrap 1973; Hornborg 2005; Erickson 2009), it is reasonable to assume that routine crossings of *major* waterways by people who may have lacked watercraft would have posed a significant challenge (see Henry 1964 on southern Jê groups in Brazil). The weighting can be expected to have a strong structuring effect on movement near and around the Río Paraná. On this topic, it is worth acknowledging that the modern hydrological network is unlikely to precisely match its ancient equivalent. Although there are inherent limitations to the accuracy of the approach adopted here, withholding such significant topographical features from the analysis would, on the whole, be more detrimental to generating robust results from this model.

Together with the cost function of slope, above, the weighted stream raster described here forms the basis for understanding the environmental influences on movement towards the five MECs (Figure 7.9). A key caveat is that the physical shapes of the land and water of the study areas are privileged over sensory cognition or culturally-specific ways of understanding the landscape (see Llobera 2000). Furthermore, because the cumulative cost algorithm used in the distance analysis seeks the least "costly" path to the source features (Dijsktra 1959; ESRI 2012), the model is inextricably linked to notions of

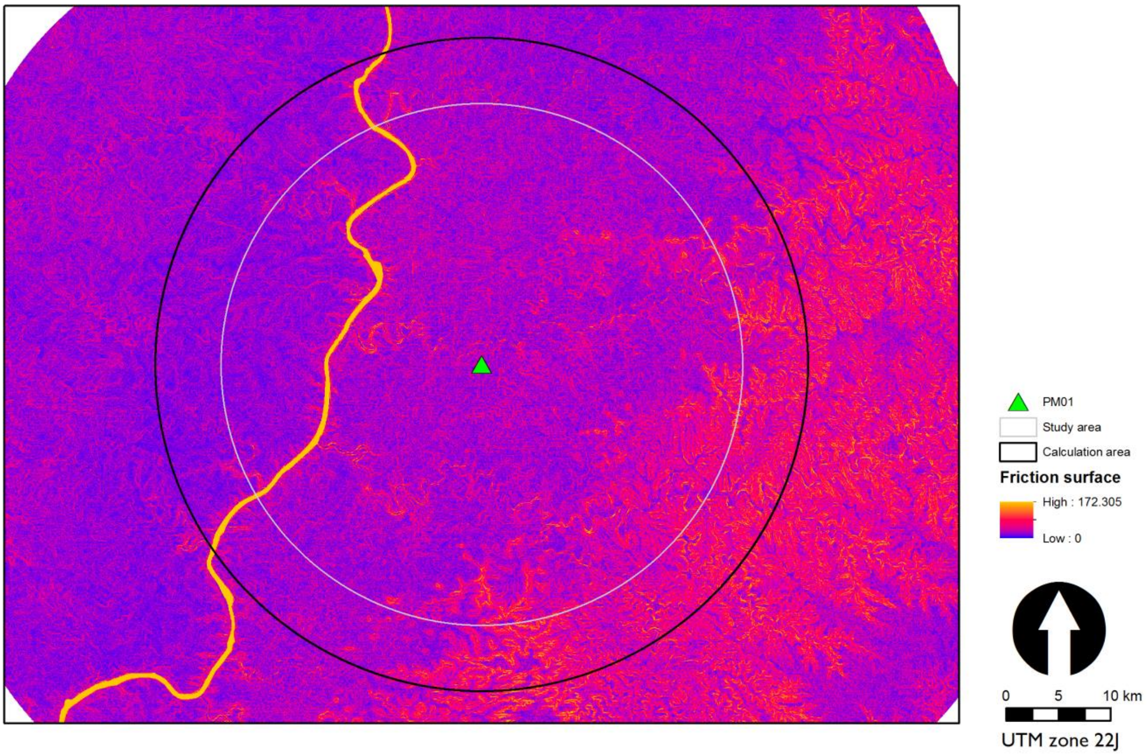


Figure 7.9: Friction surface showing the PM01 study area. Note high weighting of major rivers and steep slopes. Conversely, the gentle relief of plateaux and river floodplains translate as relatively low-cost areas for travel.

optimizing behaviour. Combined with the lack of so-called cultural variables, the ways of traversing the landscape suggested by this model cannot possibly be true in all times and places. Acknowledging the limitations of "bare-earth" cost surface analysis is, however, a key part of tempering the positivism of the modelling process. In this case, the simulation approach detailed in the previous section should secure robust results for this exercise. Overall, the friction surface approximates actualistic decision-making more closely than using slope in degrees as the only input in the cost surface analysis.

7.2.3 Model specification and focal mobility networks

The archaeological and simulated points were used as source data in 40 iterations of the Path Distance tool per study area (200 iterations total) within ArcGIS 10.2 (ESRI 2012) to calculate *focal mobility networks* for each MEC. The cost surface detailed in section 7.2.2, above, was the input for the cost raster. A DEM with a radius of 31.25 km around every point was used to model the actual geographical distance covered when moving between cells in the cost surface. The calculations for each focal point took place only within the area defined by the DEM around the points. Each run of the model contains the same area and is comparable with the remaining set of runs in each MEC study area. Using these parameters produces an accumulated cost surface (ACS) (Llobera et al. 2011, 844).

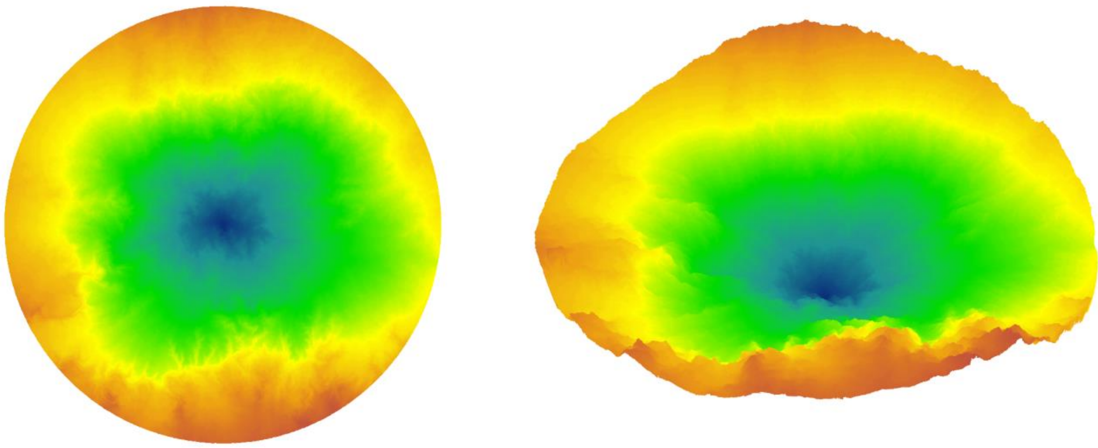


Figure 7.10: Accumulated cost landscape of SC-AG-12 in plan (L) and three-quarters perspective (R). Although all cells in the raster ultimately converge on the focal point, the use of a friction surface to generate the ACS highlights significant heterogeneities in the cost to traverse this parcel of space.

The procedure for calculating an accumulated cost surface differs from a traditional least-cost analysis; instead of a single path connecting two locations of interest, the ACS converges on the focal point. Rather than being the optimal way of getting from Point A to Point B, an ACS can be described as modelling the relative cost of travelling from *anywhere* in the study area to a single desired destination. Furthermore, Llobera et al. (2011, 844) note that like a real landscape, ACS landscapes have topographies. Valleys and ridges, rather than representing different elevations, are areas where the cumulative cost of traversal is locally at a minimum and a maximum, respectively. Plateaux and plains reflect a constant rate of accumulation. Sharp slopes show where the rate of accumulation increases or decreases rapidly, while gentler slopes show more gradual changes. These qualities mean that ACS landscapes can be characterized using some of the same tools as a real landscape.

Following from these topographical aspects, hydrological modelling tools can be applied to characterize their particular "physiography", including the direction and accumulation of cell "flow" in the ACS (Fábrega-Álvarez and Parcero-Oubiña 2007). That is, the algorithm calculates the "flow" of movement opportunities from high cost cells into lower cost cells in an 8-cell neighbourhood. Given the assumptions of the model, this gives a representation of how geographical space is structured by directed movement towards the focal point by identifying corridors of high "flow" (i.e. low cost) in the landscape. In order to extract these areas of high flow, a threshold value of 10% of the maximum was applied to the flow accumulation rasters derived from the ACS and converted to polylines.

The result, visualized in Figure 7.11, is termed a focal mobility network (Llobera et al. 2011, 845) and is analogous to a real hydrological network in several ways discussed below. They are unique signatures of spatial structure of the focal point in relation to its surroundings. As can be seen, each FMN affords distinctive opportunities for movement towards their respective mound and enclosure complexes. It is important to note that these paths are not literal reflections of how past actors accessed MECs. Instead they are thought of as corridors of movement where the accumulation of cells in the ACS, and hence its degree of accessibility, is locally maximal. The edges in the network are not necessarily the optimal pathway, as in least-cost path analysis, but rather, the most likely to be taken.

An FMN has several of the same topological elements as real-world stream networks:

- Edges and nodes, the flows and their points of convergence.
- Basins, areas in which all cells flow towards a single node.
- Hierarchies, the order of the above elements in the overall network.

The exploratory power of an FMN lies in the comparability it affords between a larger set of identical procedures carried out on other locations of interest. On the scale of the individual monuments, this means the relative accessibility of the monument in relation to the simulated null data in the study area.

To this end, the notion of "mobility basins" was established as a baseline for FMN comparability. A mobility basin describes the surface area indexed by each node in the

FMN, and can be thought of as areas of the landscape that are accessible after passing through nodes along the FMN hierarchy (Llobera et al. 2011, 846). Crossing nodal points in the focal mobility network has two consequences for travel towards the MECs. First, new possibilities for movement are afforded as a new basin in the hierarchy is accessed. Second, opportunities to take "the road less travelled" in previous mobility basins are closed off, resulting in a narrower range of choices available as the MEC is approached. This element of potential versus actual choice was leveraged to create an index of accessibility. In this case, accessibility is a function of distance from the focal point over surface area "contained" in each mobility basin.

To quantify the accumulation of mobility basins as the FMN converges, the order of the basins in the network was measured in linear distance every kilometre away from the focal point (both real archaeological points and simulated null-points). At 1 km away, the area accumulated by the basins "behind" this distance threshold was summed and the next distance threshold moved to until the 25th threshold was reached and the extent of the entire study area of each FMN had been added to the total. In doing so, an accessibility signature (Llobera et al. 2011) can be graphed as area versus distance for each MEC and the background of simulated null points. The outcome of this procedure is discussed in detail in the next section.

7.3 Results

7.3.1 Mobility basins and network

The application of the model results in the generation of focal mobility networks which are unique to the environment of each MEC. The differences between each monument are apparent in visual terms when comparing the various networks and mobility basin hierarchies (Figure 7.11 and Figure 7.12). A hierarchy can be conceptualized as the procession of mobility basins a traveller must take to arrive at the destination from a given point of origin. All paths within a hierarchy converge on the same terminal node before ultimately entering the "neighbourhood" of the MEC. Travellers crossing between different hierarchies will have significantly different affordances for movement available to them.

The effect of certain environmental parameters is very apparent, most significantly the influential role of the Paraná. The network to the south of the monument (green) crosses gentle terrain and is highly fragmented, suggesting the range of choices and relative ease of access are sustained until within a few kilometres of the MEC. Compare this to the basins which cross the Paraná to the south- and north-east (purple and red), which rapidly converge into a few dominant pathways at a greater distance, possibly reflecting restricted access. A similar result can be seen in the Urubici 21 study area, which centers on the upper valley of the Canoas River, running S-E to N-W through it. In this case, paths converge on the low-lying valley bottoms quickly in each hierarchy. The result is a few dominant corridors of movement within the tributary valleys of the Canoas, echoing the findings of a least-cost pathway analysis on southern proto-Jê sites in the area (Corteletti 2012). The reverse can be observed in the RS-PE-21 study area, where two plateaux are separated by the steep (and costly to traverse) valley of the Pelotas River. The most of the network is relatively fragmented, but the network as a whole is contained within one restricted hierarchy that reduces to a single terminal node.

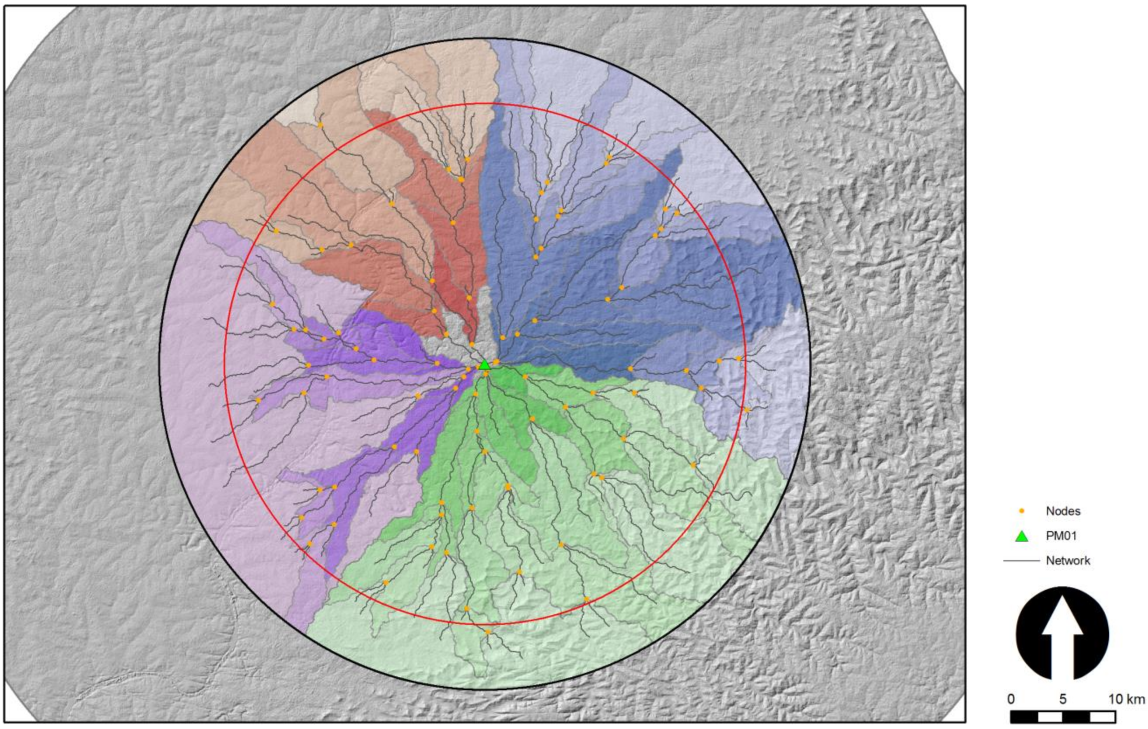


Figure 7.11: The focal mobility network of PM01, showing four distinct movement hierarchies from different sectors of the landscape, with their basins and nodes.

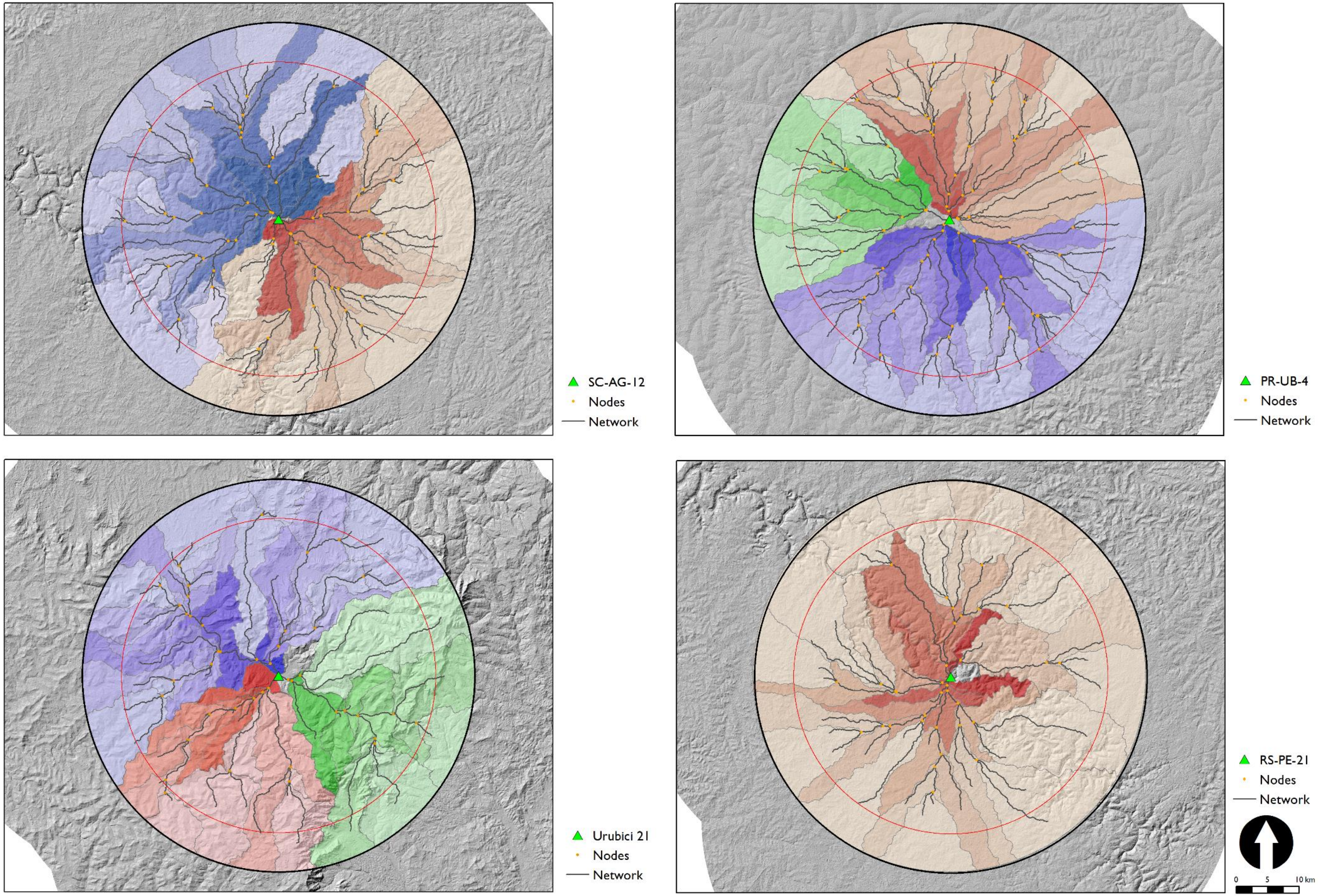


Figure 7.12: Focal mobility networks and hierarchies of mobility basins for each scenario. SC-AG-12 has two distinct hierarchies, RS-PE-21 only has a single hierarchy, while Urubici 21 and PR-UB-4 have three each. Opacity of the mobility basins reflects accessibility, with low opacity indicating low accessibility (little choice of pathway) from within that basin. Highly opaque basins index many preceding network edges and are close to the MECs, indicating high accessibility.

Visual comparison of the networks can only reveal a limited amount of information on the degree to which monument location influenced its accessibility, and hence whether southern proto-Jê groups were engaging in territorially exclusive or inclusive behaviour. The rate of network branching or fragmentation is, furthermore, only one aspect of the modelling results. Furthermore, visual inspection does not lend itself to comparing the archaeological networks with the 39 simulated point networks per study area. The next section derives an index of accessibility based on the rate of accumulation of mobility basins, using the simulated data as a "null model". This will provide a quantitative basis for comparison that can make full use of the runs of the model on simulated data.

7.3.2 Accessibility signature graphs

At a conceptual level, a traveller beginning a journey from any point on the outer edge of a study area towards an MEC would have a large range of overland routes to choose from, as no terrain has been traversed yet and the entire hierarchy of movement possibilities lies ahead.

This scenario can be thought through with an analogy from the modern era. An imaginary person standing in Trafalgar Square, London desiring to travel to the Place de la Concorde in Paris city centre will have a variety of means at their disposal to fulfil their goal. The traveller will have access to any major airport connecting London and Paris, the Eurostar railway service, the Channel tunnel by car, and ferries exist from Kent to Normandy, for example. Once a choice is made, the available routes from the starting point acquire a structure. If the traveller passes through certain points, for instance boarding a ferry, the traveller will inevitably have to ride out the voyage until the port at Calais. Upon arrival, a different range of choices are available, albeit fewer relative to those in distant Trafalgar Square. Several minor and major highways connect the Pas-de-Calais to the capital, which the ferry passenger could take advantage of. After arriving in the metropolitan area of Paris, the routes available towards the Place de la Concorde are substantially more limited than at any preceding point in the journey, as access to an ever-reducing area is sought. The choice of path available will gradually restrict as the destination is approached and, upon arrival by any hypothetical route, a person can physically only enter the square by a single entry point, completing their journey through one of a series of (potentially) very different decisions.

Returning to the modelled scenario, the imaginary journey outlined above is analogous to the process of traversing an ACS landscape. The traveller has a destination, a defined range of terrain to traverse and a shifting notion of the "optimal" route to take from a given point in the journey. Based on the assumptions of the model input, the focal mobility network indicates the route most likely to be taken within a hierarchy of basins. The individual mobility basins are a spatial representation of the full range of routes within a given parcel of land that converge on a node in the hierarchy. Nodes in the network are thresholds that once crossed, close off the mobility basin "behind" and present new movement possibilities "ahead" in the next basin in the hierarchy.

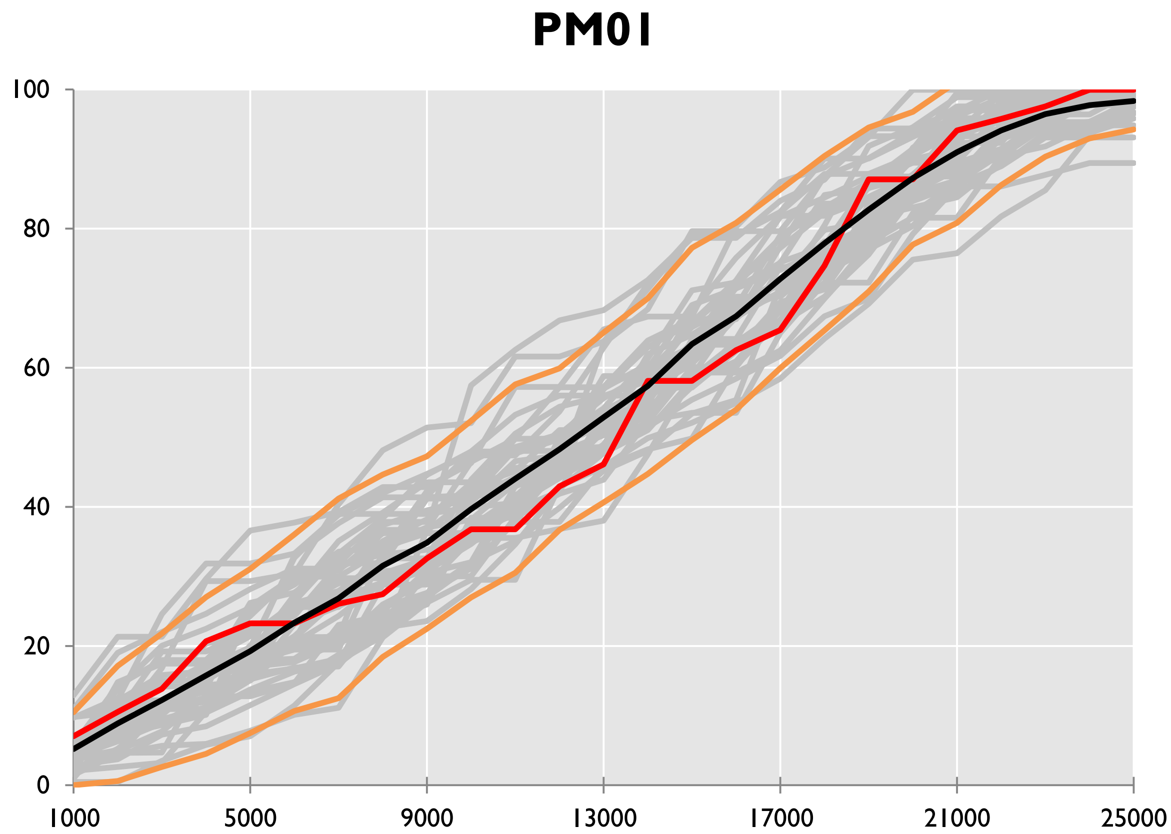


Figure 7.13: Accessibility signature for Misiones study area (PM01) in red, with simulated null points (grey), 95% confidence intervals (orange) and dataset mean (black). Vertical axis is displayed as a percentage of accumulated area (100% = 3068 km^2); horizontal axis is in metres moved *towards* the focal points. Locations on the curve below the mean line are on average more accessible, while those above are less

Measuring the rate of accumulation of basins indexes the relative accessibility of MECs in their environments, expressed as a function of distance as explained previously. That is, the surface area contained by each mobility basin was summed every 1000 m out from the focal point, using the nodes as proxies for "entryways" into the basins until the edge of the study area was reached. The total area at each threshold can be expressed as a percentage of the surface of the study area and graphed against distance from the focal point (Figure 7.13 and Figure 7.14). This produces accessibility signature graphs, which display a summary of the shifting range of affordances of movement as the MEC is approached. The slope of the curve is the most informative aspect of the graph, since it captures the change in the range of choices available as the focal point is approached.

To this end, travellers exiting a particularly large mobility basin (and passing through its node), corresponds to a spike in the accumulation of surface area, as a lot of terrain has been "put behind" them and hence closed off. In turn, this indicates that the total number of possibilities for accessing the monument has been sharply reduced. On the other hand, exiting a smaller basin would result in a shallower curve, reflecting the fact that a comparatively broad range of choice of route remains, while still reducing the range of choice on the whole. Each location has a unique accessibility signature related to the rate of accumulation (i.e. reduction of choices) of that particular ACS landscape. Distance thresholds with signatures above the mean curve are *less* accessible on average in the landscape of the MEC study area, while those below the mean are *more* accessible. The 95% confidence interval curves provide an indication of the significance of the pattern. As this aspect of mobility is summarized in relation to fixed distance thresholds from the focal points with varying levels of relative accessibility, the graphs allow for a multi-scalar assessment of how the environment was structured in relation to the MECs. The use of simulated data in this exercise permits greater confidence in making comparisons between the modelled scenarios.

Inspecting the graphs produced by the model for each MEC, three modalities of accessibility can be put forward. SC-AG-12 and Urubici 21 constitute the first, showing an

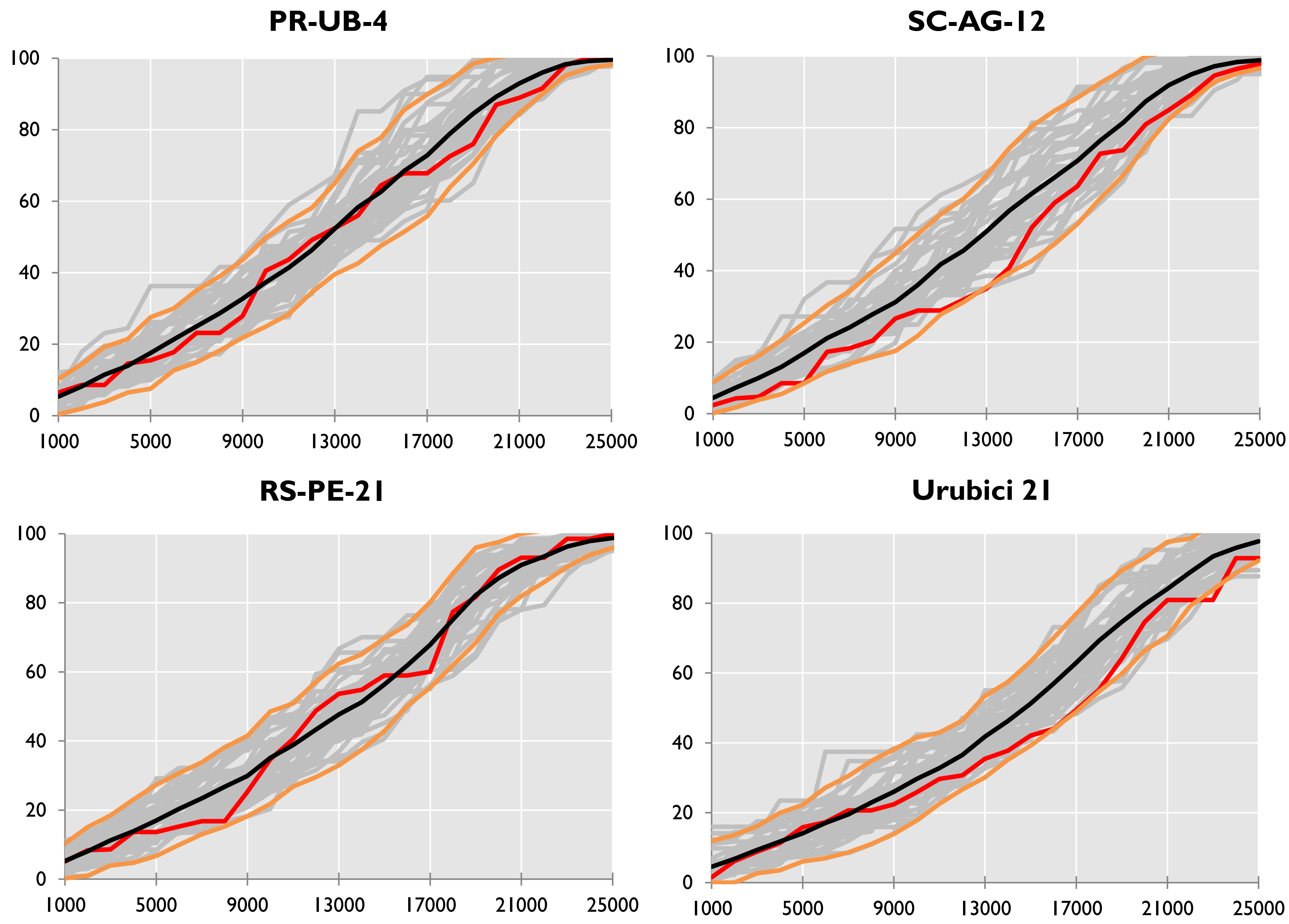


Figure 7.14: Accessibility signatures for a) Piquiri study area (PR-UB-4), b) Campos Novos (SC-AG-12), c) Pinhal da Serra (RS-PE-21), and d) Urubici (Urubici 21).

overall high degree of accessibility, with none of their basins being particularly inaccessible. The zone of 10 – 18 km is especially conducive to movement, however, with access peaking at 13 km for SC-AG-12 and at 17 km for Urubici 21. Urubici is also unique in having above-average accessibility at a very short range, within 1 km of the MEC. The second modality is made up of PR-UB-4 and RS-PE-21, which have two zones of accessibility at 5 – 10 km and at 16 – 19 km separated by a zone of inaccessibility. The pattern is stronger in the second MEC, most likely because the topographical relief is sheerer. Finally, PM01 is unique out of all the modelled scenarios. Two small zones of relative inaccessibility (at 3 – 6 km and 18 – 19 km) bracket two larger areas from which the monument is easily accessed (7 – 13 km and 15 – 17 km). As can be seen from the simulated data in all five modelled scenarios, the MECs are not statistical outliers; points generated at random in their study areas can be seen to be both significantly more and less accessible. Most of the curves adhere to the mean at different points, showing that even when the MECs do not stand out in relation to their environments, they do so at different spatial scales. Finally, it should be pointed out that the MEC curves almost never break the 95% confidence interval, on either side. Two exceptions are SC-AG-12 at approximately 11 km, and Urubici 21 at approximately 15 km, which are significantly more accessible than the norm. On the whole, it can be suggested that MECs tend to lean towards ease of access rather than restricted access, although the way in which access is structured varies a lot between cases. How do these trends map on to geographical space?

7.3.3 Mapping (in)accessibility

The nodes located in the (in)accessible distance thresholds identified from the graphs were extracted from the data, together with the mobility basins they index. These areas correspond to the positions on the graphs with either a high or low degree of accessibility. The results, shown in Figure 7.15 and Figure 7.16, provide an approximation of how movement is structured in the study areas, as viewed through the accessibility signature graphs. As noted previously, large sections of the landscapes have no significantly above- or below-average accessibility, which is also reflected in the visualized results. These maps are "good to think with" and display several noteworthy trends that are not apparent from the graphs alone.

In the case of PM01, the alternating bands of accessible and non-accessible mobility basins creates nested hierarchies of movement, where affordances open up and close off in turn as the monument is approached. Changing levels of accessibility have implications for understanding these landscapes as relational social fields. Sizeable, architecturally complex MECs that were used recurrently over centuries (e.g. De Masi 2005; Iriarte et al. 2008) have been interpreted as regional centres of ritual performance integrating large amounts of people, in which each participating group had a role to play along gender-, social- and age-specific lines (De Souza and Copé 2010; Iriarte et al. 2013). Conversely, Figure 7.15 indicates that it was difficult to access PM01 from substantial portions of the PM01 landscape, making this interpretation incongruous with the model. A possible tentative explanation for the observed pattern is that the first band of inaccessibility could reflect a "zone of exclusion" around the MEC complex. In this scenario the non-significant neighbourhood in its immediate vicinity would be, in effect, an approximation of the extent

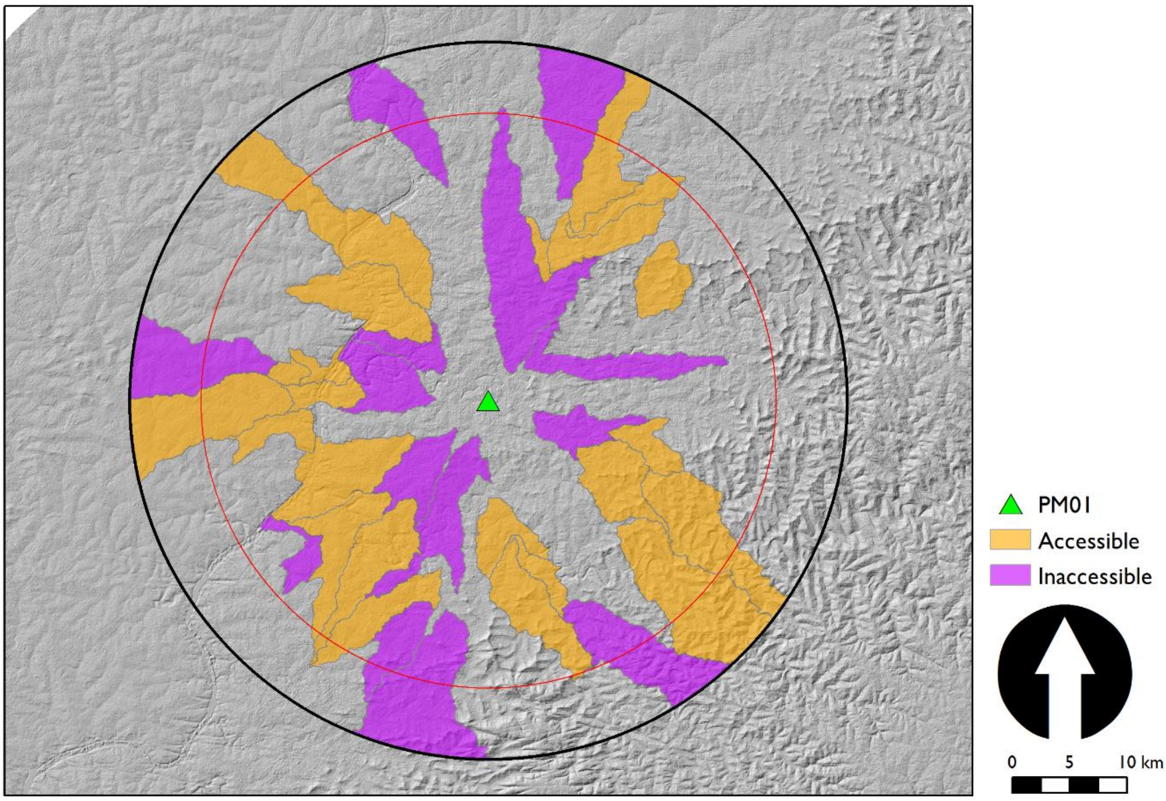


Figure 7.15: Mobility basins in the PM01 study area corresponding to distance thresholds of high accessibility (orange) and restricted accessibility (purple).

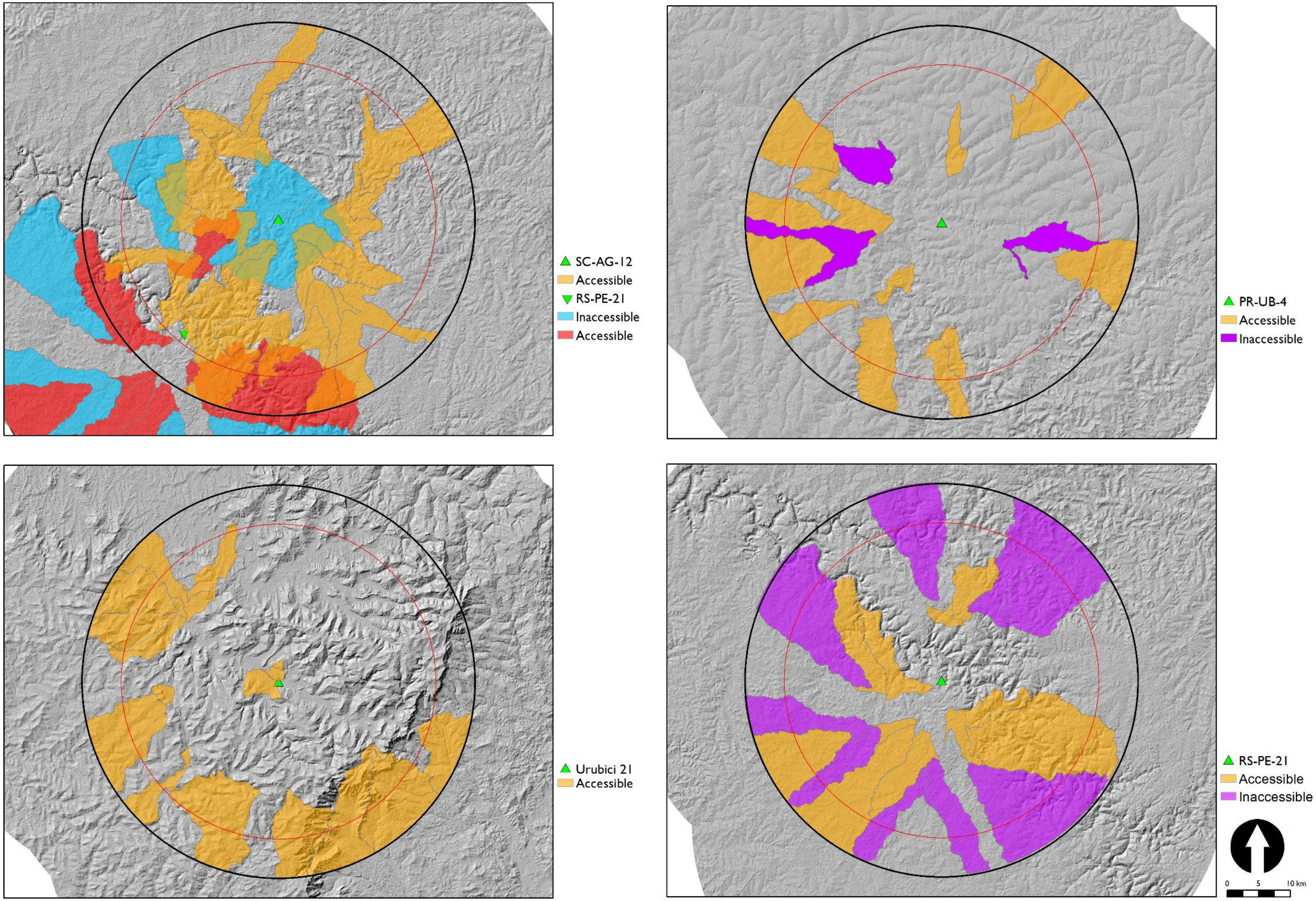


Figure 7.16: Accessible and inaccessible mobility basins for (clockwise from top left), SC-AG-12, PR-UB-4, RS-PE-21 and Urubici 21. Note overlap of study areas of SC-AG-12 and RS-PE-21 (symbolized in red and blue in top-left). Scale is the same between all cases.

of its actual territorial control and local patterns of interaction. Notably, on an East-West axis this long and narrow parcel of land corresponds to the valley of the Arroyo Piray Mini, while the inaccessible areas fall largely within the catchments of other rivers. In light of the tendency of the accessibility graph to be quite close to the average of the study region, it is difficult to assert that the PM01 MEC strongly embodies a particular territorial strategy. This problem is even more exaggerated in the case of PR-UB-4, which seldom departs from the average for its study area. This is also reflected in the small and relatively discontinuous basins which are deemed accessible or inaccessible.

The very small areas of accessibility associated with Urubici 21 at close range ($<=$ 1 km) is interesting given the physiographic characteristics of the study region, which is dominated by a broad, flat floodplain contained by a steep-sided valley. On an intuitive level, it could be expected that the entire floodplain would be accessible relative to the more removed inter-valley ridges and mountaintops, as well as the lowlands beyond the escarpment of the Serra Geral to the east. Instead, according to the model, only a small neighbourhood of approximately 26 km^2 affords ease of access at a close distance. Survey in the upper Canoas has documented a dense pattern pre-Columbian inhabitation in the area (Rohr 1971; Corteletti 2012). If multiple mutually-exclusive social groups coexisted within the study area, the observed pattern could relate to a local pattern of spatial aggregation of MECs with settlements, possibly representing kin groups using small monuments for ancestor veneration (see De Souza and Copé 2010; Iriarte et al. 2013). The patterns seen in the RS-PE-21/SC-AG-12 examples, conversely, suggested that at greater distances MECs were subject to spatial inhibition as opposed to aggregation, possibly as a result of contesting the outer edges of their respective spheres of interaction.

It is worth noting the group of mobility basins in the south-east portion of the Urubici 21 study area. These notionally accessible areas include the escarpment of the Serra Geral and its foothills, some 500 m below the level of the plateau where the MEC is located. The angle of slope of the cliffs separating the highlands and lowlands is often more than 40° and can be up to 70°, and hence extremely difficult to actually traverse. The lowland areas in question are categorically not more accessible to travellers than the upper Canoas floodplain, in spite of what the model results display. This illustrates the need to be critical of the model inputs and their effects on the output, which in this case do not match reality. Specifically, the comparatively low cost of traversal allocated by the Bell and Lock (2000) function to steep slopes may have caused this artefact in the results. Using alternative cost functions to generate the friction surfaces in future models (e.g. Minetti et al. 2002; Llobera and Sluckin 2007) can provide a means to test which performs the best for modelling relative accessibility. As discussed in section 7.2, the simplest approach was taken in constructing the model (Epstein 2008). Some unintended effects emerged in the results, but this cannot be taken as a collective indictment of the results. Instead, a more fruitful option may be to compare different mobility basin hierarchies and their accessibility signatures directly.

To this end, the mobility basins of SC-AG-12 were plotted with those of RS-PE-21 overlaid in different colours, as these two MECs are located within 25 km of each other and share terrain used in the modelling process. Although the earliest date available for RS-PE-21 post-dates that of SC-AG-12 by a century or more (Iriarte et al. 2013, 82; see Table 7.1), the monumental landscapes were likely contemporaneous entities and can be discussed together for present purposes (Figure 7.16). The interplay of basins from these two study areas gives a different layer of insight into how territoriality may have been expressed through the use of MECs. Firstly, the bluffs above the Pelotas River have above-average accessibility for both mobility networks, indicating the degree to which the territories of these monuments were shared or directly contested. As SC-AG-12 is at the centre of a large area of inaccessibility (exclusion?) belonging to the other monument, the question of whether this represents disputation of terrain is interesting. These results suggest, collectively, that *spatial* interactions between MECs mirror some aspect of their past *social* interactions.

To summarize, modelling relative accessibility with ACS landscapes and focal mobility networks appears to indicate that there is *inherent* patterning in the spatial behaviour of mound and enclosure complexes. From the perspective established by the geospatial model, this is presumed to relate to strategies that seek to control or structure access in varying ways. Patterns of differential access to the social capital of MECs, in turn, clearly support the interpretation of preceding research that these monuments played a pivotal role in the emergence of socio-political hierarchies among southern proto-Jê groups. While it is a relatively trivial finding that different environments afford different possibilities for movement, the analysis is advantageous in that it occurred on an amplified spatial scale relative to previous studies. Moreover, the model was supported by a robust method that enabled the unique accessibility signatures of each monument to be contextualized in the possibilities for movement afforded by the broader environment. This permitted interpretations to be made on a regional level and to be related directly to the geographic extent of areas incorporated by a sample of MECs.

Furthermore, due to the scale of the analysis, it was possible to raise the question of how much between-monument interaction took place in the past through the dynamics of relative accessibility. This is intriguing from the perspective of emergent territoriality, and merits further consideration of the spatial patterning *induced* by interaction between the monuments themselves. As noted under the case study selection criteria, the majority of the MECs are not isolated cases; they exist in a more broadly-studied landscape containing other MECs and inhabitation sites. Although the main subject of this enquiry (PM01) was known to co-exist with seven other monuments, its wider setting is unfortunately lacking in well-documented settlement sites except in the broadest terms (see Chapters 5 and 6; Iriarte et al. 2010b; Gessert et al. 2011). By way of contrast, Pinhal da Serra (the location of RS-PE-21) has at time of writing one of the best-studied southern proto-Jê occupations in the highlands, with a representative sample of both pit house clusters and a series of mound and enclosure complexes within a well-defined locality (Iriarte et al. 2013, 80).

As a final exercise, this potential interplay between first- and second-order spatial dependence on the locations of MECs will be explored through analyses drawn from point process modelling. These further extend the analytical approach adopted in Chapter 6 with covariate datasets and the use of an information criterion for model selection.

7.4 Point process modelling of mound and enclosure complexes

7.4.1 Model construction and covariate data

Figure 7.17 shows the distribution of MECs used in this exercise, along with the locations of pit house clusters and the general topography of the Pinhal da Serra region (see also Figure 7.12). It is immediately apparent from this map alone that these sites exhibit some form of spatial dependence, most likely on the sub-1000 m scale, but the significance of this deviance and the potential effects of external covariates cannot be assessed without direct statistical investigation. Aspects of point pattern analysis can be adapted to suit the question of how much spatial dependence exists between MECs in the Pinhal da Serra groups, and which factors played a role in the final, archaeologically extant pattern of the monuments. The method outlined here closely follows that which Eve and Crema (2014)

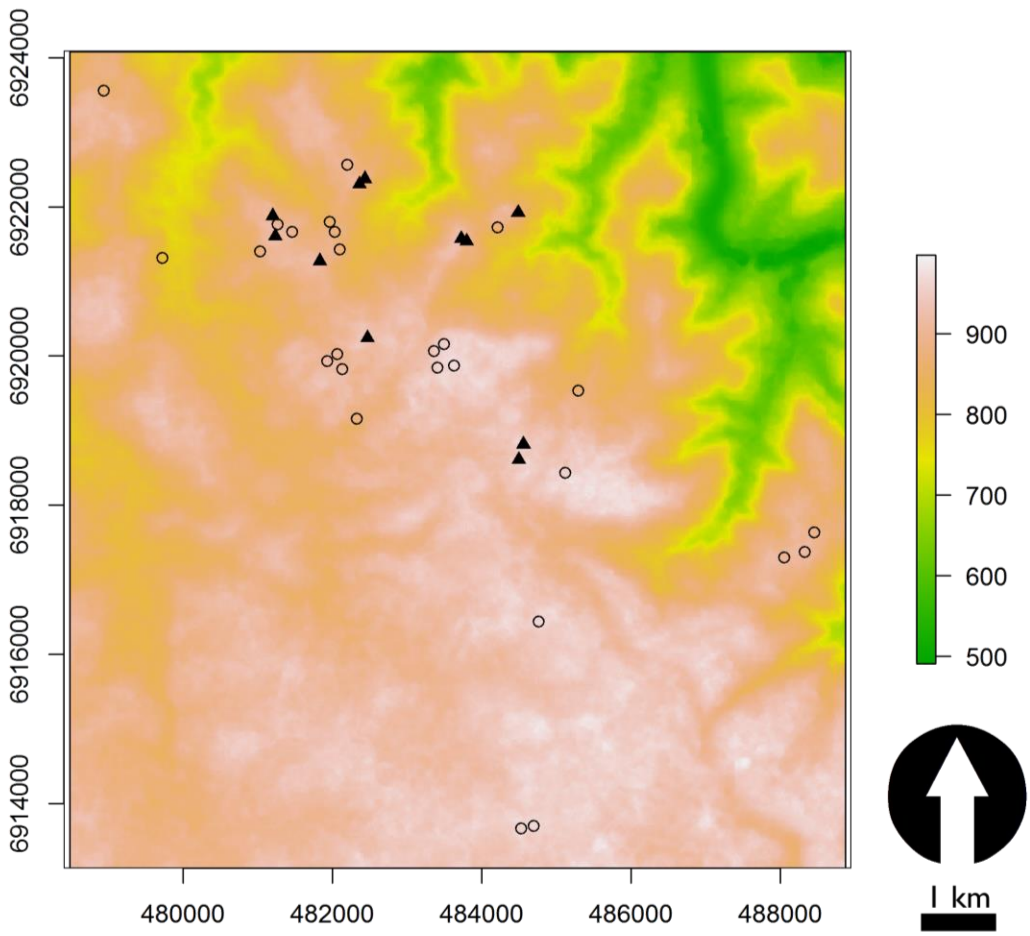


Figure 7.17: The Pinhal da Serra sub-study area with elevation model, showing distribution of MECs (black triangles) and pit house clusters (hollow circles). After: Saldanha 2005; Iriarte et al. 2013

used in their point pattern analysis of site locations in Cornwall.

In order to fit the Pinhal da Serra MEC locations to an inhomogenous point process, two artificial models using different sets of covariate data were constructed (Figure 7.18). The

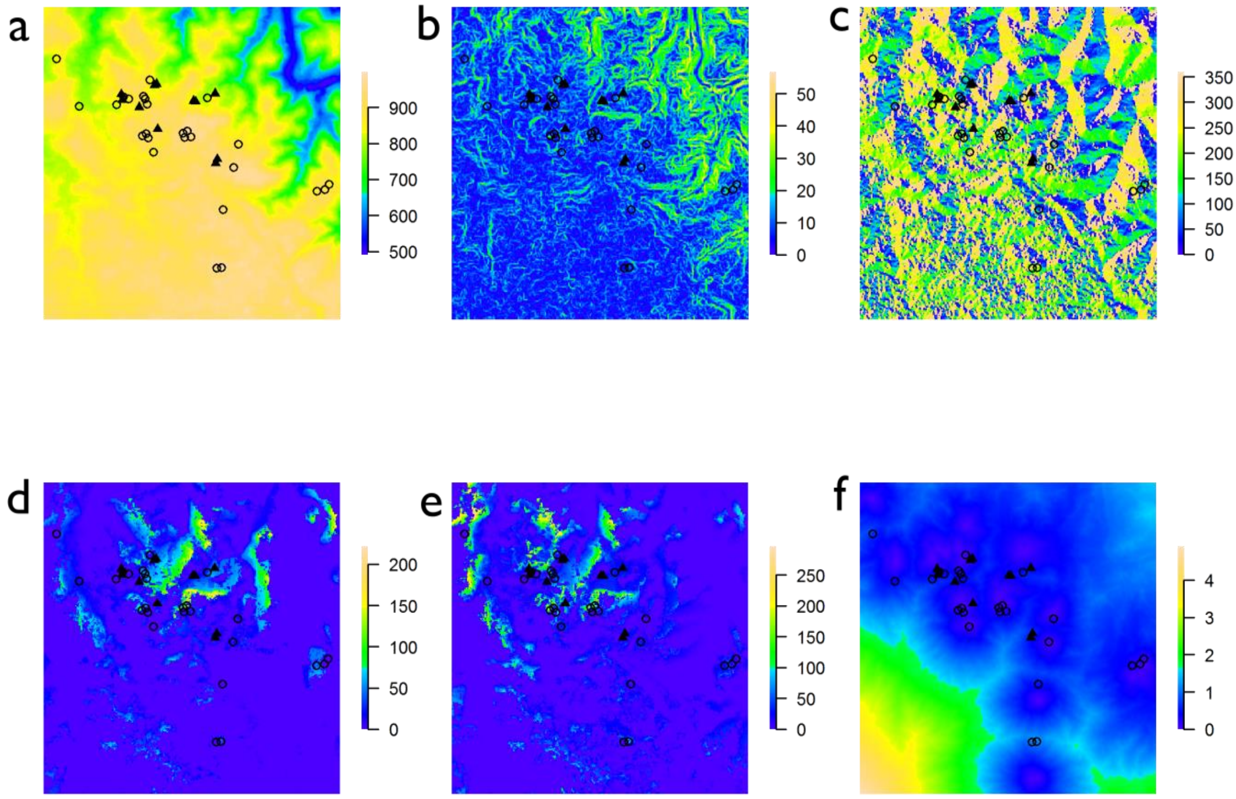


Figure 7.18: Model covariates: *a)* Elevation, *b)* Slope (degrees), *c)* Aspect, *d)* Visibility of MECs, *e)* Visibility of pit house clusters, *f)* travel time to MECs from pit houses.

first contains the elevation of the terrain and two standard derivatives: the slope and the aspect. This model can be considered to be a very basic, uncritical reflection of the factors which affected site location that are typically used in a "traditional" site location analysis framework (Parsons 1972). The second model draws upon specific interpretations concerning the role of the MECs among the groups which constructed and maintained them. Following Saldanha (2005) and Copé (2006), the promotion of inter-MEC visibility may have played a central role in their placement, implicitly invoking the concept of "visual dominance" over elements of the landscape and other monuments. Iriarte et al. (2013, 93) modify this interpretation, noting that smaller MECs were unlikely to be highly visible from far away due to their slight profiles, but ultimately that the visibility of rites, potentially featuring fires at night (Veiga 2000), was important to staging the veneration of the ancestor interred in the MEC. Furthermore, pit house clusters are interpreted as being associated and in alignment with specific sets of MECs (Iriarte et al. 2013), but that views of pit houses from MECs were more restricted (Saldanha 2005). Nonetheless, it must be taken into account that the exact patterns of vegetation are not known and may have affected views considerably.

The inverse scenario, in which MECs and the aforementioned rites are visible from settlement sites, has received less attention. These two factors were formalized through the calculation of affordance viewsheds (Gillings 2009) towards MECs from: *a)* other MECs and *b)* pit house locations. Affordance viewsheds are representations of the proportion of an area of interest (in this case, areas with MECs or pit houses) which is visible from the rest of the landscape. Arbitrary "areas of interest" to contain the MECs and pit houses were established with a radius of 100 m, and a grid of vector points generated from the underlying DEM, producing 368 points from the MEC locations and 947 from the more numerous pit houses. These were used as the input in 1315 iterations of a standard viewshed analysis, which were overlaid to produce affordance viewsheds for each set of structures. Since the objective was to quantify viewing *towards* these features rather than away from, a vertical offset of 1.70 m in each cell in the elevation model was used to approximate the height offset of a hypothetical viewer (Gillings 2009, 345). The final covariate considered for inclusion was the distance of MECs from pit house clusters. Rather than using Euclidean distance or a cost function such as the one in the geospatial model above, Tobler's hiking function (Tobler 1993) was employed to calculate the travel time (in hours) from pit house clusters to MECs (see Appendix A), as energy expenditure is unlikely to have been a direct concern over the short distances used in this case study. Spatial proximity (and hence travel time) may reflect subtle distinctions in access to specific MECs within Pinhal da Serra. These three factors were used as covariates in the second model. Finally, two additional models were considered: one employing all six covariates and one employing none. The last is effectively a null model which treats the process underlying MEC distribution as a homogenous Poisson process. This is an unlikely scenario, but serves as a benchmark for the performance of models I to III.

7.4.2 Results

Model selection and goodness-of-fit

The selection process makes use of the Bayesian Information Criterion (BIC) to identify which combination of covariates is the best fit for the observed pattern of MECs (Table 7.3). The value of the BIC itself is less important than the differences in this value (denoted as Δ) between the models, and hence their weights (Venables and Ripley 2002; Eve and Crema 2014, 273). Model III (all covariates) appears to be the clear "best fit" for the MEC dataset ($w = 0.9449$) to a very large extent; the next in line, Model II, has a fraction of its weight. Furthermore, the null model is the worst fit by two orders of magnitude. Its goodness-of-fit can be investigated directly through a version of Ripley's K function which uses the model residuals as a diagnostic tool (Baddeley and Turner 2005).

Table 7.3: Model criteria and selection, with Bayesian Information Criterion, change in BIC, degrees of freedom and model weight. The last of these is used to determine the "true" model for the given covariates.

Model	Covariate data	BIC	Δ BIC	df	*w*
I	Elevation, Slope, Aspect	370.53	27.176	4	1.185907e-6
II	Visibility (MECs), Visibility (Settlements), Travel time	349.04	5.686	4	0.05032
III	All of the above	343.36	0	7	0.9449
Null	None	379.77	36.417	1	1.167767e-8

Figure 7.19 displays the residual K function for Model III, as fitted to the MEC point pattern. This model accounts for most of the observed spatial variation in MEC locations in the Pinhal da Serra sub-study area, but clustering exists at distances of approximately 200, 300, 1000, 2000, and 2200 meters which are not explained by the covariates alone. This could be attributed to the specification of the model, meaning covariates which lie outside the realm of investigation, or due to the MECs possessing between-point interactions that are not accounted for by a Poisson process (i.e. the points are spatially independent) (Eve and Crema 2014, 275). Furthermore, although the selection of Model II might be sufficient overall, the process of selection does not consider the interplay between different combinations of covariates besides those that were established for sake

of argument above. To this end, and to seek a better goodness-of-fit, a stepwise model selection process was attempted.

Figure 7.19: Residual *K* function of Model III (all covariates in Table 7.3). Grey envelope is simulated from 99 iterations of the fitted point pattern. The interpretation of this form of analysis follows that in Chapter 6.

Stepwise model selection

Model III (all six covariates) was subjected to a stepwise selection using the Akaike Information Criterion (AIC). Using this procedure on a set of models fitted by maximum likelihood causes the one with the lowest AIC score to be interpreted as a better fit (see Appendix A). Additionally, models with greater numbers of parameters are penalized by the AIC, meaning that in general a simpler model will be considered a better fit than a

Table 7.4: Model IV covariates, with standard error, confidence intervals, and significance level. High significance of intercept can be explained as the result of pre-existing clustering in the data.

Covariate	Estimate	S.E.	95% CI Low	95% CI High	Z-test
(Intercept)	-35.293	8.092	-51.154	-19.432	***
Visibility (pit houses)	0.01	0.004	0.003	0.018	**
Elevation	0.022	0.008	0.005	0.038	**
Slope	0.135	0.046	0.044	0.225	**
Travel time	-5.835	1.813	-9.39	-2.28	**

Figure 7.20: Residual K function for Model IV (Visibility of MECs, Elevation, Slope and Travel time from pit house clusters). Spatial variation in MEC location is well-accounted for with this model.

complex one in order to avoid overfitting. Despite starting with the full set of covariates that gave Model III the highest weight in the preceding analysis, the use of an information criterion eliminated two out of the six covariates. This revised hybrid, termed Model IV, instead only makes use of the four covariates of visibility of MECs, the elevation of the terrain, its slope, and the travel time from pit houses to fit the point pattern. Table 7.4 shows the fitted trend coefficients of this model.

The revised version, Model IV, displays a higher goodness-of-fit for the spatial distribution of MECs than its predecessor (Figure 7.20), accounting for all the observed variation in site location. It is interesting to note that an even combination of “environmental” and “social” factors was selected. While this does not offer conclusive proof of any kind, it is an illustration that divergent (albeit artificial) views on the factors that are hypothesized to affect site location are not necessarily mutually exclusive (see Eve and Crema 2014). Intuitively, sharp slopes are unlikely to be favourable for the construction of monumental earthen architecture. Furthermore, higher elevations probably promoted many of the effects sought after by the builders of these monuments, such as proximity to peak features, the orientation of sites along ridges, and intervisibility (see Iriarte et al. 2013, 81-83). Although the potentially confounding effects of colinearity between elevation and visibility were not directly investigated, it is worth bearing in mind for future investigations of MECs using formalized statistical approaches. Finally, the inclusion of the factor of travel time indicates that the spatial association of pit house villages with MECs reflect some aspect of the smaller funerary structures serving the needs of local communities (De Souza and Copé 2010; Iriarte et al. 2013, 83).

7.5 Concluding summary

The status of MECs as significant structures among southern proto-Jê groups was not in question at the outset of this case study, as it built upon a solid foundation of preceding investigations by archaeologists working in Brazil and Argentina (see section 7.1.2 and Chapter 2). The brief exercise in point pattern analysis, together with the geospatial model of accessibility, illustrates how complementary analyses taking in different spatial scales can engender new questions and explanations for the empirical material record. In this vein, exploring whether differential access could explain site location as the outcome of specific land use strategies was later able to suggest that “non-utilitarian mobility”

(Whallon 2006) was structured both in relation to the environment and to other important cultural locations. MECs, as places which mediated ancestral contact and reinforced a social order, were embedded in a wider landscape sustaining a network of socio-political relations. In societies potentially transitioning towards hierarchical organization, the facilitation or constriction of access likely had crucial effects on the evolution of incipient power structures and the ability to maintain social bonds across time and landscapes. Crucially, however, the sub-study focusing on a cluster of monuments in Pinhal da Serra, Rio Grande do Sul serves to underline that local interactions and small-scale patterning must be accounted for in the study of socio-political complexity.

On a large scale, the inferred patterns of directed movement suggest to great extent that the contexts of MECs also require consideration on a regional spatial scale. To this end, the geospatial model provided a more robust means of identifying territorial behaviour as the result of differential access to socio-politically important cultural locations. Quantifying the geographical space indexed by individual monuments allowed several outstanding modalities of access to MECs to be examined. By creating a "background signature" from simulated random points, the narrative which could be drawn from a relatively straightforward operation of GIS routines was also substantially amplified and made more robust. In particular, larger mounds and enclosures (such as PM01 and SC-AG-12) seem more likely than ever to have functioned as macro-regional centres of integration. At the level of the "local cluster", smaller MECs such as RS-PE-21 can nonetheless be also implicated in large-scale socio-political trends through the inaccessibility of distant (competitive?) large MECs (in the cited case, SC-AG-12). Instead of a single spatial narrative imposed by normative geographical analysis techniques (e.g. Thiessen polygons, see Saldanha 2005), the approach placed a greater emphasis on exploring a series of plausible explanations for the observed patterns (Bevan et al. 2013).

Upon reflection therefore, the most effective use of the geospatial model was the comparative look it provided for two very different monuments in their landscape contexts (RS-PE-21 and SC-AG-12). The results displayed properties that were not anticipated when the investigation began, leading to the construction of a second exercise at a smaller, more detailed spatial scale. A key strength of computational modelling, therefore, is the relative transparency and transferability of the developed approaches (Barton et al. 2010). This means it is worth emphasizing that the interpretations put forward here are one of many narratives that could be made possible by adopting these tools. The above case studies drew upon a specific theoretical perspective to both establish the impetus for modelling and to enrich the interpretation of its results in a reflexive, mutually-reinforcing manner. Other investigators, with different datasets, questions, and outlooks can adapt any of the methods to suit their goals and generate alternative, compelling interpretations on the social use of space among the pre-Columbian southern proto-Jê. The use of an information criterion in section 7.4 to gauge the effectiveness of different models along with tests of goodness-of-fit employing Monte Carlo simulation is a step towards introducing rigor into this process of archaeological interpretation in this setting. Developing an overview of the *potential* strategies enacted by different groups in the past through modelling may in the future help broader comparisons to be made on the role of the built environment in structuring socio-political change in the pre-Columbian period of South America.

8. Concluding discussion: patterns and palimpsests in the Alto Paraná

8.1 General overview

The principal goal of this research was to understand the pre-Columbian occupation and settlement of the upper Paraná watershed in Misiones province. This was achieved by characterizing the spatial distribution of archaeological material in the study area, which helped to narrow several long-standing gaps in the extent our knowledge through the application of novel methods. Chapter 6 integrated non-site theory and lithic analysis with spatial statistical approaches in order to examine depositional behaviour as a proxy for long-term patterning in land use. This factor can be thought of as the establishment of "persistent places" (Schlanger 1992) as the result of particular and distinctive cultural regimes of landscape occupation. The analyses discussed in the chapter proceeded hierarchically from first-order and second-order global measures of autocorrelation, using both univariate and bivariate spatial statistics, to local versions of the same. This provided a set of complementary perspectives on the Piray Mini Exploration (PME) project assemblages at multiple spatial scales, as well as on archaeologically-significant subsets of the data. Crucially, however, regional patterns of land use were more problematic to obtain from the survey data.

To this end, Chapter 7 broadened the spatial scope of investigation by narrowing the temporal focus to a southern proto-Jê mound and enclosure complex (MECs) located near Eldorado city. The geospatial model in this chapter was initially constructed to provide insight into a particular facet of land use, as mediated by differentiated accessibility to culturally important monumental settings on a regional level. The modelling exercise allowed this dimension of the pre-Columbian occupation of the province to be addressed more fully than in Chapter 6. While this represented a departure from non-site approaches, in doing so it engendered new questions on how to approach these later pre-Columbian features of the eastern La Plata basin. In sum, the differences between "sited" and "non-site" theory are also a question of scale, and are not mutually exclusive. In lieu of additional data in Misiones province itself, issues with the method were further explored by casting a wider net over published data from Rio Grande do Sul state, Brazil with point process modelling. This permitted additional testing of hypotheses related to the social and environment factors responsible for producing the empirical pattern of sites.

This chapter draws together the results of the analytical approaches that were applied, with reference to the research questions set out at the beginning of this research. It will do so by addressing their impact on knowledge in the Alto Paraná and beyond, in light of the novel approaches to surface collected data in this context. Non-site archaeology, as a conceptual and analytical framework, will be evaluated in the context of the abilities it affords investigators to examine spatial point patterns associated with lithic data at multiple scales.

8.2 Pre-Columbian land use in the Alto Paraná

8.2.1 Revisiting deposition and land use

The occupation of an environment is the direct result of human activity taking place in relation to its social and physical characteristics. Although forms of activity may be widely spread in space and time, commonalities and patterns indicate where shared modes of engagement existed. The material record can in this manner be seen as a consequence of the habitual repetition and (re-) inscription of practices in specific spatial contexts (Tainter 1998; Wells et al. 2004; Holdaway and Wandsnider 2006), creating affinities for particular places which are appropriated into a landscape-level framework of relationships (Binford 1980; Schlanger 1992; Wandsnider 1998a). The material record on the surface represents a time-averaged view of this cumulative process, like an extremely long-exposure photograph of all the individual events that contributed to its formation (Ebert 1992, 251). Taking into account the results presented in Chapter 6, the remainder of this section aims to evaluate the questions that were put forward in Chapters 1 and identify where the expansion of knowledge has taken place. Initially, this concerns the questions that were introduced under the first aim of this research: to provide new perspectives on the regional pre-Columbian history of Misiones province by engaging with the patterning of material remains on a landscape level (section 1.3). More specifically, this addresses the effectiveness of surface data for studying study land use, the organization of stone technology, and the goal to bridge the gap between the modern distribution of archaeological material and past settlement.

Chapter 2 presented and discussed the prevalent models of pre-Columbian settlement patterns in both historical and current perspective. With regard to pre-ceramic cultures in the macro-study region, the interpretative process tends to focus chiefly on adaptational factors linked to the exploitation of particular ecological niches within a given landscape. For later cultures (i.e. the southern proto-Jê and Tupiguarani), this is also done with reference to the domestic built environments of these groups. In such cases, functional interpretations of surface sites (*sitios céu aberto*) are used to fill in the gaps in knowledge about tasks that are assumed to take place in the wider landscape away from the locations of settlement sites (e.g. Saldanha 2005; De Masi 2005). The lack of rigorous statistical treatments of this element in studies of pre-Columbian "settlement patterns" in the macro-region formed part of the initial impetus for this research. Drawing upon the theoretical principles established in the second chapter, the design and execution of the fieldwork (Chapters 3 and 4), and the analytical approaches to the data (Chapters 5 and 6), some clear interpretations can now be made regarding the significance of the surface record for exploring the spatial structure of pre-Columbian cultural landscapes.

The authors of one previous study based broadly in non-site methods chose to describe the empirical basis of their investigations as "discard behaviour" (Holdaway et al. 2004). That is, the locations of objects encountered in the field are a function of their last episode of use, through which broader spheres of human cultural activity can be gleaned (see Holdaway and Wandsnider 2006). The interpretation of surface assemblages in this research modifies this approach slightly, due to the presumption of the term that artefacts necessarily had a functional use. The integration of the Chapter 5 lithic analysis with spatial statistics in Chapter 6 demonstrated clearly that functional use did not underpin several of the patterns witnessed in the field site assemblages. Discard as such would be an over-interpretation of the available data. For example, in an overwhelming majority of cases among the flake assemblages, their "function" appears to have been little more than being one removal of many in the sequence of actions involved in the reduction of a core and nothing more. Furthermore, the context of an artefact's discard might be very different to its context of use; the two are not always linked (Bailey 2007, 208). Although the term could adequately describe many processes seen in the material record of the Alto Paraná, such as the abandonment of exhausted cores or the rejection of bifacial pre-forms due to an inability to impose an appropriate morphology (see Nami 2006; Riris and Romanowska 2014), the lithic analysis suggests that these examples are in the minority overall. To reflect the pervasive sense of ambiguity on artefact use in the PME project survey assemblages, the less loaded term “deposition” is used for present purposes to describe the process of artefacts entering the material record through.

The results make it clear that the surface record in Misiones, as in other parts of the world, represents a complex spectrum of overlaid, mixed, and obscured material remains. It provides archaeologists with partial representations and fragments of many, potentially very different, cultural systems. Although individual elements were deposited over unknown time frames, the record as a whole represents long-term accumulation and inhabitation of the environment. This furnishes this research with, to date, the most extensive and varied archaeological dataset for the province of Misiones. Placing interpretative emphasis on *deposition* serves to draw attention to a cultural activity that, arguably, constitutes the bulk of the archaeological record of the eastern La Plata basin. These findings therefore have clear implications for how to conceptualize the material record in both the study area and the wider macro-study region. To this end, it must be stated that the research as a whole has not documented and analyzed any one system of “land use” or group of sites pertaining to a particular cultural-historical construct. Rather, the survey and analytical strategies succeeded in characterizing the high degree of variability in the cultural activities and phenomena which led to the creation of the archaeological record across the landscape.

To a large extent, the relative intensity of deposition in the Alto Paraná can be described as low (see Chapter 4). Yet it is clearly punctuated with occasional loci that reflect comparatively intense episodes of activity, occupations of longer duration, or more likely, a combination of both factors. While the relative densities of artefacts and frequencies of types can provide a general sense of the range of activities artefacts were involved with prior to deposition in any given location, the detection and exploration of scalar patterning is more relevant to the pursuit of the research questions. Two models of data structure for surface deposits that were discussed in Chapter 2 serve to frame this discussion. Before proceeding further, it is worth having a brief recap of these "occupational" and "distributional" frameworks for non-site analyses.

The former contends that, given appropriate techniques, discrete episodes of activity can be sifted from unstratified archaeological remains encountered on the modern land surface (e.g. Carr 1984; Sullivan 1995). One approach would be to examine the relative abundance of different artefact categories in discrete sampling units and attributing variation to specific functional use-episodes (Sullivan 1995, 50). Over large areas, this permits access to the individual occupations that contributed surface record formation and in turn the cultural processes that underpin land use. Additionally, correlations can be established with locations that do yield stratified deposits of material culture (Conolly and Sullivan 1998). Conversely, the distributional model (e.g. Ebert 1992; Stern 1993; Holdaway et al. 2004; Diez-Martín et al. 2008) considers surface distributions the product of discontinuous and punctuated occupations that are repeatedly superimposed over the long term. As the timescales involved in individual occupations are far shorter than the sum of the time of formation of the material record, it is irreducible to individual episodic datasets (Shiner 2004, 48). Even in special cases where dateable surface features are present and appropriate geochronological controls can be established (e.g. Fanning and Holdaway 2001; Shiner 2004), these still represent envelopes of time beyond that of the phenomenological (or ethnographic). Land use is instead interpreted through the localized variability of surface deposits as a function of long-term occupation intensity and duration. This permits an image to of the processes which contributed to record formation to be gradually built up and linked to systemically significant behaviours.

Data collected as part of the survey strategy made it possible to characterize the surface archaeological record of Misiones as being, essentially, a composed of a ploughzone. While several different formation processes operate on this record (see Figure 4.3), ploughing introduces the most profound changes to its makeup and constituent parts. It is therefore the most poignant for this discussion. While ploughzones are qualitatively different from deflated or eroded surfaces, they fill the same interpretative niche (Zvelebil et al. 1992). Clearances are comparatively rare events; after an initial clearing, pine plantations are left to grow for over a decade. This means that unlike arid zone contexts with highly deflated and potentially geomorphologically active surfaces, the integrity of an archaeological record produced by a mix of both semi-sedentary and nomadic groups could in theory retain a high degree of spatial resolution and, perhaps, separation (Odell and Cowan 1987; Cherry et al. 1988; Navazo and Díez 2008). In light of this, the occupational-distributional models initially formed a reasonable theoretical point of departure for characterizing spatial relationships and behaviours contained in the surface record. In large part, their juxtaposition served as a useful framing device for asking relevant questions on the variability in the behaviours which produced the pre-Columbian material record of the study area. To this end, spatial statistics provided a rigorous, quantitative means to test hypotheses concerning the archaeological significance of patterning in the point data (Cressie 1993; Diggle 2003). Applications of these methods to the research problems in a non-site framework produced novel results on deposition patterns of a range of different artefact categories with systemic significance. In synergy with the spatial analysis, this research argued that understanding the organization of stone technology (Odell 2001; Andrefsky 2009; Carr and Bradbury 2011) provides a direct link to land use in the Alto Paraná. This strategy emphasized accounting for global spatial trends in homogeneous point pattern data, before homing in on more targeted analyses of technologically significant subsets of the data.

The family of statistical methods deployed, which were based primarily on Ripley's K function, thoroughly demonstrated the challenge of detecting a definitive spatial scale at which the empirical point patterns "resolve" into entities correlating to specific activities that can be isolated from the remainder of the record as per the occupational model. The three systems of technological organization (core and flake, bifacial tool, and unifacial tool) that were identified through the analysis of stone artefacts were found to interact at a variety of spatial scales, mostly forming clusters at ranges of *up to* 40 m, but usually more significantly below this range. Activities related to specific technological strategies, for example debitage resulting from the thinning of bifacial artefacts, were found to have distinctive spatial behaviours in relation to other types of artefacts. The depositional patterning of utilized flakes and unifacial tools contrasted with that of bifacial tools, as these two groups of tools were randomly distributed in a majority of cases. Finally, cores (the sources of flakes and unifacial tools) also had distinctive patterns of clustering with regard to bifacial tools. Applying local statistics of autocorrelation such as the local bivariate K statistic, however, enabled the analysis to highlight how the significance of the relationships themselves varied spatially. Even apparently homogenous and unambiguous clusters of material were found to be problematic when dissected in sufficient detail and specific technological hypotheses. Bearing in mind the sampling issues involved in working with biased surface data, this research provides a strong case for the distributional framework to be the stronger of the two in the Alto Paraná. Long-term diffuse land use with occasional episodes of more intensive, spatially-circumscribed deposition is clearly best conceptualized as a spatial palimpsest. In exploratory work such as that presented and discussed here, this can be considered a question of the scale of analysis.

It must also be emphasized that the data permitting these conclusions to be drawn was drawn from an extant archaeological landscape at a single moment in time over a relatively restricted spatial coverage. Chapter 4 provided an in-depth evaluation of this facet of the spatial data, and identified the fact that some of the patterns detected could be partially due to the increased visibility of archaeology in certain areas, while in other cases the lack of remains might be due to obfuscating formation processes. In particular, the descent of small artefacts through the ploughzone could greatly increase the relative representation of larger ones such as cores and tools on the surface. The difficulty in quantifying the true extent to which plantation activity (including ploughing, fire-setting, and planting) affects data representativity is a limitation which must be accounted for. Following from this, it would be incorrect to treat the group of five "analytical sites" as more important in archaeological and interpretative terms than the remaining majority of "low-density" sites. The former were the focus of Chapter 6 due to the statistical robustness their assemblages afforded the analysis, as opposed to conforming to any preconceived notion of sites forming discrete occupations. It is argued here that the differences between the two groups of field sites primarily come down to the scale and intensity of land use in different parts of the landscape, albeit mediated through post-depositional processes also operating at a range of scales and intensities. This issue is addressed in greater detail in the next section by means of a thought experiment on the analytical site assemblages.

8.2.2 From signal to noise, and back

It was noted early in the analysis that randomness in point patterns is not as useful a heuristic for interpreting the material record as clustering or dispersal, as a lack of structure in the data implies a lack of structure in the behaviour which produced it. Within the relatively small and bounded sampling frames that the field sites represent, there is some truth in this assumption, but it makes a crucial omission: a lack of reference to scale (see section 2.6). Still bearing in mind the record formation processes discussed in Chapter 4, it can be argued that the limited quantities of archaeological data gathered in low-density field sites might be an accurate representation of a genuine archaeological pattern of extremely sporadic episodes of deposition over areas much larger than the field sites. In other words, might the diffuse scatters of material in the thirteen low density field sites represent elements of elusive large-scale patterns of land use (e.g. management of arboreal resources, forest clearances, and travel) that rarely leave direct material evidence from artefact loss or discard, and were consequently undetected in the predominantly short- and medium-range analyses?

The point patterns in Chapter 6 were analyzed between maximum ranges of between approximately 40 to 80 m in the global statistics. These were determined automatically by the methods with reference to the size of the survey quadrat, i.e. the actual area of coverage under investigation. Although the use of sensible “default ranges” (see Baddeley and Turner 2005) is statistically acceptable and afforded the analysis robust results at a variety of scales, they do not permit strong archaeological inferences to be made at spatial scales beyond the boundaries of the field sites. Due to this, clustered elements of the field site distributions (which turned out to be the mostly short-range runs of the analyses) formed the main loci of interpretation in much of this research. This can be considered as coming close to reproducing another dichotomy that underpins many investigations of surface collected data: the goal of finding the “signal” in the “noise” (Gallant 1986; Wandsnider and Camilli 1992; Steinberg 1996).

The implications of this may be addressed with an experiment that deals with the results of the Local L statistic (section 6.2.4) reflexively. Non-clustered points (which likely includes both random and dispersed subsets) were detected in the patterns of every field site that was examined, even at the largest ranges evaluated by this function ($r = 80$). What is the archaeological significance of seemingly noisy points for understanding pre-Columbian land use? Can the alleged noise be said to possess a structure of its own? Almost certainly; it is not unreasonable to anticipate that the landscape was inhabited and saw use at a range of scales. Aumer I and Ziegler IV have the benefit of displaying such points in significant absolute quantities, possibly allowing for different types of relationships to be explored further in these datasets.

To this end, the local L analysis was repeated on each analytical site at the ranges indicated on the legends in Figure 8.1, which correspond to the maximum "sensible" ranges used by the global functions in section 6.2.2. The resulting point patterns can be considered conservative estimates of the quantity of non-clustered points in each field site,

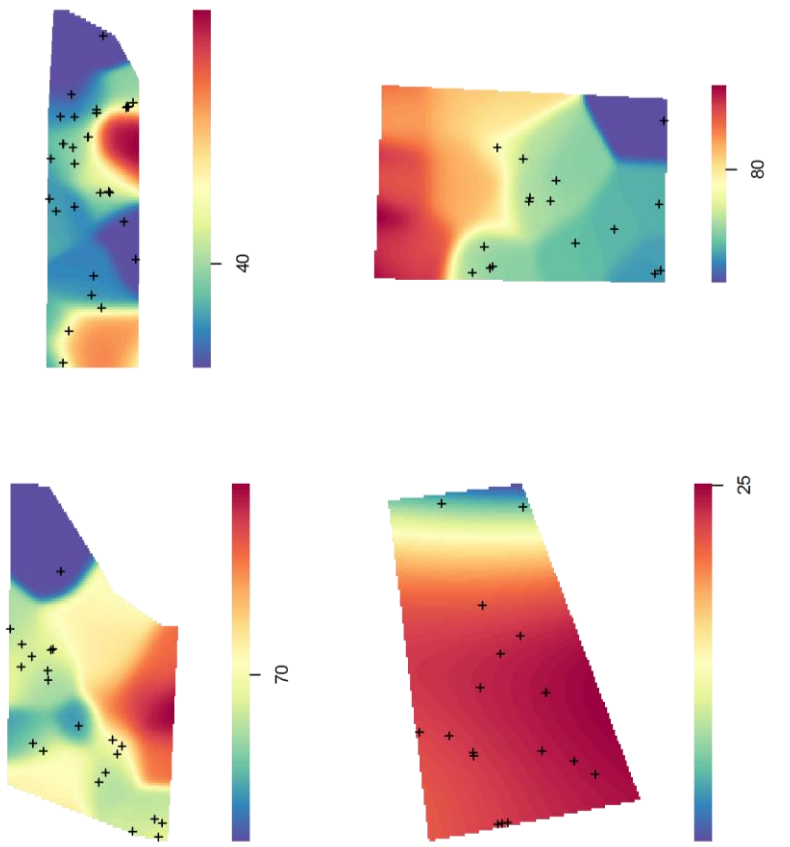


Figure 8.1: Local L at five spatial scales corresponding to the maxima investigated by the global functions. Although areas of significant aggregation are shown, these points are not shown; only non-clustered are plotted above. These points were used in a second global analysis, below.

since employing these scales will likely maximize the degree of detectable aggregation present in any given location.

Running a new global analysis with the pair-correlation function on the "thinned" distributions of archaeological points provides a different perspective on spatial structure in these locations (Figure 8.2). Restricting discussion to the two distributions with a significant quantity of data, it is immediately apparent how they differ from the results presented in Chapter 6. As would be expected, the thinned pattern is random in Aumer I at a majority of scales, although it is worth noting that relatively close-range clustering is retained to some degree. This phenomenon is likely caused by the "halo" of artefacts which surrounds the two main clusters that were identified in Chapter 4, but the patterning is significantly less profound than the witnessed in the full assemblage. Second, the thinned data of Ziegler IV actually shows the inverse patterning to that witnessed in the whole assemblage, returning the highest values of $g(r)$ at around 20 m. This is commensurate with the visual appearance of the empirical pattern in Figure 8.1. Together,

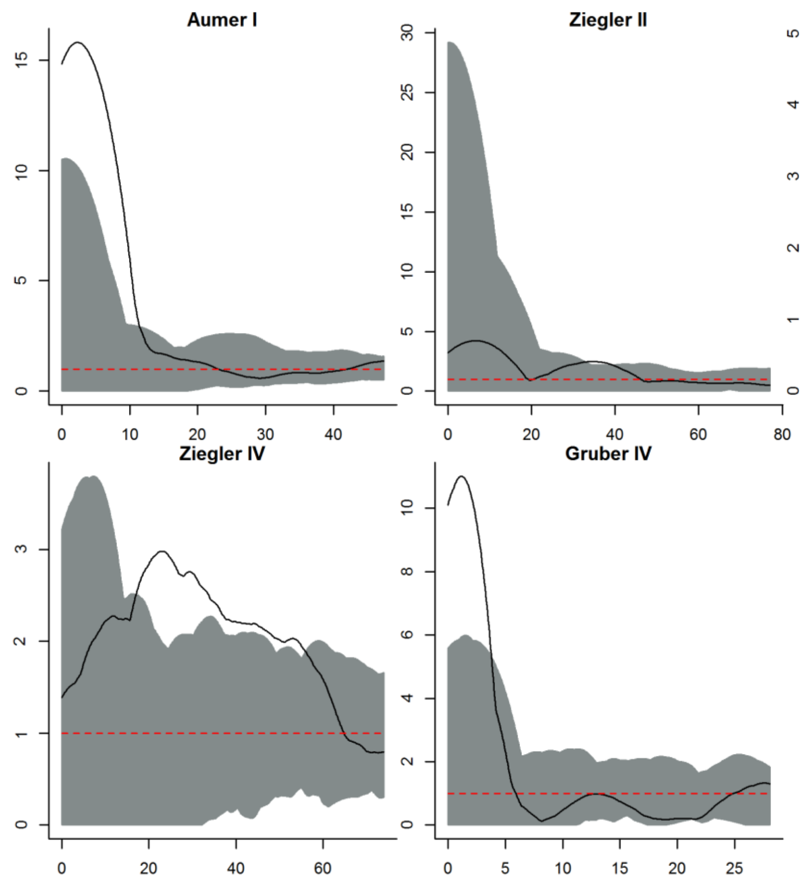


Figure 8.2: The pair-correlation function for each analytical site with the largest groups of aggregated points withheld from the analysis. Note that in all cases except Aumer I and Ziegler IV each pattern has less than the 20 point minimum required for a robust analysis. The above results are to be considered demonstrative of the problem of defining either "sites" *or* "noise" in surface collected data, as both possess spatial structure.

these vignettes attempting to analyze "noise" in spatial point patterns demonstrate the difficulty with which it can be reliably identified in the data. The problem, once again, appears to be primarily one that figures in terms of the scale of analysis. What then do these diffuse groups of artefacts represent in archaeological terms?

Table 8.1 shows a breakdown of the artefacts contained in the five thinned distributions. The first point to notice is that cores are even more overrepresented than before, and account for 37% of the thinned assemblage, compared to 21% of the total assemblage. It is most pronounced in Ziegler II, where they form 73% of the thinned assemblage. Indeed, one low density site assemblage (MPM022) consists only of four cores, three of which are reduced to a significant degree. This is difficult to explain from a technological perspective at present. Knapping products would almost necessarily be expected to associate with cores in some numbers, as the lithic analysis established that cores functioned as prolific expedient sources of flakes in the Alto Paraná assemblages. Specimens with five or less removals (tested cores) are only 8% of the thinned core assemblage (n = 3), meaning that relatively well-reduced examples of cores were deposited far from spatial association with other artefacts. In the low-density group field sites, the proportion is only slightly higher (13%).

Table 8.1: Summary of non-clustered artefact data from the analytical sites

Field site	Flakes	Tools	Cores	Ceramics
Aumer I	16	3	10	3
Ziegler II	3	2	14	0
Ziegler III	4	3	4	0
Ziegler IV	15	1	5	0
Gruber IV	11	0	5	2
Total	49	9	38	5

Utilized flakes in the Aumer I data account for 25% of the flake assemblage in the thinned data (n = 4), compared to 11% in the total assemblage. In Ziegler IV they make up 40% (n = 6) of the thinned flake assemblage while only forming 12% out of the total for the field site. The higher proportion of used flakes in the thinned assemblages is less problematic to interpret, as retouched artefacts represent tools whose use-life has been extended to meet functional requirements. For instance, on foraging trips tasks where flakes could not readily be replaced, the rejuvenation of an edge to meet situational needs and the subsequent deposition of the flake after use might be the only physical trace left by such tasks (see Kelly 1988). The expectation would therefore be for these artefacts to tend more towards widely spaced and unstructured depositional patterns (Ebert 1992).

Bifacially flaked tools are not represented in sufficient quantities to draw any solid inferences about their characteristics in the thinned datasets. This being the case, however, there is an implication that a majority bifaces and biface preforms are deposited in spatial association with other types of artefacts. This clustering behaviour can be partially explained with reference to the fact that many of them are pre-forms, and could therefore be more likely to be spatially associated with large quantities flaking debris. Further to this, none of the bifacial thinning flake candidates identified in Aumer I are in the thinned dataset; here too this class of flake is found only in clusters. As noted in Chapter 2, however, the normative cultural-historical framework of the eastern La Plata basin assigns large bifacial artefacts of the kind that dominate the assemblages to the material culture package of pre-ceramic hunter-gatherers. Why are final stage bifacial tools and their broken counterparts not found deposited widely across the landscape, as might be expected for objects that were ostensibly produced and used by a diffuse and highly mobile population?

The answer may lie in the fact that over occupations of terrain by different archaeological cultures that last millennia, areas where deposition took place are bound to abut, overlap, and intermingle. The surface record in the Alto Paraná, like elsewhere in the world, encapsulates the products of a tremendous range of human behaviour. This aspect of the data is difficult to assess in traditional, site-centric ways of thinking. The results of the analysis in Chapter 6, and the ideas tentatively presented in the above experiment, reinforce the notion that without an explicit method to account for such spatial and technological variation in the data, it can easily be subsumed in hegemonic discourses that skirt too closely to the fallacy of representing surface sites as discrete space-time events. Single events, occupations, systems, and ultimately cultures are, emphatically, not the subject of enquiry in a non-site framework. This also serves to underline the current paucity of research into the types of subtle spatial relationships contained in surface collected data in the wider study region. For the lack of representative data the above experiment does not constitute conclusive proof of any of the hypotheses that were advanced. Rather, it is illustrative of the fact that an inability to detect *statistically* significant patterning in palimpsestic data does not necessarily mean that the point patterns are *archaeologically* unimportant. It is clear that the low density field sites (Figure 8.3), which were not subjected to the distributional analysis in Chapter 6, are more representative of the material record of the Alto Paraná than the few dense scatters

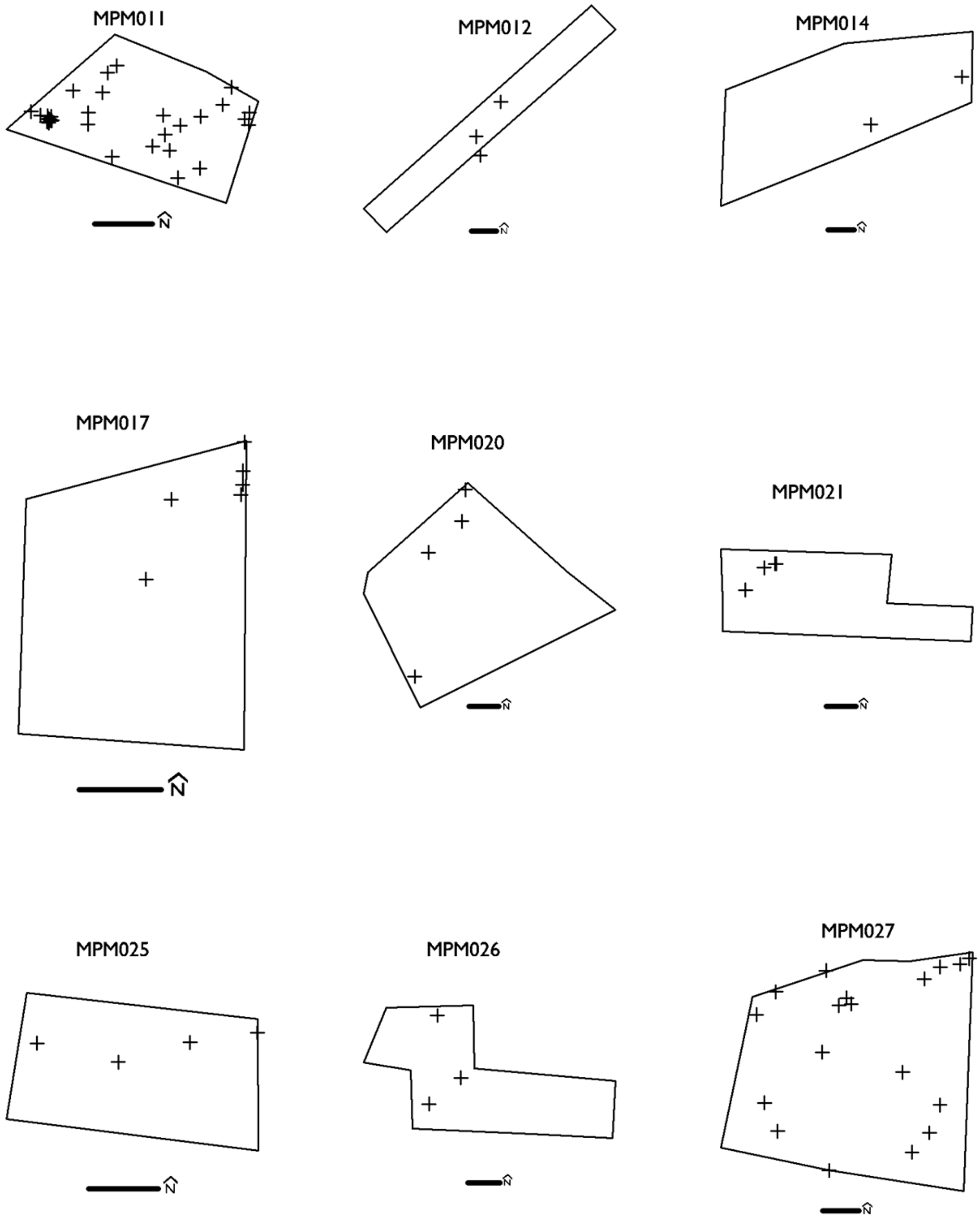


Figure 8.3: The unanalysed point patterns of nine low-density sites, representative of the majority of the record of the Alto Paraná surface record as encountered by the PME project.

encountered within the five analytical sites.

With respect to evaluating how a departure from site-centric models might affect the perception of pre-Columbian cultural landscapes (the first question under the second aim), Chapter 6 and the above sections can be seen as a significant step in the right direction. The notion that significance is primarily a question of analytical scale has strong support in the analysis presented and evaluated here. The methods deployed in this research were robust at a variety of scales, and appropriate for characterizing variability in long-term depositional trends and land use. Following from this, they also proved highly suited to characterizing the organization of flaked stone technology in this setting. Understanding the social use of space, however, is more problematic to grasp at present. Resolving this quandary is not straightforward, because of the still-limited extent of archaeological knowledge in the province as a whole. This can only be ameliorated through additional data collection (see below). Finally, the presumption of studying "social space" at the level of the artefact or the field site can be categorically stated as unsuitable for the degrees of spatio-temporal precision and imprecision in the surface record. As befits the grounding of much social theory in the disciplines of sociology, geography, and anthropology, including authors cited in this research (Soja 1971; 1980; Giddens 1984; Bourdieu 1985; Lefebvre 1991), these are more suited to much narrower scales of time than is typically encapsulated by remains on the modern land surface. Consequently, when Chapter 7 augmented the spatial scale of analysis and narrowed the temporal focus of investigation, this particular branch of critical social theory served as a useful point of departure in more than one respect.

8.2.3 Modelling spatial practice in pre-Columbian societies

Among archaeologists invested in using computational methods for studying the past it is almost inevitable that the question of "Why model?" will be posed by well-meaning colleagues, often tinged with a modicum of scepticism. As a humanistic discipline, the abstraction that computational modelling can entail is a source of contention for many archaeologists. In light of the perceived richness of the material record, something essential is perhaps felt to be lost in translation from semantic to numeric (Llobera 2012, 499; Edmonds et al. 2013). This issue has been explored succinctly in more general terms for the social sciences by Epstein (2008). For this author, one answer comes down to the fact that everyone is a modeller, but only computational models by their nature make their assumptions explicit. Their transparency fundamentally foregrounds the principles that guide the analytical procedures and, importantly, allows them to be examined in ways that implicit or conceptual models cannot. Second, the exploratory nature of the modelling exercise is valuable in a didactic sense. The process as a whole allows data to be seen in new ways, and for a balance to be found between the theoretical and methodological drivers of the research (McGlade 2014, 289; Nowak et al. 2013). Even if the results themselves are unexpected or unsuited to the pursuit of the modelling hypothesis, the field of candidates for alternative hypotheses can be narrowed to a significant degree.

To this end, the geospatial model was created as an explicit empirical framework for understanding specific aspects of spatial practice in the macro-study region, framed through accessibility as a function of structured mobility patterns. For want of archaeological remains which could be directly related to the southern proto-Jê monument near Eldorado (PM01), the geospatial model provided a quantitative framework for interpreting the role of these earthworks. Over the past decade of research, new investigations throughout the eastern La Plata basin have made the importance of MECs to later pre-Columbian groups increasingly apparent (see De Masi 2005; Saldanha 2005; Copé 2006a; Iriarte et al. 2008; 2013; Corteletti 2012). Consequently, the analysis in the chapter was founded on the explicit assumption that monument locations were non-random in relation to their wider environment. Put another way, because significance was assumed to be present by the nature of archaeological record, the model output required further statistical grounding to be proven robust. This was met with Monte Carlo methods performed on the simulated random data, which enabled the modelling exercise to successfully identify areas of terrain in the study areas that, under the assumptions of the analysis, hindered or facilitated access to important cultural locations. The approach to relative accessibility was also multiscalar, in that it assessed the affordances for directed movement in expanding distance bands around each mound and enclosure complex in the sample. Mobility basins were found to form a segmented hierarchy of accessibility on a landscape level, which permitted stronger statements to be made on precisely *how* MEC locations were significant on an anthropic scale.

Although the modelling hypothesis was strengthened through an observed relationship between the spatial locations of monuments and different modalities of access, elements of the material record were deliberately simplified in order to accomplish specific goals with the analysis. This included the need to standardize the study areas in order to preserve the overall comparability of each case study. When discussing the impact of modelling differential access to cultural location, it is important to be reminded that:

"[w]hile there is utility in identifying and *describing* the degree to which some private or public *practices or places* appear inclusionary, group oriented, and corporate versus exclusionary, individualizing, and self-aggrandizing, the power of these terms is *descriptive* only." (Pauketat 2007, 84, author's emphasis).

Heuristics are never fully accurate descriptions of cultural systems and processes, but their isolation and dissection can help clarify and pin down specific aspects of the material record (Eve and Crema 2014). It is recognized here, in agreement with the broader archaeological literature that, plainly, not all MECs are created equal. Significant variability in monument layout, biography, and function is clearly apparent even among the limited sample discussed in this research (Figure 7.4). It would therefore be naïve to expect an analytical method to produce similar results for such a heterogeneous group of features, located in highly varied environments.

Some artefacts of the analysis were discovered upon close inspection of the resulting relative accessibility maps. For example, the highland location Urubici 21 possessed notionally "accessible" mobility basins below the sheer escarpment of the Serra Geral to its southeast. This is patently an inaccurate representation of geographical reality, and is acknowledged as such. Additionally, both inaccessible and accessible mobility basins pertaining to PM01 in Misiones province have extents which cross the Río Paraná. By any measure (including the friction surface used to generate the mobility basins) this river should be considered a significant barrier. Unfortunately, the path distance analysis algorithms (ESRI 2012) are computationally incapable of recognizing this fact without directly removing a significant portion of the study area from the procedure (see Figure

7.9). This would, however, bias the model in this context and an early decision was made to apply the model with equal parameters throughout every case study, irrespective of the particularities of each environment. The comparability that the modelling exercise sought was therefore maintained, and this broad approach provides overall more fertile grounds for discussion than specifically "tailor-made" models which provide less of a basis for facilitating cross-context comparisons.

Modelling, in this case, intended to go "beyond the tool" (Chrysanthi et al. 2012). In other words, using rigorous quantitative methods as a set of integrated approaches, as opposed to simply a toolkit (Llobera 2012, 497), provided this research with the means to test specific interpretations of monument function and meaning. The fact that common modalities of access were discovered points to new ways that mound and enclosure complexes can begin to be understood. To reiterate, in societies transitioning towards more stratified forms of organization, the facilitation or constriction of access likely had crucial effects on the evolution of incipient power structures and the ability to maintain social bonds by different components of the wider social group. The interpretations advanced in Chapter 7 to this effect are not exceptionally novel in the context of recent scholarship on the phenomenon of late Holocene monumentality among the southern proto-Jê (see Saldanha 2005; Copé 2006a; Iriarte et al. 2008; 2013; De Souza and Copé 2010; Corteletti 2012). Comparing the outcome of the model on simulated data to our archaeological data allowed for an assessment of the most probable processes that influenced the creation of the archaeological record (Premo 2010, 29-30; Lake 2014, 268).

8.3 Directions for future research in the eastern La Plata basin

From the outset, this research, its data collection, and analytical approaches were designed with a non-site outlook on the material record. For the purpose of exploring and characterizing spatial structure in the surface archaeology of the Alto Paraná from "first principles", these were appropriate methods to deploy. Nonetheless, several key areas for development are worth identifying. These are discussed in the context of directions for future research to take in Misiones province.

8.3.1 Artefact analysis

As noted in Chapter 3, the decision to separate all the collected material into four broad classes (cores, flakes, tools, and ceramics) was a deliberate strategy to manage the anticipated diversity of the record in the study area. The subsequent lab analysis and a separate study of bifacial tools (Riris and Romanowska 2014) brought the variability within these categories into focus, showing in part how imperfect the initial heuristics were for characterizing technological variability. In particular, the recording methods introduced ambiguity of membership in certain artefact categories. For example, the differences between utilized flakes and unifacial tools at present seem largely qualitative rather than truly technological. More detailed characterization is required to establish if any substantial differences exist beyond those tentatively identified in Chapter 5. Furthermore, the intra-group heterogeneity of cores and the relatively small quantity of recorded attributes renders the technological generalizations that were presented open to significant review. The same applies to the flake assemblages, which although abundant, posed analytical problems due to their largely amorphous and informal nature. To mitigate these problems, some recommendations can be made.

The non-metric recorded attributes (retouch, scar count, cortical cover) were deficient in scope for characterizing the variability in reduction intensity, technology, and function of the lithic artefacts. At the conclusion of this research, it appears that only the surface of the spatial distribution of these aspects of organization has been scratched. To this end, some specific attributes can be put forward to describe reduction strategies in greater detail. The method of preparation of cores might serve as a useful guide to different reduction strategies, in particular how striking platforms are prepared (if at all) among and within different assemblages. Recording this attribute on flakes can help determine whether detachments occurred by pressure or percussion, and in turn the reduction stage or sequence to which they adhere. Additionally, a separate record of cortical cover on flake platforms and their dimensions can provide a more complete picture of how the initial preparation of raw material occurred. If, as the flake analysis suggests, knapping products were mostly simple and undifferentiated after the initial removal of cortex from a core, then understanding the first steps of core preparation may be the only way of identifying why particular strategies were adopted. More complex or prepared platforms (*sensu* Andrefsky 2005) might reveal the relative degree of investment in controlling tool shapes. In turn this can resolve some of the problems associated with the definition of unifacial artefact categories proposed here, as well as help pin down the attributes of bifacial thinning flakes in this context.

The management of stone with particular qualities is a key determinant of technological variability (Andrefsky 1994; Inizan et al. 1995; Andrefsky 2005), yet the small quantities of "exotic" (in comparative view) grey basalt in the PME project assemblages only permitted tantalizing glimpses of the potential of this attribute in the study area. The homogenous raw material of lithics in Misiones province is not a factor that can be discussed in a comparative technological framework at present, unless future fieldwork can succeed in recording a significant quantity of artefacts in different raw materials. Concerning the predominant red basalt, developing a better understanding of raw material variability can enable better inferences as to what degree lithic resources were conserved, as well as whether riverine cobbles always formed the principal sources.

Finally, focused studies of ceramic vessels in the province, including style, chemical composition, and morphology are sorely needed. While broad cultural types can be easily distinguished (i.e. Tupiguarani or Taquara/Itararé), the spatio-temporal, technological, and stylistic variability of pottery in Misiones province remains an open question.

8.3.2 Survey technique

As noted at the outset (see section 1.2), little concerted effort at systematic prospection for archaeological remains has taken place in Misiones since the mid-twentieth century. This is particularly apparent on the Argentinean side of the Uruguay valley, which has received even less attention in comparison to the Paraná and its tributaries (Sempé and Caggiano 1985) likely for historical reasons. This lacuna is, moreover, curious given that indigenous settlements were documented near San Pedro as late as the end of the nineteenth century (Ambrosetti 2006 [1895]). This section identifies specific areas of the province which might provide the means to explore its archaeology in greater depth. Four departments in the south-eastern sector of the province (San Pedro, Guaraní, 25 de Mayo, and Oberá) fall principally or wholly within the Uruguay watershed, while one (Cainguás) straddles the boundary between it and the Paraná in the Sierra Central (Figure 8.4). Together these departments represent a significant proportion of the total area of Misiones, but are attractive for targeted efforts in several regards.

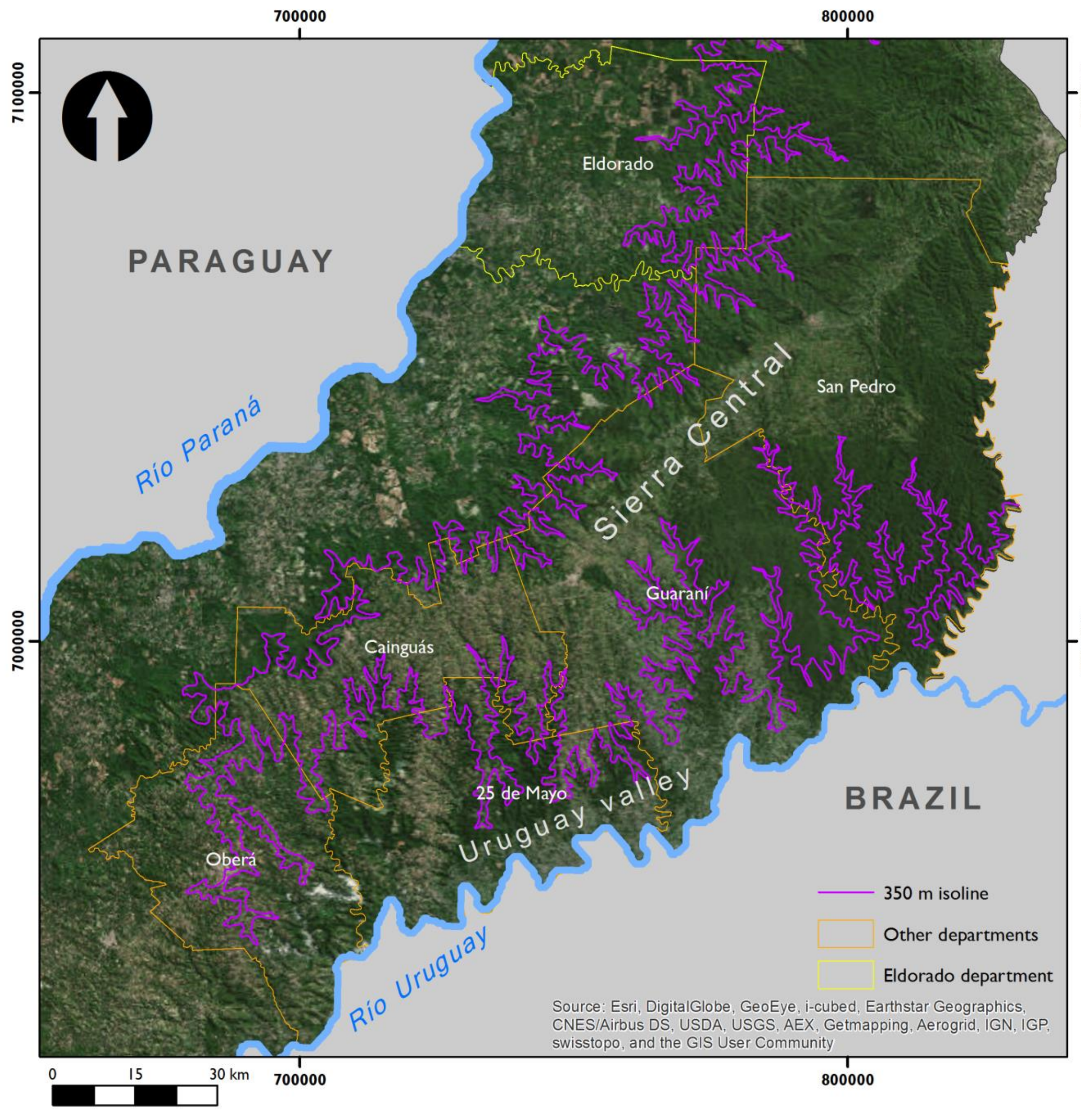


Figure 8.4: Zones in south-eastern Misiones province that could prove valuable targets for future investigations: the cultivated Uruguay valley and the conserved Sierra Central.

The relatively populous municipalities in this area, for instance within Oberá and Guaraní, possess large contiguous areas of agricultural and plantation clearances clustered around towns and villages. The severe impact of development on the *monte* is readily apparent in the satellite imagery (see Figure 8.4). This can, however, afford future fieldwork the ability to map archaeological surface data in larger and more contiguous units, which would provide an improvement over the relatively dispersed units of coverage that were achieved in Eldorado. Data collection in this manner can help resolve issues identified in section 8.2.2, meaning whether elusive, large-scale patterns of land use can truly be detected in the province through surface collected material.

Nonetheless, additional non-site prospection does not address lack of chronology in surface data, which curtails the ability to explore temporal change as well as spatial variability in land use. This was an accepted part of the research design, however, the state of the surface record in this setting naturally presents obstacles to reliably locating subsurface deposits and extracting datable material. This is in part due to the homogenized soil profiles that ploughing produces. Continued use of this research strategy is unlikely on its own to produce any information with a time dimension. Recent excavations along the Paraná demonstrates that detecting Guarani settlements along major watercourses can be relatively straightforward, the anthropogenic dark earths associated with these locations being relatively clear against light riverine sands (Loponte and Carbonera 2014). Equally, however, the detection of an "intact" low-density record is hampered by the *monte* environment. As in other tropical settings, survey by airborne light detection and ranging (LiDAR) might prove instrumental in detecting intact features such as earthworks or pit houses beneath the forest canopy (see Devereux et al. 2005; Crow et al. 2007; Chase et al. 2011). It can be suggested that the ability to remotely survey inaccessible and distant areas of forest can greatly increase the likelihood of detecting southern proto-Jê pit house clusters and additional mound and enclosure complexes, which would otherwise be almost impossible to locate.

The Sierra Central sports numerous large areas of conserved forest (see Figure 8.4), which are generally located above the 350 meter contour of the highland zone. The terrain in both the areas of native highland forest and cultivation above this elevation is a relatively gently undulating plateau. A two-phase strategy combining renewed non-site surveys with airborne remote sensing can take advantage of the topography of the highland zone both for enabling pedestrian access to survey units and ground truthing remotely sensed data. Sub-canopy candidates for archaeological features detected in this manner could serve as excavation targets, to the end of producing a more holistic view of settlement and land use in this setting.

8.4 Final Remarks: non-site archaeology as integrated strategy in the eastern La Plata basin

This research has demonstrated the impetus for integrating non-site approaches into programs of archaeological research in the eastern La Plata basin by developing an in-depth case study in Misiones province. Through a threefold approach that integrated technological analysis, spatial statistics, and computational modelling, several theoretical and methodological points with a wider impact on archaeological practice and interpretation were made. This includes the need to make analytical and interpretative assumptions clear at the outset, and ground the concept of significance in the archaeological record in relation to the environment in a broader sense. Overall, this provides a strong backing for the argument that close readings of the material record *in combination with* rigorous statistical analysis offers a solution to many of the problems faced in study of the past in the macro-study region, particularly as concerns large-scale patterns of land use. To this end, the computational modelling allowed for multiscalar explorations of alternative hypotheses for the processes that may have affected the locations of mound and enclosure complexes, in this case of late Holocene territoriality as a function of differentiated accessibility. In its second part, however, the point process modelling also afforded the ability to test aspects of existing hypotheses in a robust and explicit framework.

Data analysis throughout this research was kept conservative in order to avoid a “kitchen sink”-style approach confounding the goal to characterize any actual spatial structure in the archaeological assemblage. In cognitive neuroscience, the term *apophenia* is used to describe the human capacity for attaching deeper significance and meaning to otherwise meaningless information (Brugger 2001), and within Big Data scientists coined the neologism "patternicity" to describe broadly the same phenomenon (Shermer 2008). In the context of spatial data analysis, these are analogous to clustering illusions and confirmation bias leading to the perception of patterning in data that actually has a random structure (Wickham et al. 2010). While both are examples of Type I statistical errors, the latter is especially dangerous for how archaeologists conceptualize surface collected data from first principles. As Wandsnider (2004) notes, it is easy to fall prey to the "tyranny of familiar things" (see Plog 1974) and view the distribution of surface archaeology as occurring within static and internally homogenous entities, meaning sites. While primarily functioning as a managerial device that permits easy reference to be made to a partial and biased record, sites also come laden with assumptions on the significance of their content. This is often held in contrast to an often poorly understood wider landscape context, which breeds uncritical interpretations on the reasons for why sites are found where they are, ignoring the fact that "sites" are only "there" by virtue of the archaeologist. They derive from the assumption that the deposition of material follows directly from specific functional activities that took place the past and, moreover, that the timescales of both are commensurate with that of the modern observer (see Holdaway and Wandsnider 2006). In other words, by looking for sites, one will discover sites. The theoretical pillar of this research was to do away with this sophisticated epistemological fiction (Dunnell 1992; Ebert 1992; Holdaway et al. 2004) and let the data speak for itself.

In the archaeology of arid and semi-arid zones, it is well-established that surface archaeology forms a continuous carpet of material on the modern land surface, and that this is not necessarily commensurate with its subsurface structure. By way of contrast, the extension of this proposition to tropical settings is a nontrivial outcome of this research. This should not be seen as a novel or unexpected finding on the structure of the material record itself, rather, it points to the deeper informative potential of surface archaeology in such contexts. Due to the lack of appropriate analytical frameworks with which to deploy non-site theory, however, it has not received due attention in the wider study region. In terms of method, therefore, the thrust of this thesis was to shift the main analytical emphasis from the concept of the functional site-type to the individual artefact (see Thomas 1975). This recognizes that a broad spectrum of activities unfolded in the landscape, which rarely left behind tangible remains or occurred in exactly the same location over the long term, and consequently cannot be completely accurately characterized as only, for example, “special activity areas”, quarries, processing areas, temporary satellite settlements, or garden plots (see Beber 2005; De Masi 2005; Saldanha 2005; Schmitz 2006; De Souza and Merenecio 2013). Interpretations such as these are founded upon implicit and unsupported assumptions about the structure, scale, and temporality of surficial archaeology. In summary, treating archaeological remains on the modern land surface as occupational episodes poorly represents their spatial structure, technological variability, and systemic significance. With sufficient sampling, accurate spatial data, and detailed characterization of surface deposits, several trends can be, and were, identified from a wide variety of artefacts. The methods used to achieve this were not complex or reliant upon prohibitively expensive or technically demanding toolkits to achieve their goals. Indeed, the majority of data analysis was carried out with open-source solutions (see R Development Core Team 2013; Baddeley and Turner 2005).

Exploring scalar patterns, whether socio-political, economic, demographic, or as in this case, spatial, is central to revising the standard model of South American lowland prehistory (Stahl 2002; Denevan 2012; Walker 2012). When dealing with an ephemeral surface record produced by highly mobile or small groups, detecting variability at multiple scales allows more nuanced and contextual patterns to emerge from data than top-down impositions. Considering the evidence of human activity in a given region as spatially contiguous (Foley 1981) allows less strongly patterned or obtrusive signatures to be analyzed in the same framework as salient areas of long-term or intensive inhabitation (Thomas 1975, 81; Grove 2007, 4). Both form part of the continual re-use of landscape elements over long periods of time (Cherry et al. 1988; Tainter 1996, 170; Wandsnider 1998a). The organization of objects and assemblages in space can therefore be readily apprehended through appropriate analytical techniques, reducing the limitations that a flattened time axis would traditionally place on research (Lucas 2008, 59-61). In turn, by understanding how the accumulation of individual actions and events emerged through long-term cultural processes, scalar patterns can be detected and explained (Chapman 1996, 38; Lock and Molyneaux 2006, 9). Interrogating archaeological data across the landscape at multiple scales provides the impetus for a fuller consideration of the range of tasks and systems of land use that unfolded in the past, only some of which entered the material record. In conclusion, the findings of this research have implications beyond the confines of the study area for both data collection, and the conceptual framework for interpreting the landscape-level patterning of cultural material. It has proposed solutions to both these aspects of archaeological practice which are flexible, transferrable and above all, powerful.

Appendix A: Equations

A.1 Introduction

This appendix presents the spatial statistics that were employed in Chapter 6 (Distributional Analysis), with notation. Many are reproduced from the documentation of the R package 'spatstat' (Baddeley and Turner 2005), which contains the implementations that were exclusively used in this research. The current version (1.39-1) should be consulted for specific details regarding the implementation of these statistical methods. Together with this document, other publications are cited here where appropriate, and all descriptions of notations have been adapted from them.

A.2 Spatial statistics

The Clark-Evans test for spatial aggregation measures the spacing of individuals in a population of points with a known intensity (Clark and Evans 1954), meaning the mean number of points in an area, denoted hereafter as a constant λ). In the applications reported in Chapter 6, a cumulative density function was used for correcting edge effects. The test is reported as R, which is the ratio between the expected number of points r_e and the actual observed number, r_o.

$$\mathrm{R} = \frac{r_o}{r_e} \tag{2}$$

The mean observed number of points, r_o, is defined as the sum of the distances to the nearest neighbour in a given population, $\sum r$ divided by the size of the population, N:

$$r_o = \frac{\sum r}{N} \tag{3}$$

The expected number of points in a region, r_e, is defined as:

$$r_e = \frac{1}{\sqrt{2\lambda}} \tag{4}$$

A value of $\mathrm{R} > 1$ indicates spatial dispersal, while $\mathrm{R} < 1$ suggests spatial aggregation. The significance of departure from the expectation of normality can be calculated with:

$$Z = \frac{r_e - r_o}{\sigma\, r_e} \tag{5}$$

Where $\sigma\, r_e$ is the standard error of the expected number of points, calculated as:

$$\sigma\, r_e = \frac{0.26136}{\sqrt{N\lambda}} \tag{6}$$

The reduced second moment function (Ripley 1977), also known as Ripley's K-function, of a point process is defined in Baddeley and Turner (2005) as:

$$K(r) = \frac{a}{n(n-1)} \sum_i \sum_j I\left(d_{ij} \leq r\right) e_{ij} \tag{7}$$

Where a is the area of the window, n is the number of data points, and the sum is taken over all ordered pairs of points i and j in a point pattern X. Here d_{ij} is the distance between the two points, and $I(d_{ij} \leq r)$ is the indicator that equals 1 if the distance is less than or equal to r. The term e_{ij} is the edge correction weight, which in all applications was Ripley's isotropic correction. This formula effectively summarizes the degree of positive and negative autocorrelation of a point pattern at multiple spatial scales. The empirical value of $K(r)$ is usually compared to its value under theoretical conditions of complete spatial randomness (CSR), in which $K(r) = \pi r^2$.

In practice, transformations of this function are used in spatial point pattern analysis due to one or more qualities that they possess which are superior to those of the original formulation. In the case of this research, both the square root transformation of Besag (1977), known as the L-function, and the derivative pair correlation function (Stoyan and Stoyan 1994) were used to characterize the spatial structure of the Piray Mini Exploration project point patterns. The former function makes the theoretical curve of $K(r)$ accumulate in a linear manner, which produces a more visually intuitive output. It is defined as:

$$L\,(r) = \sqrt{\frac{K(r)}{\pi} - r} \tag{8}$$

The pair correlation function, also termed the O-ring statistic (Wiegand and Moloney 2004), is a derivative of the K-function that replaces the circles of r in the K-function with annuli. It is defined as:

$$g(r) = \frac{K'(r)}{2\pi r} \tag{9}$$

Where $K'(r)$ is found through the differentiation of $K(r)$. The value of the function under CSR = 1, giving a linear output. The interpretation of the function can be considered as the probability of finding two points in different locations at a fixed distance band r. In the case of this research, a modified divisor was used for the function due to the detection of clustering through visual inspection. This provides the analysis with improved estimations of the function value at distances close to zero (Baddeley and Turner 2005).

The bivariate pair correlation function is related to the bivariate K function $K_{12}(r)$, defined as the expected number of points of type 2 within a given distance of an arbitrary point of type 1 (Wiegand and Moloney 2004).The notation for this is:

$$\lambda_2 K_{12}(r) = \pi r^2 \frac{\frac{1}{n_1}\sum_{i=1}^{n_1} Points_2[C_{1,i}(r)]}{\frac{1}{n_1}\sum_{i=1}^{n_1} Area[C_{1,i}(r)]} \tag{10}$$

Where n_1 is the total number of points of pattern 1, $C_{1,i}(r)$ is the circle with radius r centred on the ith point of pattern 1, the operator $Points2[X]$ counts the points of pattern 2 in a region X, and the operator $Area[X]$ determines the area of the region X. λ_2 is the intensity of the type 2 point pattern.

Following from this, the bivariate pair correlation function $g_{12}(r)$ is defined as:

$$g_{12}^{w}(r) = \frac{\frac{1}{n_1}\sum_{i=1}^{n_1} Points_2[R_{1,i}^{w}(r)]}{\frac{1}{n_1}\sum_{i=1}^{n_1} Area[R_{1,i}^{w}(r)]} \tag{11}$$

Where the circle $C_{1,i}(r)$ variable is replaced by $R_{1,i}^{w}(r)$, a ring with radius r and width w centred on the ith point of pattern 1. This notation defines the statistic for one instance of r. To integrate the data across multiple values of r, Equation 11 is extended to calculate the average weighted number of points of type 2 across all N instances taken over the average weighted area over all N instances:

$$g_{12}^{w}(r) = \frac{\sum_{i^j=1}^{n_1^j} Points_2\left[R_{1,i^j}^{w}(r)\right] + \cdots + \sum_{i^N=1}^{n_1^N} Points_2\left[R_{1,i^N}^{w}(r)\right]}{\sum_{i^j=1}^{n_1^j} Area\left[R_{1,i^j}^{w}(r)\right] + \cdots + \sum_{i^N=1}^{n_1^N} Area\left[R_{1,i^N}^{w}(r)\right]} \tag{12}$$

Where i^j is the ith point of pattern 1 and instance j and n_1^j is the number of points of pattern 1 and instance j. $N = \sum j\ n_1^j$ is the total number of points of pattern 1 in all instances.

Local L-function (Getis and Franklin 1987; Baddeley and Turner 2005) computes the value of $L(r)$ for a single point i in a point pattern X.

$$L_i(r) = \sqrt{\frac{a}{(n-1)\pi} \sum_j e_{ij}} \tag{13}$$

Where the sum is over all points $j \neq i$ that lie within a distance r of the ith point being investigated, a is the area of the observation window, n is the number of points in X, and e_{ij} is an edge correction term. In effect, the computed value of $L_i(r)$ can be interpreted as one of the summands that contributes to the global estimate of the L-function.

A.2 Other equations

Tobler's hiking formula (Tobler 1993) is an exponential function that models the time expended to cross terrain in kilometres per hour, based on the input of terrain slope in degrees. It is defined as:

$$v = 6e^{-3.5\left|\tan\frac{x}{57.29578}\right|+0.05} \tag{14}$$

Where $v = km/h$ and $x = slope\ in\ degrees$.

For full descriptions of the Bayesian Information Criterion (BIC) and Akaike's Information Criterion (AIC), refer to Schwartz (1978) and Sakamoto et al. (1986), respectively. For any statistical model, the AIC is defined as:

$$\mathrm{AIC} = 2k - 2\ln(L) \tag{15}$$

Where k is the number of parameters in the model, and L is the maximized value of the likelihood of the model in question. As noted in Chapter 7, the preferred model has the smallest value of AIC.

Conversely, the Bayesian Information Criterion is defined as:

$$\mathrm{BIC} = -2\ln(L) + k\ln(n) \tag{16}$$

Where n is the number of data points in the observed data, k is the number of parameters in the model, and L is the maximized value of the likelihood of the model in question. Unlike Akaike's Information Criterion, the value of BIC itself is not the target. Rather, the differences between the values of the BIC for i models, denoted as Δ_i, are used to derive model weights. Formally:

$$\Delta_i = \mathrm{BIC}_i - min\mathrm{BIC} \tag{17}$$

The "best" model will have a value of zero for Δ. The relative strength of a model given the set of models m can be estimated using delta as a parameter. Model "weights" are interpreted as the probability that a given model can plausibly explain the modelled phenomenon. Larger values of ω_i reflect the increasing probability that this is the case and can be calculated as:

$$\omega_i = \frac{e^{-0.5\,\Delta_i}}{\sum_{i=1}^{m} e^{-0.5\,\Delta_i}} \tag{18}$$

The morphometric classification of landforms from an elevation raster employs a bivariate quadratic equation where the change in gradient of a target cell is examined in relation to the cells around it. This takes the form of:

$$z = ax^2 + by^2 + cxy + dx + ey + f \tag{19}$$

Where x, y, and z are coordinates of the cells and a to f are quadratic coefficients. Derivatives of this function are used to bin cells into planes, peaks, passes, channels, ridges, and pits based on a moving window of analysis. For a full description of these, refer to Wood (1996; 1998) and the Landserf User Guide.

Appendix B: Excavation report

B.1 Introduction

MPM013 is the eighth known earthwork in the cluster of southern proto-Jê mound and enclosure complexes (MECs) to which PM01 belongs (Wachnitz 1984; Iriarte et al. 2010a). It is hereafter referred to as Circle 8 (see Figure X), and is only one of two MECs documented in plan by Wachnitz (1984) as having a central mound feature with a likely funerary function, the other being PM01 (Iriarte et al. 2008). Due to the failure to preserve the other seven earthworks and their subsequent destruction by plantation activity, Circle 8 was thought to be the only known surviving southern proto-Jê monument in Misiones province. As part of the University of Southampton-INAPL collaboration termed the *Piray Mini Exploration project*, the relocation of the site and its documentation was deemed to be of high priority.

Circle 8 is located in a mature eucalyptus (*Eucalyptus* sp.) plantation that is currently the property of Sra. Karin Schlagenaufer. The central mound feature is within 50 m of a municipal road that extends off the principal highway of Eldorado city. The understory of the plantation is not maintained, hindering pedestrian access and clear vision of the earthworks. Due the labour requirements of clearing the full area of the site and the limited time available for excavation, only the central feature was drawn in plan. Although the enclosing feature was located in parts of its extent (with a radius and width of approximately 30 meters and 2 meters, respectively), the preservation of its full extent in the present could not be verified.

Unfortunately, at the beginning of the PME project fieldwork, portions of Circle 8 were found to have suffered attempts at looting on at least six separate occasions. The majority of these large irregular pits (five) are located on the central mound itself. At present, the central feature is 4 x 1 m in an amorphous sub-oval shape. To this end, the goal of the excavation was also to assess the extent to which the looting had damaged the mound and to ascertain if undisturbed cultural remains could be recovered from layers in the mound. The soils encountered were uniformly red-brown clayey silt of the Oberá formation, typical of this part of Misiones province.

Figure B.1: Panorama of Circle 8 central feature after clearing the understory in advance of excavation, view from the south (immediately in front of the future location of TU1). Note the presence of several spoil heaps in the left of the image. Photo by I. Romanowska.

B.2 Excavations in Circle 8 (MPM013)

Two test pits were established to investigate the central mound feature and the interior of Circle 8. The first, Test Unit 1 (2 x 2 meters), was located at the midpoint between the inferred centre of the mound and the enclosing bank, i.e. 15 m out in a straight line. No cultural material or discernible layers were discovered in this sterile test unit.

Figure B.2: Test Unit 1 at a depth of 1 m, 20 cm below the natural layer (context 100) in the central feature. East section. Photo by I. Romanowska

Test Unit 2 (2 x 1) was placed over the deepest robber cut in the central mound feature (Figure B.3) in order to clean the profile of the cut and document the profundity of the modern interferences. Any intact layers in the feature (including possible lenses of charcoal related to mortuary activity) could also be sampled if observed.

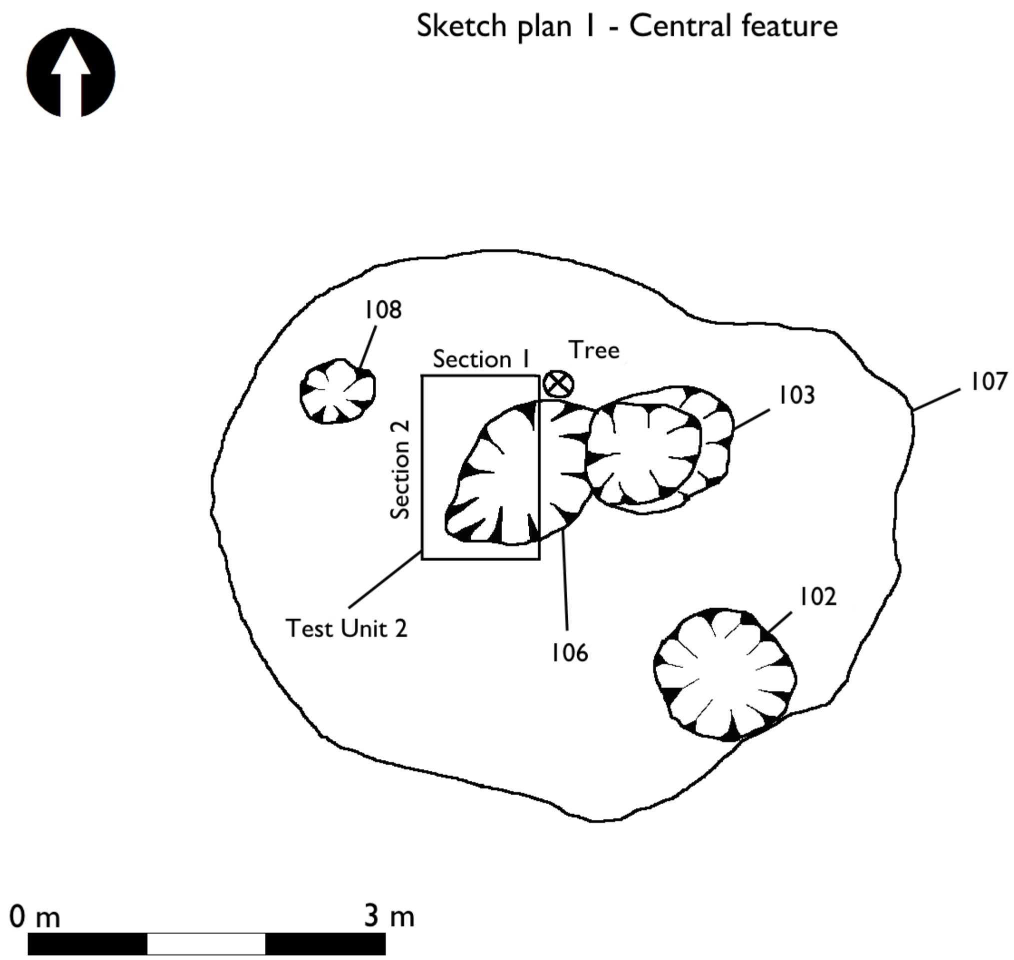


Figure B.3: Sketch plan of central mound feature, with five robber cuts, Test Unit 2 and a eucalyptus planted on the highest point. Contexts are numbered according to the site Harris matrix. Sketch by K. Maynard.

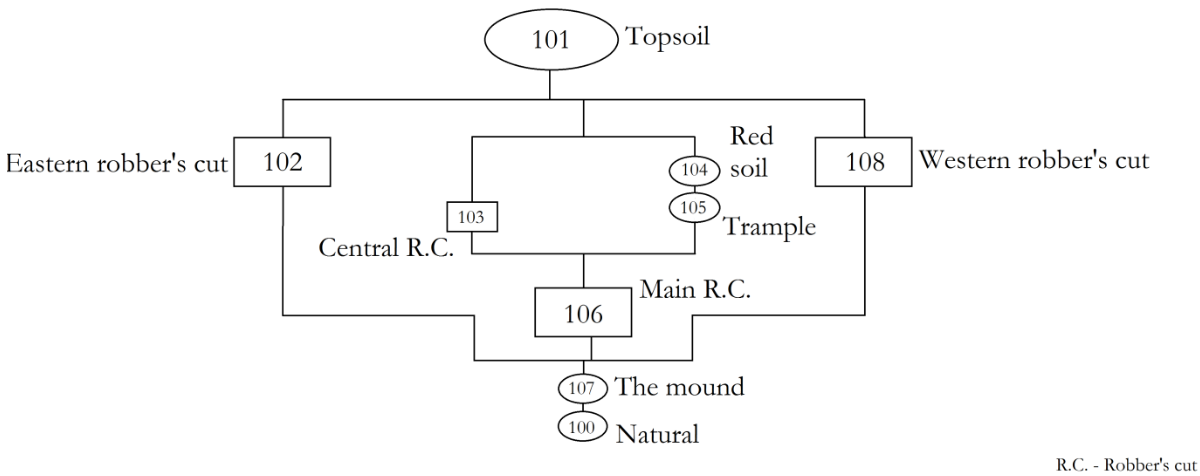


Figure B.4: Harris Matrix of the central mound feature.

Table B.1: Key to Harris matrix

Context	Description
100 – Natural	Reddish clayey silt, with no inclusions. Occasional rooting.
101 – Topsoil	A layer of consisting of low vegetation, old leaves, and roots. Fill of **102, 103,** and **106**. Covering **104, 107**.
102 – Eastern robber's cut	A deep (approximately 1,2 m) and wide hole. Sub-circular with sheer sides and rounded base. Cut into the eastern sector of context **107**. Filled by **101**.
103 – Central robber's cut	Large, oval pit with moderately steep sides and a rounded base. Approximately 1.7 m deep as measured from the highest point of **107.** Cuts context **106** and **107**, filled by **101**. No stratigraphic relationship can be discerned from the section alone, but is clearer in plan.
104 – Red soil, fill of context **106**	Reddish clayey silt with no inclusions. Top layer of the main robber's cut **106**. Most likely this is the spoil that resulted from the excavation of **103**. Fill of **106**, covers **105**, and covered by **101**. Indistinguishable from **100**.
105 – Trample	A layer of trampling and organic material, similar to 101, but located below a sterile soil layer. Probably deposited after **106** and abandoned after **103** was excavated. Fills **106**, covered by **104**.
106 – Main robber's cut	A large circular robber's cut with sheer sides and a rounded base. Formation earlier than **103**, and filled partially with its spoil **104**. Approximately 0.9 m deep as measured from the top of the mound feature. Two fills: a layer of trampling **105** and a layer of spoil **104**. Cut into **107**, covered by **101**.
107 – The central mound feature	Approximately circular mound feature. Northern and western sectors likely to be the most preserved parts of its layout. Archaeological integrity compromised to a significant degree by four robber cuts: **102**, **103**, **106**, and **108**. Cut **102** and its spoil obscure the eastern limit of the mound feature. Approximately 1 m higher than the natural ground level. Composed of red-brown clayey silt, with occasional inclusions of solid red clay.
108 – Western robber's cut	Small robber's cut with sheer sides and a rounded base cut into **107**. No stratigraphic relation to the other robber cuts.

Figure B.5: Eastern section of TU 2, note dark layer of (modern) organic material in the centre of the section. Photo by I. Romanowska.

The stratigraphic sequence of the central mound feature is described and summarized in Figure B.4 and Table B.1. No artefacts or pre-Columbian layers were encountered in either test unit, other than context **107**, i.e. the red-brown clayey silt used to erect the feature. Additionally, to conclusively determine whether any carbonized remains relating to funerary activity might be preserved in the extant mound, the profile of the deepest robber cut (context **103**) was cleaned of vegetation and topsoil (Figure B.6).

Figure B.6: Cleaned northern profile of **103** (central robber cut). No discernable cultural layers other than **107** were visible.

B.3 Interpretation and summary

Since the original documentation of Circle 8 (Wachnitz 1984) and its relocation in the twenty-first century (Iriarte et al. 2010a), it suffered several catastrophic interferences to its archaeological integrity. These were likely exacerbated by the wet climate and the repeated attempts at excavation by looters, spurred on by local legends of Jesuit or Portuguese treasure being buried in the region. No artefacts or datable material could be found or extracted from Circle 8. This severely curtails the ability of archaeologists to relate this feature to its wider landscape context. The excavation succeeded only in documenting the profundity of these interferences.

Appendix C: Accompanying material

C.1 Description and link

This appendix provides a link to the material which accompanies this research. The link to this information is provided in the interest of creating an environment of transparency, transferability, and replicability of both methods and results in archaeological research. There are three components to this effort for the Piray Mini Exploration project data:

1) An ESRI geodatabase of find locations and survey quadrats.
2) An Excel spreadsheet containing the data from the lab analysis of stone artefacts.
3) Python scripts of the models presented in Chapter 7 in .py format.

The above is available at the following link: http://1drv.ms/1ztXiVF

The R code of the analysis in Chapter 6 is available on request, but documentation for the package 'spatstat' (Baddeley and Turner 2005) should be consulted first for clearer examples of its implementation.

Bibliography

Ab'Saber, A.N. (trans. P.E. Vanzolini) 2000 [1977]. "Spaces Occupied by the Expansion of Dry Climates in South America during the Quaternary Ice Ages." *Revista do Instituto Geológico* 21 (1/2): 71-78.

Ahler, S.A. 1989. "Mass Analysis of Flaking Debris: Studying the Forest Rather Than the Tree" *Archeological Papers of the American Anthropological Association* 1: 85-118.

Aldstadt, J. 2010. Spatial Clustering. In: Fischer, M.M. and A. Getis (Eds.), *Handbook of Applied Spatial Analysis*. London: Springer. 279-300.

Ambrosetti, J.B. 2006 [1895]. *Os Indios Kaingang de San Pedro (Misiones)*. São Paulo: Editora Curt Nimuendajú.

Ambrosetti, J.B. 2008 [1896]. *Tercer Viaje a Misiones*. Buenos Aires: Editorial Albatros.

Ameghino, F. 1880. *La antigüedad del hombre en el Plata*. Buenos Aires: G. Masson.

Ammerman, A.J. 1981. "Surveys and Archaeological Research." *Annual Review of Anthropology*. 10: 63-88.

Andrefsky, W. 1991. "Inferring Trends in Prehistoric Settlement Behaviour from Lithic Production Technology in the South Plains." *North American Archaeology* 12 (2): 129–144.

Andrefsky, W. 1994. "Raw-Material Availability and the Organization of Technology." *American Antiquity* 59 (1): 21-34.

Andrefsky, W. 2005. *Lithics: Macroscopic Approaches to Analysis*. 2nd edition. Cambridge: Cambridge University Press.

Andrefsky, W. 2009. "The Analysis of Stone Tool Procurement, Production, and Maintenance." *Journal of Archaeological Research* 17 (1): 65-103.

Anschuetz, K.F, R.H. Wilshusen and C.L. Scheick. 2001. "An Archaeology of Landscapes: Perspectives and Directions." *Journal of Archaeological Research* 9 (2): 157 – 211.

Araujo, A.G.M. 2001. *Teoria e Método em Arqueologia Regional: Em estudo de Caso no Alto Paranapanema, Estado de São Paulo*. Museu de Arqueologia e Etnologia: University of São Paulo, São Paulo. Unpublished PhD dissertation.

Araujo, A.G.M. 2007. "A tradição cerâmica Itararé-Taquara: características, área de ocorrência e algumas hipóteses sobre a expansão dos grupos Jê no sudeste do Brasil." *Revista de Arqueologia* 20: 9-38.

Araujo, A.G.M. and J.C. Marcelino. 2003. "The Role of Armadillos in the Movement of Archaeological Materials: An Experimental Approach." *Geoarchaeology* 18 (4): 433 – 460.

Araujo, A.G.M. and Pugliese, F. 2009. The Use of Non-Flint Raw Materials by Paleoindians in Eastern South America: A Brazilian Perspective. In: Sternke, F., Eigeland, L. and Costa, L.-J. (Eds.), *Non-Flint Raw Material Use in Prehistory – Old Prejudices and New Directions.* Oxford: Archaeopress.

Araujo, A.G.M., W.A. Neves, L.B. Piló, J.P.V. Atui. 2005a. "Holocene dryness and human occupation in Brazil during the "Archaic Gap" *Quaternary Research* 64: 298-307.

Araujo, A.G.M., L.B. Piló, W.A. Neves, J.P.V. Atui 2005b. "Human occupation and palaeoenvironments in South America: expanding the notion of an "Archaic Gap" *Revista do Museu de Arqueologia e Etnologia* 15-16: 3-35.

Araujo, A.G.M., W.A. Neves and R. Kipnis. 2012. "Lagoa Santa Revisited: An overview of the chronology, subsistence, and material culture of Paleoindian sites in eastern Central Brazil" *Latin American Antiquity* 23 (4): 533-550.

Arroyo-Kalin, M. 2010 "The Amazonian Formative: Crop Domestication and Anthropogenic Soils." *Diversity* 2 (4): 473–504.

Ashmore, W. 2002. "'Decisions and Dispositions': Socializing Spatial Archaeology: Archeology Division Distinguished Lecture 99th AAA Annual Meeting, San Francisco, CA, November 2000." *American Anthropologist* 104 (4): 1172–1183.

Ashton, N. P. Dean and J. McNabb. 1991. "Flaked flakes: what, where, when and why?" *Lithics* 12: 1-11.

Baddeley, A. and R. Turner. 2005. *spatstat: An R Package for Analyzing Spatial Point Patterns. Journal of Statistical Software* 12(6): 1-42. Available: http://cran.r-project.org/web/packages/spatstat/index.html

Bailey, G. 2007. "Time perspectives, palimpsests and the archaeology of time." *Journal of Anthropological Archaeology* 26 (2): 198-223.

Baker, C. 1978. "The size effect: an explanation of variability in surface artifact assemblage content." *American Antiquity* 43 (2): 734-40.

Baldus, H. 1937. *Ensaios de etnologia brasileira*. São Paulo: Companhia Editorial Nacional.

Balée, W.L. and C.L. Erickson 2006. Time, Complexity and Historical Ecology. In: Balée, W.L. and C.L. Erickson (Eds.), *Time and Complexity in Historical Ecology: Studies in the Neotropical Lowlands.* New York: Columbia University Press. 235-278.

Bamforth, D.B. 1991. "Technological Organization and Hunter-Gatherer Land Use: A California Example." *American Antiquity* 56 (2): 216–234.

Banning, E.B. 2002. *Archaeological Survey*. New York: Springer.

Barreto, C. 1998. "Brazilian archaeology from a Brazilian perspective." *Antiquity*, 72(277), 573-581.

Barreto, C. 2014. Social Complexity in Ancient Amerindian Societies: Perspectives from the Brazilian Lowlands. In: Gnecco, C. and C. Langebaek (Eds.), *Against Typological Tyranny in Archaeology*. New York: Springer. 1-8.

Barth, F. 1966. "Anthropological Models and Social Reality." *Proceedings of the Royal Society of London. Series B, Biological Sciences* 165 (998): 20-34.

Barth F. l969. Introduction. In: Barth, F. (Ed.), *Ethnic Groups and Boundaries: The Social Organization of Culture Difference*. London: Allen & Unwin. 9–38.

Barton, C.M., I. Ullah and H. Mitasova. 2010. "Computational modelling and Neolithic socioecological dynamics: a case study from southwest Asia" *American Antiquity* 75 (2): 364-386.

Baxter, M.J., C.C. Beardah and R.V.S. Wright. 1997. "Some Archaeological Applications of Kernel Density Estimates." *Journal of Archaeological Science* 24 (4): 347-354.

Beber, M.V. 2005. O Sistema de assentamento dos grupos ceramistas do planalto Sul-Brasilerio: O Caso da Tradição Taquara/Itararé. *Documentos* 10. São Leopoldo: Instituto Anchietano de Pesquisas. 5–125.

Becker, I.I.B. and P.I. Schmitz. 1969. Uma cerâmica do tipo Eldoradense: fase Itapiranga. In: *Estudos de Pré-história Geral* e *Brasileira*. São Paulo: Universidade de São Paulo. 499-506.

Behling, H. 1995. "Investigations into the Late Pleistocene and Holocene history of vegetation and climate in Santa Catarina (S Brazil)" *Vegetation History and Archaeobotany* 4: 127–152.

Behling, H. 1997. "Late Quaternary vegetation, climate and fire history of the Araucaria forest and campos region from Serra Campos Gerais, Paraná State (South Brazil)." *Review of Palaeobotany and Palynology* 97 (1-2): 109-121.

Behling, H. 1998. "Late Quaternary vegetational and climatic changes in Brazil." *Review of Palaeobotany and Palynology* 99 (2): 143-156.

Behling, H. 2002. "South and southeast Brazilian grasslands during Late Quaternary times: a synthesis." *Palaeogeography, Palaeoclimatology, Palaeoecology* 177 (1-2): 19-27.

Behling, H., H.W. Arz, J. Pätzold and G. Wefer. 2002. "Late Quaternary vegetational and climate dynamics in southeastern Brazil, inferences from marine cores GeoB 3229-2 and GeoB 3202-1." *Palaeogeography, Palaeoclimatology, Palaeoecology* 179 (3): 227-243.

Behling, H., V. Pillar, L. Orloci and S. Bauermann. 2004. "Late Quaternary Araucaria forest, grassland (Campos), fire and climate dynamics, studied by high-resolution pollen, charcoal and multivariate analysis of the Cambará do Sul core in southern Brazil." *Palaeogeography, Palaeoclimatology, Palaeoecology* 203 (3-4): 277-297.

Behling, H., V.D. Pillar, and S.G. Bauermann. 2005. "Late Quaternary grassland (Campos), gallery forest, fire and climate dynamics, studied by pollen, charcoal and multivariate analysis of the São Francisco de Assis core in western Rio Grande do Sul (southern Brazil)." *Review of Palaeobotany and Palynology* 133 (3-4): 235-248.

Behling, H. and V.D. Pillar. 2007. "Late Quaternary vegetation, biodiversity and fire dynamics on the southern Brazilian highland and their implication for conservation and management of modern Araucaria forest and grassland ecosystems." *Philosophical transactions of the Royal Society of London. Series B, Biological sciences* 362 (1478): 243-51.

Bell, T. and G.R. Lock. 2000. Topographic and cultural influences on walking the Ridgeway in later prehistoric times. In: Lock, G.R. (Ed.), *Beyond the Map: Archaeology and Spatial Technologies.* Amsterdam: IOS Press. 85-100.

Bender, B. 2002. "Time and Landscape." *Current Anthropology* 43: 103-112.

Besag, J. 1977. "Contribution to the discussion of Dr. Ripley's paper" *Journal of the Royal Statistical Society* B 39 (2): 193-195.

Bevan, A. 2011. Computational models for understanding movement and territory. In: Mayoral Herrera, V. and S. Celestino-Pérez, S. (Eds.), *Tecnologías de información geográfica y análisis arqueológico del territorio: Actas del V Simposio Internacional de Arqueología de Mérida*. Mérida: Consejo Superior de Investigaciones Científicas. 383-394.

Bevan, A. 2012. "Spatial methods for analysing large-scale artefact inventories" *Antiquity* 86: 492-506.

Bevan, A. and J. Conolly. 2002. "GIS, Archaeological Survey, and Landscape Archaeology on the Island of Kythera, Greece." *Journal of Field Archaeology* 29 (1/2): 123-138.

Bevan, A. and J. Conolly. 2006. Multiscalar Approaches to Settlement Pattern Analysis. In: Lock, G. and B.L. Molyneaux (Eds.), *Confronting Scale in Archaeology: Issues of Theory and Practice.* New York: Springer. 217-234.

Bevan, A. and J. Conolly. 2009. "Modelling spatial heterogeneity and nonstationarity in artifact-rich landscapes" *Journal of Archaeological Science* 36: 956-964.

Bevan, A. and M. Lake. (Eds.) 2013. *Computational Approaches to Archaeological Spaces*. Walnut Creek: Left Coast Press.

Bevan, A., E.R. Crema, X. Li and A. Palmisano. 2013. Intensities, interactions and uncertainties: some new approaches to archaeological distributions. In: Bevan, A. and M. Lake. (Eds.), *Computational Approaches to Archaeological Spaces*. Walnut Creek: Left Coast Press.

Beyer, H.L. 2012. *Geospatial Modelling Environment.* Available: http://www.spatialecology.com/gme/. Last accessed 10 Dec 2013.

Binford, L.R. 1964. "A Consideration of Archaeological Research Design." *American Antiquity* 29 (4): 425-441.

Binford, L.R. 1980. "Willow Smoke and Dog's Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation." *American Antiquity* 45 1: 4-20.

Binford, L.R. 1982. "The Archaeology of Place." *Journal of Anthropological Archaeology* 1 (1): 5-31.

Bintliff, J., and A. Snodgrass. 1988. "Off-Site Pottery Distributions: A Regional and Interregional Perspective." *Current Anthropology* 29 3: 506-513.

Bitencourt, A.L.V., and P.M. Krauspenhar. 2006. "Possible prehistoric anthropogenic effect on Araucaria angustifolia (Bert.) O. Kuntze expansion during the late Holocene." *Revista Brasileira de Paleontologia* 9 (1): 109-116.

Blades, B. 2008. Reduction and Retouch as Independent Measures of Intensity. In: Andrefsky, W. (Ed.), *Lithic Technology: Measures of Production, Use and Curation.* Cambridge: Cambridge University Press. 136-149.

Bonomo, M., F.J. Aceituno, G.G. Politis, and M.L. Pochettino. 2011a. "Pre-Hispanic horticulture in the Paraná Delta (Argentina): archaeological and historical evidence." *World Archaeology* 43 (4): 37–41.

Bonomo, M., G. Politis, C. Gianotti-García. 2011b. "Montículos, jerarquía social y horticultura en las sociedades indígenas del Delta del Delta del río Paraná." *Latin American Antiquity* 22 (3): 297-333.

Bonomo, M., R. Costa Angrizani, E. Apolinaire, F.S. Noelli. 2015. "A model for the Guaraní expansion in the La Plata Basin and littoral zone of southern Brazil" *Quaternary International* 356: 54-73 http://dx.doi.org/10.1016/j.quaint.2014.10.050.

Bourdieu, P. 1977. *Outline of a Theory of Practice.* Cambridge: Cambridge University Press.

Bourdieu, P. 1985. "The Social Space and the Genesis of Groups." *Theory and Society* 14 (6): 723-744.

Bradbury, A.P., J.L. Allgood, J.M. Anderson, M.D. Richmond and D.L. Rotman. "Exploring surface collected data with spatial analysis methods" *North American Archaeologist* 29 (1): 13-36.

Brenner, N. 2001. "The limits to scale? Methodological reflections on scalar structuration." *Progress in Human Geography* 25 (4): 591–614.

Brochado, J.P., V. Calderón, I. Chmyz, O.F. Dias, C. Evans, S. Marancas, B.J. Meggers, E.T. Miller, N.A.S. Nasser, C. Perota, W.F. Piazza, J.W. Wrauth, and M.F. Simões. 1969. "Arqueologia Brasileira em 1968." *Publicações Avulsas do Museu Paraense Emílio Goeldi* 12: 2-39.

Brochado, J.P. 1984. *An Ecological Model of the Spread of Pottery and Agriculture into Eastern South America.* Department of Anthropology: University of Illinois, Urbana-Champaign. Unpublished PhD dissertation.

Broxton, P.D., X. Zeng, D. Sulla-Menashe, and P.A. Troch. 2014. "A Global Land Cover Climatology Using MODIS Data". *J. Appl. Meteor. Climatol.,* 53: 1593–1605. doi: http://dx.doi.org/10.1175/JAMC-D-13-0270.1

Brugger, P. 2001. From Haunted Brain to Haunted Science: A Cognitive Neuroscience View of Paranormal and Pseudoscientific Thought In: Houran, J. and R. Lange (Eds.), *Hauntings and Poltergeists: Multidisciplinary Perspectives.* Jefferson: McFarland & Co, Inc. Publishers. 195-213.

Bruhns, K.O. *Ancient South America*. Cambridge: Cambridge University Press.

Bryan, R.B. 2000. "Soil erodibility and processes of water erosion on hillslope." *Geomorphology* 32 (4): 385–415.

Bueno, L. 2010a. "Beyond Typology: Looking for Processes and Diversity in the Study of Lithic Technology in the Brazilian Amazon." *Journal of World Prehistory* 23 (3): 121–143.

Bueno, L. 2010b. "Tecnologia litica, cronologia e sequencia de ocupacao: o estudo de um sitio a ceu aberto na regiao de Lagoa Santa, MG. *Revista do Museu de Arqueologia e Etnologia* 20: 91-107.

Bueno, L., A.S. Dias and J. Steele. 2013. "The Late Pleistocene/Early Holocene archaeological record in Brazil:A geo-referenced database" *Quaternary International* 301: 74-93.

Burger, O., L.C. Todd, P. Burnett, T.J. Stohlgren and D. Stephens. 2002. "Multi-Scale and Nested-Intensity Sampling Techniques for Archaeological Survey." *Journal of Field Archaeology* 29 3/4: 409-423.

Burger, O. and L.C. Todd. 2006. Grain, Extent and Intensity: The Components of Scale in Archaeological Survey. In: Lock, G. and B.L. Molyneaux (Eds.), *Confronting Scale in Archaeology: Issues of Theory and Practice.* New York: Springer. 235-256.

Cabral, M.P. 2005. *Sobre coisas, lugares e pessoas: Uma prática interpretativa na arqueologia de caçadores coletores do Sul do Brasil*. Faculdade de Filosofia e Ciências Humanas: Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre. Unpublished MA dissertation.

Caggiano, M.A. 1984. "Prehistoria del N.E. Argentino, sus vinculaciones con la República Oriental del Uruguay y Sur de Brasil." *Pesquisas (Antropología)* 38: 5-109.

Callegari-Jacques, S.M., E.M. Tarazona-Santos, R.H. Gilman, P. Herrera, L. Cabrera, S.E.B. dos Santos, L. Morés, M.H. Hutz, and F.M. Salzano. 2011. "Autosome STRs in native South America-Testing models of association with geography and language." *American Journal of Physical Anthropology* 145 (3): 371–81.

Camilli, E.L. and J.I. Ebert. 1998. Artifact Reuse and Recycling in Continuous Surface Distributions and Implications for Interpreting Land Use Patterns. In: Rossignol, J. and L. Wandsnider (Eds.), *Space, Time, and Archaeological Landscapes.* New York: Plenum Press. 113-136.

Caraher, W.R., D. Nakassis and D.K. Pettegrew. 2006. "Siteless Survey and Intensive Data Collection in an Artifact-rich Environment: Case Studies from the Eastern Corinthia, Greece." *Journal of Mediterranean Archaeology* 19 (1): 7–43.

Carbonera, M. 2009. "Patrimônio arqueológico no oeste de Santa Catatina: do Colecionismo ao Científico." *Revista de Arqueologia* 21 1: 83-98.

Carbonera, M. 2013. "Notas sobre a história das sociedades précoloniais do oeste catarinense." *Tempos Acadêmicos* 11: 117-134.

Carr, C. 1984. "The Nature of Organization of Intrasite Archaeological Records and Spatial Analytic Approaches to Their Investigation." *Advances in Archaeological Method and Theory* 7: 103-222.

Carr, C. 1987. Removing Discordance from Quantitative Analysis. In: Aldenderfer, M. (Ed.), *Quantitative Research in Archaeology: Progress and Prospects*. New York: SAGE Publications. 185-243.

Carr, P.J. 1994. The Organization of Technology: Impact and Potential. In: Carr, P.J. (Ed.), *The Organization of North American Prehistoric Chipped Stone Tool Technologies*. Ann Arbor: International Monographs in Prehistory, Archaeological Series No. 7. 1-8.

Carr, P.J. and A.P. Bradbury. 2011. "Learning From Lithics: A Perspective on the Foundation and Future of the Organization of Technology." *Palaeoanthropology* 2011: 305-319.

Chase, A.F., D.Z. Chase, J.F. Weishampel, J.B. Drake, R.L. Shrestha, K.C. Slatton, J.J. Awe and W.E. Carter. 2011. "Airborne LiDAR, archaeology, and the ancient Maya landscape at Caracol, Belize" *Journal of Archaeological Science* 38: 387-398.

Chebez, J.C. and Hilgert, N. 2003. Brief history of conservation in the Paraná Forest. In: Galindo-Leal, C. and Câmara, I.G. (Eds.), *The Atlantic Forest of South America: Biodiversity Status, Threats, and Outlook.* Washington D.C.: Island Press, 141–159.

Cherry, J.F., J.L. Davis, A. Demitrack, E. Mantzourani, T.F. Strasser, and L.E. Talalay. 1988. "Archaeological Survey in an Artifact-Rich Landscape: A Middle Neolithic Example from Nemea, Greece." *American Journal of Archaeology* 92 (2): 159-176.

Chmyz, I. 1967. "Dados sobre a arqueologia do Vale do Paranapanema." *Publicações Avulsas do Museu Paraense Emilio Goeldi*. 6: 59-73.

Chmyz, I. 1968. "Considerações sobre duas novas tradições ceramistas arqueológicas no Estado do Paraná." *Pesquisas (antropología)* 18: 115-125.

Chmyz, I. 1981. *Relatório das Pesquisas Arqueológicas Realizadas na Área da Usina Hidrelétrica de Salto Santiago (1979-80)*. Curitiba: Convênio Eletrosul-IPHAN.

Chmyz, I. 1983. *Projeto Arqueológico Itaipu: Sétimo Relatório das Pesquisas Realizadas na Área de Itaipu (1981/83)*. Curitiba: Convênio Itipu/IPHAN.

Chmyz, I., and Z.C. Sauner. 1971. "Notas prévia sobre as pesquisas arqueológicas no vale do Rio Piquiri." *Dédalo* 13: 7-31.

Chmyz, I., E.M. Sganzerla and J.E. Volcov. 1999 *Arqueologia da Área Prioritária – Projeto Hidroelétrico Tijuco Alto – Rio Ribeira – São Paulo – Paraná.* Curitiba: FUNPAR.

Clark, P. and C. Evans. 1954. "Distance to Nearest Neighbor as a Measure of Spatial Relationships in Populations" *Ecology* 35(4): 445-453.

Clarke, D.L. 1973. "Archaeology: Loss of Innocence." *Antiquity* 47 (185): 7-18.

Clarke, D.L. (Ed.). 1977. *Spatial Archaeology*. London: Academic Press.

Clinger, J. 2005. Our Elders: Six Bay Area Life Stories. Bloomington: Xlibris.

Close, A.E. 2000. "Reconstructing Movement in Prehistory" *Journal of Archaeological Method and Theory* 7 (1): 49-77.

Chrystanthi, A., P. Murrieta-Flores and C. Papadopoulos (Eds.) 2012. *Thinking Beyond the Tool: Archaeological computing and the interpretive process*. Oxford: Archaeopress. BAR International Series 2344.

Conolly, R.P. and A.P. Sullivan. 1998. Inferring Activities at Middle Woodland Earthworks with Surface Archaeological Data. In: Sullivan, A.P. (Ed.), *Surface Archaeology*. Albuquerque: University of New Mexico Press. 61-74.

Conolly, J. and M. Lake. 2006. *Geographical Information Systems in Archaeology*. Cambridge: Cambridge University Press.

Copé, S.M. 2006a. *Les grands constructeurs précoloniaux du plateau du sud du Brésil: étude de paysages archéologiques à Bom Jesus, Rio Grande do Sul, Brésil.* Institut d'Art et d'Archéologie : Université de Paris I, Paris. Unpublished PhD dissertation.

Copé, S.M. 2006b. "Narrativas espaciais das ações humanas História e aplicação da arqueologia espacial como teoria de médio alcance: o caso das estruturas semi-subterrâneas do planalto Sul-brasileiro." *Revista de Arqueologia* 19: 111-123.

Copé, S.M. 2007. "El uso de la arquitectura como artefacto en el estudio de paisajes arqueológicos." *Revista de Arqueologia* 2: 15–34.

Copé, S.M and J.D.M. Saldanha. 2002. "Em busca de um sistema de assentamento para o Planalto Sul-Riograndense: escavações no sítio RS-NA-03, Bom Jesus, RS." *Pesquisas, Antropologia* 58:107-120.

Copé, S.M., J.D.M. Saldanha and M. Cabral. 2002. "Contribuições para a pré-história do planalto: estudo da variabilidade de sítios arqueológicos de Pinhal da Serra, RS." *Pesquisas, Antropologia* 58: 121-138.

Corteletti, R. 2008. *Patrimônio Arqueológico de Caxias do Sul*. São Leopoldo: Editora Nova Prova.

Corteletti, R. 2012. *Projeto Arqueológico Alto Canoas – PARACA: Um Estudo da Presença Proto-Jê no Planalto Catarinense*. Museu de Arqueologia e Etnologia: University of São Paulo, São Paulo. Unpublished PhD dissertation.

Corteletti, R. R. Dickau, P. DeBlasis, J. Iriarte. 2015. "Revisiting the economy and mobility of southern proto-Jê (Taquara-Itararé) groups in the southern Brazilian highlands: starch grain and phytoliths analyses from the Bonin site, Urubici, Brazil" *Journal of Archaeological Science* 58: 46-61 http://dx.doi.org/10.1016/j.jas.2015.03.017.

Couteron, P. and K. Kokou. 1997. "Woody vegetation spatial patterns in a semi-arid savanna of Burkina Faso, West Africa" *Plant Ecology* 132: 211-227.

Cowan, F.L. 1999. "Making Sense of Flake Scatters: Lithic Technological Strategies and Mobility." *American Antiquity* 64 (4): 593-607.

Cowgill, G.L. 1990. Toward Refining Concepts of Full-Coverage Survey. In: Fish, S.K. and S.A. Kowalewski (Eds.), *The Archaeology of Regions*. Washington D.C.: Smithsonian Institution Press. 249-259.

Crema, E.R. and E. Bianchi. 2013. Looking for patterns in the noise: non-site spatial analysis at Sebkha Kalbia (Tunisia). In: Mulazzani, S. (Ed.), *Le Capsien de hergla (Tunisie). Culture, environnement et économie.* Frankfurt: Africa Magna Verlag. 385-395

Crépeau, R.R. 1994. "Mythe et rituel chez les indiens Kaingang du Bresil meridional" *Religiologiques* 10: 143-157.

Cressie, N.A.C. 1993. *Statistics for Spatial Data (Revised Edition)*. London: John Wiley & Sons.

Crow, P., S. Benham, B.J. Devereux and G.S. Amable. 2007. "Woodland vegetation and its implications for archaeological survey using LiDAR" *Forestry* 80 (3): 241-252.

Crumley, C.L. 1995. "Heterarchy and the Analysis of Complex Societies." *Archeological Papers of the American Anthropological Association* 6 (1): 1–5.

Curet, L.A. 2003. "Issues on the Diversity and Emergence of Middle-Range Societies of the Ancient Caribbean: A Critique." *Journal of Archaeological Research* 11 (1): 1–42.

Curtoni, R.P., and G.G. Politis. 2006. "Race and racism in South American archaeology." *World Archaeology* 38 (1): 93-108.

Da Silva, S.B. 2001. *Etnoarqueologia dos Grafismos Kaingang: um modelo para a compreensão das sociedades Proto-Jê meridionais*. Faculdade de Pós-graduação em Antropologia Social: University of São Paulo, São Paulo. Unpublished PhD dissertation

Da Silva, S.B. 2002. "Dualismo e cosmologia Kaingang: o xamã e o domínio da floresta." *Horizontes Antropológicos* 8 (18): 189-209.

Da Silva, R.T. 2010. "Some Aspects of 'Grey Literature' in Brazil." *Archaeologies* 6 (2): 327–336.

DeBoer, W., K. Kintigh and A.G. Rostoker. 1996. "Ceramic Seriation and Site Reoccupation in Lowland South America." *Latin American Antiquity* 7 (3): 263-278.

DeBlasis, P., A. Kneip, R. Scheel-Ybert, and M.D. Gaspar. 2007. "Sambaquis e paisagem: dinâmica natural e arqueologia regional no litoral sul do Brasil." *Arqueologia Sudamericana/Arqueologia Sul-Americana* 3 (1): 29-61.

Delle, J.A. 2003. "Views and Commentaries On Collaboration , Class Conflict , and Archaeology in Brazil." International Journal of Historical Archaeology 7 (3): 223-237.

De Luis, M., J. Raventós, T. Wiegand and J. González-Hidalgo. 2008. "Temporal and spatial differentiation in seedling emergence may promote species coexistence in Mediterranean fire-prone ecosystems" *Ecography* 31: 620-629.

DeMarrais, E., L.J. Castillo, and T. Earle. 1996. "Ideology, Materialization, and Power Strategies." *Current Anthropology* 37 (1): 15–31.

de Oliveira, P.E., H. Behling, M.-P. Ledru, M. Barberi, M. Bush, M.L. Salgado-Labouriau, M.J. Garcia, S. Medeanic, O.M. Barth, M. Barros and R. Scheel-Ybert. 2005. Paleovegetação e Paleoclimas do Quaternário do Brasil. Cap. In: Souza, C.R.G., K. Suguio, A.M.S. Oliveira, and P.E. de Oliveira (Eds.), *Quaternário do Brasil*. São Paulo: Ribeirão Preto, 52–74.

De Masi, M.A.N. 1999. *Mobilidade de caçadores coletores pré-históricos na costa sulbrasileira*. Department of Anthropology: Stanford University, Stanford. Unpublished PhD dissertation.

De Masi, M.A.N. 2005. *Projeto de Salvamento Arqueológico Usina Hidrelétrica de Campos Novos*. Florianópolis: Brazil.

De Masi, M.A.N. (Ed.). 2006. *Xokleng 2869 a.C. As terras altas do sul do Brasil.* Tubarão: Editora Unisul.

De Masi, M.A.N. 2007. Análise de Isotopos Estáveis de 13/12C e 15/14N em resíduos de incrustações carbonizadas de fundo de recipientes cerâmicos das Terras Altas do Sul do Brasil. In: *XIV Congresso da SAB*. Vol. 4. Florianópolis, Brazil.

De Masi, M.A.N. 2009. "Centros Cerimoniais do Planalto Meridonal: Uma Análise Intrasítio". *Revista de Arqueologia* 22 (1): 99-113.

De Masi, M.A.N. and L. Artusi. 1985. "Fase Itapiranga: Sítios da tradição planáltica" *Pesquisas, Antropologia* 40: 99-121.

Denevan, W.M. 1966. "A Cultural-Ecological View of the Former Aboriginal Settlement in the Amazon Basin." *The Professional Geographer* 18 (6): 346–351.

Denevan, W.M. 2012. "Rewriting the Late Pre-European History of Amazonia." *Journal of Latin American Geography* 11 (1): 9-24.

De Souza, J.G. 2011. "Linguistics, archaeology, and the histories of language spread: the case of the Southern Jê languages, Brazil." *Cadernos de Etnolingüística* 3 (2).

De Souza, J.G. and S.M. Copé. 2010. "Novas perspectivas sobre a arquitetura ritual do planalto meridional Brasileiro: Pesquisas recentes em Pinhal da Serra, RS." *Revista de Arqueologia*, 23 (2): 104–117.

De Souza, J.G. and F.T. Merencio. 2013. "A diversidade dos sítios arqueológicos Jê do Sul no Estado do Paraná" *Cadernos do LEPAARQ* 20: 93-130.

Devereux, B.J., G.S. Amable, P. Crow and A.D. Cliff. 2005. "The potential of airborne lidar for detection of archaeological features under woodland canopies" *Antiquity* 79: 648-660.

Dias, A.S. 2003. *Sistemas de Assentamento e Estilo Tecnológico: Uma Proposta Interpretativa para a Ocupação Pré-colonial do Alto Vale do Rio dos Sinos, Rio Grande do Sul*. Faculdade de Filosofia, Letras e Ciências Humanas: University of São Paulo, São Paulo. Unpublished PhD dissertation.

Dias, A.S., 2004. "Diversificar para poblar: el contexto arqueológico braliseño en la transición Pleistoceno-Holoceno" *Complutum* 15: 249-263.

Dias, A.S. 2006. Indústrias Líticas da Tradição Taquara no Alto Vale do Rio Dos Sinos. In: De Masi, M.A.N. (Ed.). 2006. *Xokleng 2869 a.C. As terras altas do sul do Brasil.* Tubarão: Editora Unisul. 178-187.

Dias, A.S. 2007a. "Novas perguntas para um velho problema: escolhas tecnológicas como índices para o estudo de fronteiras e identidades sociais no registro arqueológico." *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas* 2 (1): 59-76.

Dias, A.S. 2007b. Da Tipologia à Tecnologia. In: Bueno, L. and A. Isnardis (Eds.), *Das Pedras aos Homens: Tecnologia Lítica na Arqueologia Brasileira*. Belo Horizonte: Argumentum. 33-66.

Dias, A.S. 2012. "Hunter-gatherer occupation of south Brazilian Atlantic Forest: Paleoenvironment and archaeology." *Quaternary International* 256: 12-18.

Dias, A.S. and A. Jacobus. 2001. "The antiquity of the peopling of southern Brazil" *Current Research in the Pleistocene* 18: 17-19.

Dias, A.S., and S.E. Hoeltz. 2010. "Indústrias líticas em contexto: o problema Humaitá na Arqueologia Sul Brasileira." *Revista de Arqueologia* 23 (2): 40-67.

Dibble, H. L., U.A. Schurmans, R.P. Iovita and M.V. McLaughlin. 2005. "The Measurement and Interpretation of Cortex in Lithic Assemblages." *American Antiquity* 70 (3): 545–560.

Diez-Martín, F., P. Sánchez-Yustos, J.A. Gómez-González and D. Gómez de la Rúa. 2008. "Earlier Palaeolithic Settlement Patterns: Landscape Archaeology on the River Duero Basin Plateaus (Castilla y León, Spain)." *Journal of World Prehistory* 21 (2): 103–137.

Diggle, P.J. 2003. *Statistical Analysis of Spatial Point Patterns*. 2nd ed. London: Arnold.

Dijkstra, E.W. 1959. "A note on two problems in connexion with graphs" *Numerische Mathematik* 1: 269–271.

Douglass, M.J., S.J. Holdaway, S.J., P.C. Fanning and J.I. Shiner. 2008. "An Assessment and Archaeological Application of Cortex Measurement in Lithic Assemblages." *American Antiquity* 73 (3): 513–526.

Douglass, M. 2010. *The Archaeological Potential of Informal Lithic Technologies: A Case Study of Assemblage Variability in Western New South Wales, Australia*. Department of Anthropology: University of Auckland, Auckland. Unpublished Ph.D. dissertation.

Downey, J.T. 2010. Working With Expedient Lithic Technologies in the Northern Highlands of Peru. *vis-à-vis: Explorations in Anthropology* 10(2): p.77–95.

Dunnell, R.C. and W.S. Dancey. 1983. "The Siteless Survey: A Regional Scale Data Collection Strategy." *Advances in Archaeological Method and Theory* 6: 267-287.

Dunnell, R.C. 1992. The Notion Site. In: Rossignol, J. and L. Wandsnider (Eds.), *Space, Time, and Archaeological Landscapes.* New York: Plenum Press. 21-41.

Ebert, J.I. 1992. *Distributional Archaeology*. Salt Lake City: University of Utah Press.

Ebert, J.I. 2000. The State of the Art in "Inductive" Predictive Modeling: Seven Big Mistakes (and Lots of Smaller Ones). In: Wescott, K.L. R.J. and Brandon (Eds), *Practical Applications of GIS for Archaeologists: A Predictive Modeling Toolkit.* London: Taylor & Francis. 129-134.

Edmonds, B., P. Lucas, J. Rouchier and R. Taylor. 2013. Human Societies – Understanding Observed Social Phenomena. In: Edmonds, B. and R. Meyer (Eds), *Simulating Social Complexity - A Handbook*. New York: Springer. 709-749.

Eidt, R.C. 1971. *Pioneer Settlement in Northeast Argentina*. Madison: University of Wisconsin Press.

El-Swaify, S.A. 1997. "Factors affecting soil erosion hazards and conservation needs for tropical steeplands." *Soil Technology* 11 (1): 3-16.

Epstein, J. 2008. "Why model?" *Journal of Artificial Societies and Social Simulation* 11 (4). http://jasss.soc.surrey.ac.uk/11/4/12.html

Erickson, C.L. 2001."Pre-Columbian Roads of the Amazon" *Expedition* 43(2): 21-30.

Erickson, C.L. 2008. "Amazonia: The Historical Ecology of a Domesticated Landscape" In: Silverman, H. and W.H. Isbell (Eds.), *Handbook of South American Archaeology*. New York: Springer. 157-183.

Erickson, C.L. 2009. Agency, Causeways, Canals, and the Landscapes of Everyday Life in the Bolivian Amazon. In: Snead, J.E., C.L. Erickson and J.A. Darling (Eds.), *Landscapes of Movement: Trails, Paths and Roads in Anthropological Perspective.* Philadelphia: University of Pennsylvania Press. 204-231.

Erickson, C.L. and W. Balée. 2006. The Historical Ecology of a Complex Landscape in Bolivia. In: Balée, W. and C.L. Erickson (Eds.), *Time and Complexity in Historical Ecology: Studies in the Neotropical Lowlands*. New York: Columbia University Press. 187-234.

ESRI. 2012. *How the path distance tools work.* Available: http://resources.arcgis.com/en/help/main/10.1/index.html#//009z00000027000000. Last accessed 10 Dec 2013.

Evans, C. 1950. *The Archaeology of the Territory of Amapa, Brazil.* Department of Anthropology, Columbia University, New York. Unpublished PhD dissertation.

Evans, C. and B.J. Meggers. 1961. *Archaeological Investigations in British Guiana*. Washington D.C.: Bureau of American Ethnology, Bulletin 177.

Eve, S.J. and E.R. Crema. 2014. "A house with a view? Multi-model inference, visibility fields, and point process analysis of a Bronze Age settlement on Leskernick Hill (Cornwall, UK)" *Journal of Archaeological Science* 43: 267-277.

Fabian, S.M. 1992. *Space-time of the Bororo of Brazil*. Gainsville: University Press of Florida.

Fábrega-Álvarez, P. and C. Parcero-Oubiña. 2007 "Proposals for an archaeological analysis of pathways and movement" *Archeologia e Calcolatori* 18: 121-40.

Fanning, P.C., S.J. Holdaway and E. Rhodes. 2007. "A geomorphic framework for understanding the surface archaeological record in arid environments." *Geodinamica Acta* 20(4): 275 – 286

Feathers, J., R. Kipnis, L. Piló, M. Arroyo-Kalin and D. Coblentz. 2010. "How Old Is Luzia? Luminescence Dating and Stratigraphic Integrity at Lapa Vermelha, Lagoa Santa, Brazil" *Geoarchaeology: An International Journal* 25 (4): 395-436.

Foley, R. 1981a. "A model of regional archaeological structure" *Proceedings of the Prehistoric Society* 47: 1-17.

Foley, R. 1981b. Off-site Archaeology: an alternative approach for the short-sited. In: Hodder, I., G. Isaac and N. Hammond (Eds.), *Pattern of the Past: studies in honour of David Clarke*. Cambridge: Cambridge University Press. 157-183.

Ford, J.A. 1962. *A Quantitative Method for Deriving Cultural Chronology.* Washington D.C.: Pan-American Union.

Fortin, M.J., M.R.T. Dale and J. ver Hoef. 2002. Spatial Analysis in Ecology. In: El-Shaarawi, A.H. and W.W. Piegorsch (Eds.), *Encyclopedia of Environmetrics*. Chichester: John Wiley & Sons. 2051-2058.

Fortin, M.J. and M.R.T. Dale. 2005. *Spatial Analysis: A Guide for Ecologists*. Cambridge: Cambridge University Press.

Francovich, R., H. Patterson and G. Barker (Eds.). 2000. *Extracting Meaning From Ploughsoil Assemblages. Volume 5 of The Archaeology of Mediterranean Landscapes.* Oxford: Oxbow books.

Frello, B. 2008. "Towards a Discursive Analytic sof Movement: On the Making and Unmaking of Movement as an Object of Knowledge" *Mobilities* 3 (1): 25-50.

Fritz, J.M. and F.T. Plog. 1970. "The Nature of Archaeological Explanation." *American Antiquity* 35 (4): 405-412.

Funari, P.P.A. 1995. Mixed features of archaeological theory in Brazil. In: Ucko, P.J. (Ed.), *Theory in Archaeology: A World Perspective*. London: Routledge, 232-246.

Funari, P.P.A. 1999. Brazilian Archaeology: A Reappraisal. In: Politis, G.G. and B. Alberti (Eds.), *Archaeology in Latin America*. London: Routledge, 17-37.

Funari, P.P.A. 2000. "Como se tornar arqueólogo no Brasil." Revista USP 44: 74-85.

Funari, P.P.A. 2002. "Class Interests in Brazilian Archaeology." *International Journal of Historical Archaeology* 6 (3): 209-216.

Galhardo, D.A. 2010. "*Tecnologia lítica: Estudo da variabilidade em sítios líticos do nordeste do estado de São Paulo.*" Museu de Arqueologia e Etnologia: University of São Paulo, São Paulo. Unpublished PhD dissertation. Unpublished MA dissertation.

Galindo-Leal, C. and I.G. Câmara (Eds.). 2003. *The Atlantic Forest of South America: Biodiversity Status, Threats, and Outlook.* Washington D.C.: Island Press.

Gallant, T.W. 1986. ""Background Noise" and Site Definition: A Contribution to Survey Methodology." *Journal of Field Archaeology* 13 (4): 403–418.

García, N.O. and R.A. Pedraza. 2008. "Daily rainfall variability over northeastern Argentina in the La Plata River basin." *Annals of the New York Academy of Sciences* 1146 (1): 303-19.

Gaspar, M.D. 1998. "Considerations of the sambaquis of the Brazilian coast." *Antiquity* 72 (277): 592-615.

Gaspar, M.D., P. DeBlasis, S.K. Fish and P.R. Fish 2008. Sambaqui (Shell Mound) Societies of Coastal Brazil. In: Silverman, H. and W.H. Isbell (Eds.), *Handbook of South American Archaeology*. New York: Springer. 319-338.

Gassón, R.A. 2002. "Orinoquia: The Archaeology of the Orinoco River Basin" *Journal of World Prehistory* 16 (3): 237-311.

Gessert, S., J. Iriarte, R.C. Ríos and H. Behling. 2011. "Late Holocene vegetation and environmental dynamics of the Araucaria forest region in Misiones Province, NE Argentina." *Review of Palaeobotany and Palynology*: 1-2: 29-37.

Getis, A. 1984. "Interaction modeling using second-order analysis" *Environment and Planning A* 16: 173-183.

Getis, A. and J. Franklin. "Second-Order Neighborhood Analysis of Mapped Point Patterns" *Ecology* 68 (3): 473-477.

Giddens, A. 1984. *The Constitution of Society: An Outline of the Theory of Structuration.* Berkeley: University of California Press.

Giesso, M. 1984. "Excavaciones arqueológicas en un sitio guaraní en cueva. El Dorado, Misiones." *Actualidad Antropológica* 20: 32-33.

Giesso, M. and R. Poujade, 1986. "Proyecto de relevamiento prehistórico e histórico en la cuenca de aprovechamiento hidroeléctrico del arroyo Uruguaí." *Arqueología* 5: 91-102.

Giesso M. and A. Rizzo. 1985. "Puerto Victoria, un sitio de tradición tupi-guaraní en el Alto Paraná, Misiones." *Ymaguaré* 1:5-28.

Giesso, M. 1998. "Sobre A Periferia: Os Arrabaldes das Missões Jesuítico-Guaraní." *Fronteiras: Revista Historia do UFMS* 2 (4): 251-274.

Giraudo, A.R., H. Povedano, M.J. Belgrano, E.R. Krauczuk, U. Pardiñas, A. Miquelarena, D. Ligier, D. Baldo and M. Castelino. 2003. Biodiversity Status of the Interior Atlantic Forest of Argentina. In: Galindo-Leal, C. and I.G. Câmara (Eds.). *The Atlantic Forest of South America: Biodiversity Status, Threats, and Outlook*. Washington D.C.: Island Press. 160-180.

Gonzalez, A.R. 1985. "Cincuenta Anos de Arqueologia del Noroeste Argentino (1930-1980): Apuntes de un Casi Testigo y Algo de Protagonista." *American Antiquity* 50 (3): 505-517.

Goodchild, M.F. and D.G. Janelle. 2010. "Toward critical spatial thinking in the social sciences and humanities" *GeoJournal* 75: 3-13.

Goreaud, F., and R. Pélissier, 1999. "On Explicit Formulas of Edge Correction for Ripley's K-Function" *Journal of Vegetation Science* 10: 433-438.

Gosden, C. 2004. Making and Display: our aesthetic appreciation of things and objects. In: Renfrew, C., C. Gosden and E. DeMarrais (Eds.), *Substance, Memory, Display: Archaeology and Art.* Cambridge: McDonald Institute for Archaeological Research. 35-45.

Gouma, M., G.J. van Wijngaarden and S. Soetens. 2011. "Assessing the effects of geomorphological processes on archaeological densities: a GIS case study on Zakynthos Island, Greece." *Journal of Archaeological Science* 38 (10): 2714 – 2725.

Gnecco, C. 2003. "Against ecological reductionism: Late Pleistocene hunter-gatherers in the tropical forests of northern South America." *Quaternary International* 109-110: 13-21.

Gillings, M. 2009. "Visual affordance, landscape, and the megaliths of Alderney" *Oxford Journal of Archaeology* 28 (4): 335-356.

Griffiths, S. 2012. GIS and Research into Historical "Spaces of Practice". In: von Lünen, A. and C. Travis (Eds.), *History and GIS: Epistemologies, Considerations and Reflections*. New York: Springer Science & Business Media. 153-173.

Grills, B.R. 2008. Placing Stone Tool Production in Context: Interpreting Small Lithic Sites in the Upper Susquehanna River Valley. In: Rieth, C.B. (Ed.), *Current Approaches to Analysis and Interpretation of Small Lithic Sites in the Northeast.* Albany: New York State Education Department. New York State Museum Bulletin Series 508. 121-146.

Haining, R.P. 2010. The Nature of Georeferenced Data. In: Fischer, M.M. and A. Getis (Eds.), *Handbook of Applied Spatial Analysis*. London: Springer. 197-218.

Harrison, R. 2011. "Surface Assemblages. Towards an archaeology in and of the present." *Archaeological Dialogues* 18 (2): 141-161.

Heberts, A.L. 2006. Arqueologia do Planalto Catarinense: Os Vales Dos Rios Chapecó e Pelotas. In: De Masi, M.A.N. (Ed.). 2006. *Xokleng 2869 a.C. As terras altas do sul do Brasil.* Tubarão: Editora Unisul. 155-165.

Heckenberger, M.J. 1996. *War and Peace in the Shadow of Empire: Socio-political Change in the Upper Xingu of Southeastern Amazonia, ca. A.D. 1400-2000*. Department of Anthropology: University of Pittsburgh, Pittsburgh. Unpublished PhD dissertation.

Heckenberger, M.J. 2005. *The Ecology of Power: Culture, Place and Personhood in the Southern Amazon, AD 1000-2000*. Routledge: London.

Heckenberger, M.J., J.B. Petersen and E.G Neves. 1999. "Village Size and Permanence in Amazonia: Two Archaeological Examples from Brazil." *Latin American Antiquity* 10 (4): 353-376.

Heckenberger, M.J., and E.G Neves. 2009. "Amazonian Archaeology." *Annual Review of Anthropology* 38 (1): 251-266.

Henry, J. 1964. *Jungle People: A Kaingáng Tribe of the Highlands of Brazil*. New York: Random House.

Henry, D.O. 1989. "Correlations Between Reduction Strategies and Settlement Patterns." *Archeological Papers of the American Anthropological Association*, 1 (1): 139–155.

Herzog, I. 2010. Theory and Practice of Cost Functions. In: Melero, F.J., P. Cano and J. Revelles (Eds.), *CAA 2009 – Fusion of Cultures*. April 6-9, Granada, Spain.

Hilbert, K. 1994. Caçadores-coletores pré-históricos no sul do Brasil: um projeto para uma redefinição das Tradições líticas Umbu e Humaitá. In: Flores, M. (Ed.), *Negros e índios: literatura e história*. Porto Alegre: EDIPUCRS. 9-24.

Hilbert, K. 2000. O Problema da Cronologia e da Interpretação Étnica. In: Kern, A.A. (Ed.), *Sociedades ibero-americanas: reflexões e pesquisas recentes. Coleção História 35*. Porto Alegre: EDIPUCRS. 373-380.

Hillier, B. and J. Hanson. 1984. *The Social Logic of Space.* Cambridge: Cambridge University Press.

Hodder, I. and C. Orton. 1976. *Spatial Analysis in Archaeology*, New Studies in Archaeology I. Cambridge: Cambridge University Press.

Hoeltz, S.E. 2005. *Tecnologia Lítica: Uma Proposta de Leitura para a compreensão das indústrias do Rio Grande do Sul, Brasil, em Tempos Remotos.* Faculdade de Filosofia e Ciências Humanas: Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre. Unpublished PhD dissertation.

Hoeltz, S. 2007. Contexto e Tecnologia: Parâmetros para uma interpretação das Indústrias líticas do Sul do Brasil. In: Bueno, L. and A. Isnardis (Eds.), *Das Pedras aos Homens: Tecnologia Lítica na Arqueologia Brasileira*. Belo Horizonte: Argumentum. 209-242.

Hoeltz, S.E. and A.A. Brüggeman. 2011. As indústrias líticas na área da UHE Foz do Chapecó, oeste catarinense: antiguidade, estratégia tecnológica e variabilidade. In: Carbonera, M. and P.I. Schmitz (Eds.), *A ocupação pré-colonial no Oeste de Santa Catarina*. Chapecó: CEOM. 84-107.

Hogg, A.G., Q. Hua, P.G. Blackwell, M. Niu, C.E. Buck, T.P. Guilderson, T.J. Heaton, J.G. Palmer, P.J. Reimer, R.W. Reimer, C.S.M. Turney and S.R.H. Zimmerman. 2013. "SHCal13 Southern Hemisphere Calibration, 0-50,000 Years cal BP" *Radiocarbon* 55 (4): 1889-1903.

Holdaway, S. and Wandsnider, L. 2006. Temporal Scales and Archaeological Landscapes from the Eastern Desert of Australia and Intermontane North America. In: Lock, G. and B.L. Molyneaux (Eds.), *Confronting Scale in Archaeology: Issues of Theory and Practice.* New York: Springer. 183-202.

Holdaway, S. and P. Fanning. 2008. "Developing a Landscape History as Part of a Survey Strategy: A Critique of Current Settlement System Approaches based on Case Studies from Western New South Wales, Australia." *Journal of Archaeological Method and Theory* 15 (2): 167-189.

Holdaway, S., and M. Douglass 2012. "A Twenty-First Century Archaeology of Stone Artifacts." *Journal of Archaeological Method and Theory* 19 (1): 1–31.

Holdaway, S., J. Shiner and P. Fanning. 2004. "Hunter-Gatherers and the Archaeology of Discard Behavior: An Analysis of Surface Stone Artifacts from Sturt National Park, Western New South Wales, Australia" *Asian Perspectives* 43 (1): 34-72.

Holdaway, S. W. Wendrich and R. Phillips. 2010. "Identifying low-level food producers: detecting mobility from lithics" *Antiquity* 84: 185-194.

Hornborg, A. 2005. “Ethnogenesis, Regional Integration, and Ecology in Prehistoric Amazonia.” *Current Anthropology* 46 (4): 589-620.

Hyslop, J. 1984. *The Inca Road System.* Orlando: Academic Press.

von Ihering, H. 1904. “A arqueologia comparativa do Brasil.” *Revista do Museu Paulista* 6: 43-65.

Imbelloni, J. 1936. *Epítome de culturología*. Buenos Aires: Humanior.

Ingold, T. 1987. *The Appropriation of Nature: Essays on Human Ecology and Social Relations.* Iowa City: University of Iowa Press.

Ingold, T. 1993 “The temporality of the landscape.” *World Archaeology* 25 (2): 152–174.

Ingold, T. 2000. *The Perception of the Environment.* London: Routledge.

Ingold, T. 2011. (Ed.), *Redrawing Anthropology: Materials, Movements, Lines.* Farnham: Ashgate Publishing.

Inizan, M.-L., M. Reduron, H. Roche and J. Tixier. 1995. *Technologie de La Pierre Taillée*. Meudon: Cercle de recherches et d'études préhistoriques.

Iriarte, J. 2006. “Landscape transformation, mounded villages and adopted cultigens: The rise of Early Formative communities in south-eastern Uruguay.” *World Archaeology* 38 (4): 644–663.

Iriarte, J. and H. Behling. 2007. “The expansion of Araucaria forest in the southern Brazilian highlands during the last 4000 years and its implications for the development of the Taquara/Itararé Tradition.” *Environmental Archaeology* 12 (2): 115-127.

Iriarte, J., I. Holst, O. Marozzi, C. Listopad, E. Alonso, A. Rinderknecht, and J. Montaña. 2004. “Evidence for cultivar adoption and emerging complexity during the mid-Holocene in the La Plata basin.” *Nature* 432 (7017): 614–7.

Iriarte, J., J.C. Gillam and O. Marozzi. 2008. “Monumental burials and memorial feasting: an example from the southern Brazilian highlands.” *Antiquity* 82 (318): 947-961.

Iriarte, J., O. Marozzi and J.C. Gillam. 2010a. “Monumentos funerarios y festejos rituales: complejos de recintos y túmulos Taquara/Itararé en Eldorado, Misiones (Argentina).” *Arqueologia Iberoamericana* 6: 25-38.

Iriarte, J., P. Riris, R. Corteletti, and J.C. Gillam. 2010b. *Investigating the socio-political organization of Early Formative Taquara/Itararé societies*. Report presented to the National Geographic Society for Exploration, December 2010.

Iriarte, J., Copé, S.M., Fradley, M., Lockhart, J. and J.C. Gillam. 2013. “Sacred landscapes of the southern Brazilian highlands: Understanding southern proto-Jê mound and enclosure complexes.” *Journal of Anthropological Archaeology* 32: 79-96.

Iriondo, M.H. and N.O. Garcia. 1993. “Climatic variations in the Argentine plains during the last 18,000 years.” *Palaeogeography, Palaeoclimatology, Palaeoecology* 101 (3-4): 209-220.

Iriondo, M., and D. Kröhling 2004. “The parent material as the dominant factor in Holocene pedogenesis in the Uruguay River Basin.” *Revista Mexicana de Ciencias Geológicas* 21 (1): 175–184.

Iriondo, M.H. and A.R. Paira. 2007. Physical Geography of the Basin. In: Iriondo, M. H., Paggi, J. C. & M.J. Parma (Eds.), *The Middle Paraná Basin: Limnology of a Subtropical Wetland*. Heidelberg: Springer-Verlag. 7-31.

Izquierdo, A.E., C.D. de Angelo and T.M. Aide. 2008. “Thirty Years of Human Demography and Land-Use Change in the Atlantic Forest of Misiones, Argentina: an Evaluation of the Forest Transition Model.” *Ecology And Society* 13 (2).

Jacobus, A.L. 1991. Alimentos utilizados pelo homem pré-histórico. In: Schmitz, P.I. (Ed.), *Arqueologia do Rio Grande do Sul*. 1st ed. São Leopoldo: Instituto Anchietano de Pesquisas.

Jacquemyn, H., R. Brys, K. Vandepitte, O. Honnay, I. Roldán-Ruiz and T. Wiegand. 2007. "A spatially explicit analysis of seedling recruitment in the terrestrial orchid *Orchis purpurea*" *New Phytologist* 176: 448-459.

Jeske-Pieruschka, V., A. Fidelis, R.S. Bergamin, E. Vélez and H. Behling. 2010. "Araucaria forest dynamics in relation to fire frequency in southern Brazil based on fossil and modern pollen data." *Review of Palaeobotany and Palynology* 160 (1-2): 53-65.

Johansen, P.G. 2010. "Site maintenance practices and settlement social organization in Iron Age Karnataka, India: Inferring settlement places and landscape from surface distributions of ceramic assemblage attributes." *Journal of Anthropological Archaeology* 29 (4): 432-454.

Jones, G.T. and C. Beck. 1992. Chronological Resolution in Distributional Archaeology. In: Rossignol, J. and L. Wandsnider (Eds.), *Space, Time, and Archaeological Landscapes.* New York: Plenum Press. 167-192.

Kantner, J. 2008. "The Archaeology of Regions: From Discrete Analytical Toolkit to Ubiquitous Spatial Perspective." *Journal of Archaeological Research* 16 (1): 37-81.

Keller, A.H. 2009. A Road by Any Other Name: Trails, Paths, and Roads in Maya Language and Thought. In: Snead, J.E., C.L. Erickson and J.A. Darling (Eds.). 2009. *Landscapes of Movement: Trails, Paths, and Roads in Anthropological Perspective.* Philadelphia: University of Pennsylvania Press. 133-157.

Kelly, R.L. 1988. "The Three Sides of a Biface." *American Antiquity* 53 (4): 717-734.

Kelly, R.L. 1992. "Mobility/Sedentism: Concepts, Archaeological Measures, and Effects." *Annual Review of Anthropology* 21: 43–66.

Kern, A.A. 1981. *Le Précéramique du Plateau Sud-Brésilien*. École des Hautes Études en Sciences Sociales, Paris. Unpublished PhD dissertation.

Kern, A.A., J.O. de Souza, and F. Seffner. 1989. "Arqueologia de salvamentoe a ocupação pré-histórica do vale do Rio Pelotas (Municípios de Bom Jesus e Vacaria)." *Veritas* 35 (133): 99-127.

Kern, A.A. 1991. Grupos Pré-Históricos de Caçadores-Coletores da Floresta Subtropical. In: Kern, A.A. (Ed.), Arqueologia Pré-Histórica do Rio Grande do Sul. Porto Alegre: Mercado Aberto. 135- 166.

Killion, T.W., J.A. Sabloff, G. Tourtellot and N.P. Dunning 1989. "Intensive Surface Collection of Residential Clusters at Terminal Classic Sayil, Yucatan, Mexico." *Journal of Field Archaeology* 16 (3): 273-294.

Kintigh, K. and A. Ammerman. 1982. "Heuristic approaches to spatial analysis in archaeology" *American Antiquity* 47 (1): 31-63.

Kirby, P.W. 2009. Lost in Space: An Anthropological Approach to Movement. In: Kirby, P.W. (Ed.), Boundless Worlds: An Anthropological Approach to Movement. New York: Berghahn Books. 1-28.

Klokler, D., X.S. Villagrán, P.C.F. Giannini, S. Peixoto and P. DeBlasis. 2010. "Juntos na costa zooarqueologia e geoarqueologia e sambaquis do litoral sul catarinense." *Revista do Museu de Arqueologia e Etnologia* 20: 3-75.

Knappett, C. 2008. Communities of Things and Objects: a Spatial Perspective. In: Malafouris, L. and C. Renfrew (Eds.), *The Cognitive Life of Things*. Cambridge: McDonald Institute for Archaeological Research. 81–90.

Knappet, C. 2011. Networks of Objects, Meshworks of Things. In: Ingold, T. (Ed.), *Redrawing Anthropology: Materials, Movements, Lines.* Farnham: Ashgate Publishing. 45-64.

Kneip, L.M. 1992. "As habitações 1 e 2 do sambaqui da Pontinha (Saquarema, RJ)" *Anais da VI Reunião da Sociedade de Arqueologia Brasileira* 2: 730-737.

Kohl, P.L. and J.A. Pérez Gollán. 2002. "Reassessing the Lingering Legacy of Oswald Menghin." *Current Anthropology* 43 (4): 561-586.

Kohler, T.A. and S.C. Parker. 1986. "Predictive Models for Archaeological Resource Location." *Advances in Archaeological Method and Theory* 9: 397-452.

Kowalewski, S.A. 2008. "Regional Settlement Pattern Studies." *Journal of Archaeological Research*. 16 (3): 225-285.

Lafón, C.R. 1971. "Introducción a la Arqueología del Nordeste Argentino." *Relaciones V* 2 *(N.S.)*: 119-152.

Laming-Emperaire, A. 1967 "Guia para o Estudo das Indústrias Líticas da América do Sul." *Manuais de Arqueologia 2*. Curitiba: Centro de Ensino e Pesquisas Arqueológicas da Universidad Federal do Paraná.

Lamont, M. and V. Molnár. 2002. "The Study of Boundaries in the Social Sciences" *Annual Review of Sociology* 28: 167-195.

Lake, M.W. 2014. "Trends in Archaeological Simulation" *Journal of Archaeological Method and Theory* 21: 258-287.

La Salvia, F. 1968. "Resumo das pesquisas arqueológicas no Planalto - Rio Grande do Sul." *Pesquisas, Antropologia*. 18: 101-113.

La Salvia, F. 1983. A habitação subterrânea, uma adaptação ecológica. In: Weimer, G. (Ed.), *A arquitetura do Rio Grande do Sul*. Porto Alegre: Editora Mercado Aberto, 7-56.

Lathrap, D.W. 1973. "The antiquity and importance of long-distance trade relationships in the moist tropics of pre-Columbian South America." *World Archaeology* 5 (2): 170-186.

Law, R., J. Illian, D.F.R.P. Burslem, G. Gratzer, C.V.S. Gunatilleke and I.A.U.N. Gunatilleke. 2009. "Ecological information from spatial patterns of plants: insights from point process theory" *Journal of Ecology* 97: 616-628.

Lawrence, D.L. and S.M. Low. 1990. "The built environment and spatial form." *Annual Review of Anthropology* 19, 453-505.

Ledru, M.-P., M.L. Salgado-Labouriau and M.L. Lorscheitter. 1998. "Vegetation dynamics in southern and central Brazil during the last 10,000 yr B.P." *Review of Palaeobotany and Palynology* 99: 131-142.

Lefebvre, H. 1991. *The Production of Space*. Oxford: Blackwell Publishers.

Leonhardt, A., and M.L. Lorscheitter. 2010. "The last 25,000 years in the Eastern Plateau of Southern Brazil according to Alpes de São Francisco record." *Journal of South American Earth Sciences* 29 (2): 454-463.

van Leusen, M. 2002. *Patterns to Process: Methodological Investigations into the Formation and Intepretation of Spatial Patterns in Archaeological Landscapes.* Faculty of Letters: Rijksuniversiteit Groeningen, Groeningen Unpublished PhD dissertation.

Lewarch, D.E. and O'Brien, M.J. 1981. "The Expanding Role of Surface Assemblages in Archaeological Research." *Advances in Archaeological Method and Theory* 4: 297-342.

Lima, T.A. and J.M. López-Mazz 1999. "La emergencia de complejidad entre los cazadores recolectores de la costa Atlántica meridional sudamericana" *Revista de Arqueologia Americana* 17-19:129-175.

Llobera, M. 2000. Understanding Movement: a pilot model towards the sociology of movement. In: Lock, G. (Ed.), *Beyond the Map: Archaeology and Spatial Technologies.* Oxford: IOS Press. 65-84.

Llobera, M. 2012. "Life on a Pixel: Challenges in the Development of Digital Methods within an "Interpretive" Landscape Archaeology Framework" *Journal of Archaeological Method and Theory* 19 (4): 495-509.

Llobera, M. and T.J. Sluckin. 2007. "Zigzaging: theoretical insights on climbing strategies" *Journal of Theoretical Biology* 249: 206-217.

Llobera, M., P. Fábrega-Álvarez and C. Parcero-Oubiña. 2011. "Order in movement: a GIS approach to accessibility." *Journal of Archaeological Science* 38 (4): 843–851.

Lloyd, C. 1938. The Archaeological Survey in the Ackmen-Lowry area. In: Martin, P.S., C. Lloyd and A. Spoehr (Eds.), *Archaeological work in the Ackmen-Lowry area, Southwestern Colorado, 1937*. Chicago: Field Museum of Natural History, Anthropological Series, No. 13. 282-292.

Lock, G. 2010. Representations of Space and Place in the Humanities. In: Bodenhamer, D.J., J. Corrigan and T.M. Harris (Eds.), *The Spatial Humanities: GIS and the Future of Humanities Scholarship*. Bloomington: Indiana University Press. 89-108.

Lock, G. and B.L. Molyneaux. 2006. Introduction: Confronting Scale. In: Lock, G. and B.L. Molyneaux (Eds.), *Confronting Scale in Archaeology: Issues of Theory and Practice.* New York: Springer. 1-14.

López Mazz, J.M. 1999. Some Aspects of the French Influence upon Uruguayan and Brazilian Archaeology. In: Politis, G.G. and B. Alberti (Eds.), *Archaeology in Latin America*. London: Routledge, 38-58.

López Mazz, J.M. 2001. "Las estructuras tumulares (cerritos) del litoral atlantico uruguayo." *Latin American Antiquity* 12 (3): 231–255.

Loponte, D. 2012. "Los Extremos de la Distribución: La Llanura Pampeana y La Provincia de Misiones en la Arqueología del Nordeste." *Anuario de Arqueología* 4 (4): 39-72.

Loponte, D. and A. Acosta. 2013. 'La construcción de la unidad arqueológica guaraní en el extremo meridional de su distribución geográfica' *Cuadernos del Instituto Nacional de Antropología y Pensamiento Latinoamericano - Series Especiales* 1 (4): 193-235.

Loponte, D. and M. Carbonera. 2013. "Arqueologia sem fronteiras: projeto de cooperação binacional para o estudo arqueológico da provínica de Misiones (Argentina) e oeste de Santa Catarina (Brasil)" *Revista Memorare* 1 (1): 43-50.

Loponte, D. and M. Carbonera. 2014. *El sitio arqueológico Corpus. Nuevos datos para la arqueología guaraní en la provincia de Misiones*. Unpublished manuscript.

Lourdeau, A., S.E. Hoeltz and S.A. Viana. 2014. "Early Holocene blade technology in southern Brazil" *Journal of Anthropological Archaeology* 35: 190-201.

Lovis, W.A., R. Whallon and R.E. Donahue. 2006. "Social and Spatial Dimensions of Mesolithic Mobility." *Journal of Anthropological Archaeology* 25 (2): 271-274.

Lucas, G. 2002. *Critical Approaches to Fieldwork: Contemporary and Historical Archaeological Practice*. 2nd ed. London: Routledge.

Lucas, G. 2008. "Time and Archaeological Event." *Cambridge Archaeological Journal* 18 (1): 59-65.

Lyon P.J. (Ed.) 1974. *Native South America: Ethnology of the Least Known Continent*. Boston: Little Brown

Mabilde, P.F.A.B. 1983 [1897-1899]. *Apontamentos Sobre Os Indígenas Selvagens da Nação Coroados dos Matos da Província do Rio Grande do Sul*. São Paulo: IBRASA/INL.

Madrazo, G.B. and J.C. Laguzzi Rueda. 1967. "Un Viaje Arqueologico a la provincia de Misiones." *Runa* 10: 371-382

Magne, M.P. 1989. Lithic Reduction Stages and Assemblage Formation Processes. In: Amick, D.S. and R.P. Mauldin (Eds.), *Experiments in Lithic Technology*. Oxford: BAR International Series 528. 15-32.

Mantha, A. 2009. "Territoriality, social boundaries and ancestor veneration in the central Andes of Peru" *Journal of Anthropological Archaeology* 28: 158-176.

Markofsky, S.B. 2010. *Illuminating the Black Sands: Survey and Settlement in the Bronze Age Murghab Delta, Turkmenistan*. Institute of Archaeology: University College London, London. Unpublished PhD dissertation.

Markofsky, S.B. 2014. "When Survey Goes East: Field Survey Methodologies and Analytical Frameworks in a Central Asian Context" *Journal of Archaeological Method and Theory*. DOI: 10.1007/s10816-013-9172-9

Markofsky, S. and A. Bevan. 2011. "Directional analysis of surface artefact distributions: a case study from the Murghab Delta, Turkmenistan." *Journal of Archaeological Science* 39 (2): 428–439.

Mathieu, J.R. and R.E. Scott. 2004. Exploring the Role of Analytical Scale in Archaeological Interpretation. In: Mathieu, J.R. and R.E. Scott (Eds.), *Exploring the Role of Analytical Scale in Archaeological Interpretation*. Oxford: Archaeopress. 1-9.

Maybury-Lewis, D. 1974. *Akwe-Shavante Society*. Oxford: Oxford University Press.

Mayle, F.E and J. Iriarte. 2014. "Integrated palaeoecology and archaeology – a powerful approach for understanding pre-Columbian Amazonia" *Journal of Archaeological Science* 51: 54-64 http://dx.doi.org/10.1016/j.jas.2012.08.038.

Métraux, A. 1946. The Caingang. In: Steward, J. (Ed.), *Handbook of South American Indians. Volume 1: the Marginal Tribes*. Washington D.C.: Smithsonian Institution, 445-475.

McCoy, M.D. and T.N. Ladefoged. 2009. "New Developments in the Use of Spatial Technology in Archaeology." *Journal of Archaeological Research* 17 (3): 263–295.

McGlade, J. 2014. "Simulation as Narrative: Contingency, Dialogics, and the Modeling Conundrum." *Journal of Archaeological Method and Theory* 21 (2): 288-305.

McNabb J. 1998. On the Move. Theory, Time Averaging and Resource Transport at Olduvai Gorge. In: Ashton, N., F. Healy & P. Pettit (eds.), *Stone Age Archaeology. Essays in honour of John Wymer*. Oxford: Oxbow Monograph 102, 15-22.

Meggers, B.J. 1952. *The Archaeological Sequence on Marajo Island, Brazil, with Special Reference to the Marajoara Culture*. Department of Anthropology: Columbia University, New York. Unpublished PhD dissertation.

Meggers, B.J. 1954. "Environmental Limitation on the Development of Culture." *American Anthropologist* 56 (5): 801-824.

Meggers, B.J. 1955. The Coming of Age of American Archaeology. In: Newman, M.T. (Ed.), *New Interpretations on Aboriginal American Culture History*. Washington D.C.: Anthropological Society of Washington, 116–129.

Meggers, B.J. 1985. "Advances in Brazilian Archeology, 1935-1985." *American Antiquity* 50 (2): 364– 373.

Meggers, B.J. 1987. El uso de secuencias cerámicas seriadas para inferir conducto social. In: Zamora, O.M.F. (Ed.), *Actas del Primer Simposio de la Fundación de Arqueología Social.* 11-24.

Meggers, B.J. 2010. *Prehistoric America: An Ecological Perspective.* 3rd ed. New Brunswick: Transaction.

Meggers, B.J. and C. Evans. 1957. *Archaeological Investigations at the Mouth of the Amazon.* Washington D.C.: Bureau of American Ethnology, Bulletin 167, Smithsonian Institute.

Meggers, B.J. and C. Evans. 1970. *Como interpretar a linguagem da cerâmica: guia para arqueólogos*. Washington D.C.: Smithsonian Institution.

Meggers, B.J., C. Evans and E. Estrada. 1965. *Early Formative cultures of coastal Ecuador.* Washington D.C.: Smithsonian Contributions to Anthropology 1.

Mena, M., M.J. Orgeira, and S. Lagorio. 2006. "Paleomagnetism, rock-magnetism and geochemical aspects of early Cretaceous basalts of the Paraná Magmatic Province, Misiones, Argentina." *Earth Planets Space* 58: 1283-1293.

Menghin, O. 1955/56. "El Altoparanaense." *Ampurias* 17/18: 171 - 200.

Menghin, O. 1957. "El Poblamiento Prehistorico de Misiones." *Anales de Arqueología y Etnologia* 11: 19-40.

Menghin, O. 1961. "Vorkolumbische Haushühner in Südamerika." *Zeitschrift für Tierzüchtung und Züchtungsbiologie* 76 (1-4): 349-355.

Mentz Ribeiro, P.A. 1980. "Casas subterrâneas do planalto meridional, município de Santa Cruz do Sul, Brasil." *Revista do CEPA.* 9: 1-52.

Mentz Ribeiro, P.A. and C. Ribeiro. 1985. "Levantamentos arqueológicos no município de Esmeralda, RS, Brasil." *Revista do CEPA.* 12: 49-105.

Miller, E.T. 1967. "Pesquisas arqueológicas efetuadas no nordeste do Rio Grande do Sul. Programa Nacional de Pesquisas Arqueológicas - Resultados Preliminares do Primeiro Ano, 1965-1966." *Publicações Avulsas do Museu Paraense Emílio Goeldi*. 6: 15-38.

Miller, E.T. 1969. "Pesquisas arqueológicas efetuadas no oeste do Rio Grande do Sul (Campanha-Missiões)." *Publicações Avulsas do Museu Paraense Emílio Goeldi* 13: 13–30.

Miller, E.T. 1971. "Pesquisas arqueológicas efetuadas no planalto meridional, RS (Rios Uruguai, Pelotas e das Antas)". *Publicações Avulsas do Museu Paraense Emílio Goeldi.* 15: 37-60.

Miller, E.T. 1987. "Pesquisas arqueológicas paleoindígenas no Brasil ocidental" *Estudíos Atacameños* 8: 37-61.

Minetti, A.E., C. Moia, G.S. Roi, D. Susta and G. Ferretti. 2002. "Energy cost of walking and running at extreme uphill and downhill slopes." *Journal of Applied Physiology* 93 (3): 1039-1046.

Morrás, H., L. Moretti, B. Glaser, C. Hatté and W. Zech. 2006. Paleoenvironments in the subtropical northeastern Argentina as deduced from stable carbon isotopes composition of ferrallitic soils. In: *Short Papers Book, V South American Symposium on Isotope Geology.* Punta del Este, Uruguay, April 2006. 267-270.

Morrás, H., L. Moretti, G. Píccolo and W. Zech. 2009. "Genesis of subtropical soils with stony horizons in NE Argentina: Autochthony and polygenesis." *Quaternary International* 196 (1-2): 137-159.

Mueller, J.W. 1974. "The Use of Sampling in Archaeological Survey." *Memoirs of the Society for American Archaeology* 28: 1-91.

Müller, L.M. 2008. *Sobre índios e ossos.* Faculdade de Filosofia e Ciências Humanas: Pontífica Universidade Católica do Rio Grande do Sul, Porto Alegre. Unpublished PhD dissertation.

Mújica, J.I. 2000. Informe de sitios arqueológicos en el centro de la provincia de Misiones – municipio de San Vicente. Paper in: XX *Encuentro de Geohistoria Regional*. Resistencia: Instituto de Investigaciones Geohistóricas.

Mújica, J.I. 2007. Prospección arqueológica en la cuenca del arroyo Yarará-Puerto Esperanza - Misiones– Argentina. Paper in: *XXVII Encuentro de Geohistoria Regional*. Resistencia: Instituto de Investigaciones Geohistóricas.

Murrieta-Flores, P.A. 2011. *Travelling through past landscapes Analysing the dynamics of movement during Late Prehistory in Southern Iberia with spatial technologies.* Faculty of Humanities: University of Southampton, Southampton. Unpublished PhD dissertation.

Nami, H. 2006. Preliminary experimental observations on a particular class of bifacial lithic artifact from Misiones Province, northeastern Argentina. In: Apel, J. and K. Knutsson. (Eds.), *Skilled Production and Social Reproduction: aspects of traditional stone-tool technologies*. Uppsala: Societas Archaeologica Upsaliensis, 139-150.

Nance, J.D. 1983. "Regional Sampling in Archaeological Survey: The Statistical Perspective." *Advances in Archaeological Method and Theory. 6*: 289–356.

Navazo, M. and Díez, C. 2008. "Redistribution of Archaeological Assemblages in Plowzones." *Geoarchaeology: An International Journal* 23 (3): 323-333.

Neves, E.G. 1998. "Twenty years of Amazonian archaeology." *Antiquity* 72 (277): 625-632.

Neves, E.G. 1999. Changing Perspectives in Amazonian Archaeology. In: Politis, G.G. and B. Alberti (Eds.), *Archaeology in Latin America*. London: Routledge, 216-243.

Neves, E.G. 2000. *Paths in Dark Waters: Archaeology as Indigenous History in the Upper Rio Negro Basin, Northwest Amazon*. Department of Anthropology: Indiana University, Bloomington. Unpublished PhD dissertation.

Neves, W.A., R. González-José, M. Hubbe, R. Kipnis, A.G.M. Araujo and O. Blasi. 2004. "Early Holocene Human Skeletal Remains from Cerca Grande, Lagoa Santa, Central Brazil, and the Origins of First Americans" *World Archaeology* 36 (4): 479-501.

Neves, W.A. and Okamura, M. 2005 "Afinidades biológicas de grupos pré-históricos do vale do rio Ribeira de Iguape (SP): uma análise preliminar" *Revista de Antropologia* 48 (2): 525-558.

Neves, W.A. and L.B. Piló 2008. *O Povo de Luzia: Em Busca dos Primeiros Americanos*. São Paulo: Editora Globo.

Nimuenjadú, C. 1952. The Tapajo. *Kroeber Anthropological Society Papers* 6: 1-25.

Noelli, F.S. 1998. "The Tupi: explaining origin and expansions in terms of archaeology and of historical linguistics." *Antiquity* 72 (277): 648-663.

Noelli, F.S. 1999/2000. "A ocupação humana na região sul do Brasil: arqueologia, debates e perspectivas 1972-2000". *Revista da USP* 44: 218-269.

Noelli, F.S. 2004a. "La distribución geográfica de las evidencias arqueológicas guaraní." *Revista de Indias* 64 (230): 17–34.

Noelli, F.S. 2004b. "Settlement patterns and environmental changes in human occupation on the left bank of the Paraná river (Parana State, Brazil)." *Arqueoweb* 6 (1): 1-24.

Noelli, F.S. 2005. Rethinking Stereotypes and the History of Research on Jê Populations in South Brazil: An Interdisciplinary Point of View. In: Funari, P.P.A., A. Zarankin and E. Stovel (Eds.), *Global Archaeological Theory: Contextual Voices and Contemporary Thoughts.* New York: Plenum Publishers, 167-190.

Nordenskiöld, E. 1916. "Die anpassung der Indianer an die verhältnisse in den uberschwemmungsgebeiten in Südamerika." *Ymer* 36: 138-155.

Nowak, A., A. Rychwalska and W. Borkowski. 2013. "Why Simulate? To Develop a Mental Model." *Journal of Artificial Societies and Social Simulation* 16 (3). http://www.jasss.soc.surrey.ac.uk/16/3/12.html.

Odell, G.H. 2001. "Stone Tool Research at the End of the Millennium: Classification, Function, and Behavior" *Journal of Archaeological Research* 9 (1): 45-100.

Odell, G.H. and F. Cowan. 1987. "Estimating Tillage Effects on Artifact Distributions." *American Antiquity* 52(3): 456-484.

Okamura, M. and A.G.M. Araujo. 2014. "Long-term cultural stability in hunter-gatherers: a case study using traditional and geometric morphometric analysis of lithic stemmed bifacial points from Southern Brazil." *Journal of Archaeological Science* 45: 59-71.

Orquera, L.A. 1987. "Advances in the archaeology of the Pampa and Patagonia." *Journal of World Prehistory* 1 (4): 333-413.

Orton, C. 2000. *Sampling in Archaeology*. Cambridge: Cambridge University Press.

Orton, C. 2004. "Point Pattern Analysis Revisited" *Archeologia e Calcolatori* 15: 299-315.

Paasi, A. 1998. "Boundaries as social processes: Territoriality in the world of flows" *Geopolitics* 3 (1): 69-88.

Parellada, C.I. 2008a. "Revisão dos sítios arqueológicos com mais de seis mil anos BP no Paraná: discussões geoarqueológicas." *FUMDHAMentos* 7: 117–135.

Parsons, J.R. 1972."Archaeological Settlement Patterns." *Annual Review of Anthropology* 1 (1): 127-150.

Pauketat, T.R. 2007. *Chiefdoms and Other Archaeological Delusions*. Lanham: Altamira Press.

Pearsall, D.M. 2000. *Palaeoethnobotany: A Handbook of Procedures.* 2nd ed. California: Academic Press

Peate, D.W. 1997. The Paraná-Etendeka Province. In: Mahoney, J. & Coffin, M. (Eds.), *Large Igneous Provinces: Continental, Oceanic, and Planetary Flood Volcanism*. Washington D.C.: American Geophysical Union, 217-245.

Pélissier, R. and F. Goreaud. 2001. "A practical approach to the study of spatial structure in simple cases of heterogeneous vegetation" *Journal of Vegetation Science* 12: 99-108.

Perry, J.N., A.M. Liebhold, M.S. Rosenberg, J. Dungan, M. Miriti, A. Jakomulska and S. Citron-Pousty. 2002. "Illustrations and guidelines for selecting statistical methods forquantifying spatial pattern in ecological data" *Ecography* 25: 578-600.

Perry, G.L.W., B.P. Miller and N.J. Enright. 2006. "A comparison of methods for the statistical analysis of spatial point patterns in plant ecology" *Plant Ecology* 187: 59-82.

Peterson, C.E. and R.D. Drennan. 2005. "Communities, Settlements, Sites, and Surveys: Regional-Scale Analysis of Prehistoric Human Interaction." *American Antiquity* 70 (1): 5-30.

Piazza, W.F. 1969. "A área arqueológica dos Campos de Lages." *Publicações Avulsas do Museu Paraense Emílio Goeldi* 13: 63-74.

Plens, C. 2007. *Sítio Moraes, uma biografia não autorizada: análise do processo de formação de um sambaqui fluvial.* Faculdade de Filosofia, Letras e Ciências Humanas: Universidade of São Paulo, São Paulo. Unpublished PhD dissertation.

Plog, F. 1974. *The Study of Prehistoric Change*. New York: Academic Press.

Plog, S., F. Plog and W. Wait. 1978. "Decision Making in Modern Surveys." *Advances in Archaeological Method and Theory* 1: 383-421

Podgorny, I., M.D. Tobías and M. Farro. 2005. The Reception of New Archaeology in Argentina: A Preliminary Survey. In: Funari, P.P.A., A. Zarankin and E. Stovel (Eds.), *Global Archaeological Theory: Contextual Voices and Contemporary Thoughts.* New York: Plenum Publishers, 59-76.

Politis, G.G. 1995. The socio-politics of the development of archaeology in Hispanic South America. In: Ucko, P.J. (Ed.), *Theory in Archaeology: A World Perspective*. London: Routledge, 194-231.

Politis, G.G. 2003. "The Theoretical Landscape and the Methodological Development of Archaeology in Latin America." *American Antiquity* 68 (2): 245-272.

Politis, G.G., P.G. Messineo and C.A. Kaufmann. 2004. "El poblamiento temprano de las llanuras pampeanas de Argentina y Uruguay." *Complutum* 15: 207-224.

Politis, G.G., M. Bonomo, C. Castiñeira, and A. Blasi. 2011. "Archaeology of the Upper Delta of the Paraná River (Argentina): Mound Construction and Anthropic Landscapes in the Los Tres Cerros locality." *Quaternary International* 245 (1): 74–88.

Politis, G.G. and M. Bonomo. 2013. La entidad arqueológica Goya-Malabrigo (Ríos Paraná y Uruguay) y su filiación Arawak. *Revista de Arqueologia* 25 (1): 10-47.

Popson, C.P. 2003. First Lady of Amazonia. *Archaeology* 56 (3), 26-31.

Poujade, R. 1992. Poblamiento préhistorico y colonial de Misiones. *Estudos Ibero-Americanos* 18 (1): 29–70.

Poujade, R. 1995. Mapa Arqueológico de la Provincia de Misiones (Cartilla Explicativa). Asunción: Artes Graficas Zamphirópolos S.A.

Prates, L., G. Politis and J. Steele. 2013. "Radiocarbon chronology of the early human occupation of Argentina" *Quaternary International* 301: 104-122.

Pred, A. 1981. "Social Reproduction and the Time-Geography of Everyday Life." *Geografiska Annaler, Series B, Human Geography* 63 (1): 5–22.

Pred, A. 1984. "Place as Historically Contingent Process: Structuration and the Time-Geography of Becoming Places." *Annals of the Association of American Geographers* 74 (2): 279-297.

Premo, L. 2004. "Local spatial autocorrelation statistics quantify multi-scale patterns in distributional data: an example from the Maya Lowlands" *Journal of Archaeological Science* 31: 855-866.

PRONAPA, 1970. "Brazilian Archaeology in 1968: An Interim Report on the National Program of Archaeological Research." *American Antiquity* 35 (1): 1–23.

Prous, A. 1992. *Arqueologia Brasileira*. Brasília: Editora Universidade de Brasília.

Prous, A., and E. Fogaça. 1999. "Archaeology of the Pleistocene-Holocene boundary in Brazil." *Quaternary International* 53-54: 21-41.

Pugliese, F. 2007. *Os Líticos de Lagoa Santa: Um Estudo sobre Organização Tecnológica de Caçadores-Coletores do Brasil Central*. Museu de Arqueologia e Etnologia: University of São Paulo, São Paulo. Unpublished MA dissertation.

Purves, D.W. and R. Law. 2002. "Fine-Scale Spatial Structure in a Grassland Community: Quantifying the Plant's-Eye View" *Journal of Ecology* 90 (1): 121-129.

R Development Core Team. 2013. *R: A language and environment for statistical computing.* Vienna: R Foundation for Statistical Computing. http://www.R-project.org/.

Ramenofsky, A.F., F. Neiman, and C.D. Pierce. 2009. "Measuring time, population, and residential mobility from the surface at San Marcos Pueblo, North Central New Mexico." *American Antiquity* 74 (3): 505-530.

Rau, M.F. 2005. *Land Use Change and Natural Araucaria Forest Degradation Northeastern Misiones - Argentina*. Faculty of Forestry: Albert-Ludwigs-University, Freiburg. Unpublished PhD dissertation.

Redman, C.L. and P.J. Watson. 1970. "Systematic, Intensive Surface Collection." *American Antiquity* 35 3: 279-291.

Ribeiro, P.A.M. 1991. "Arqueologia do vale do Rio Pardo, Rio Grande do Sul, Brasil." *Biblios* 7: 9-87.

Ribeiro, E.R. 2008. Macro-Jê. In: Brown, K. and S. Ogilvie (Eds.), *Concise Encyclopedia of Languages of the World*. Oxford: Elsevier. 665-672.

Rinehart, N.R. 2008. Debitage Analysis: Lithic Reduction or Lithic Production? In: Rieth, C.B. (Ed.), *Current Approaches to Analysis and Interpretation of Small Lithic Sites in the Northeast*. Albany: New York State Education Department. New York State Museum Bulletin Series 508. 63-76.

Ríos, R. C. 2006. *Vegetação Arbórea em Três Unidades Pedológicas do Parque Provincial Cruce Caballero, Misiones*. Curso de Pós-Graduação em Engenharia Florestal: Universidade Federal do Paraná, Curitiba. Unpublished MSc dissertation.

Ríos, R.C., F. Galvão and G.R. Curcio. 2008. "Variaciones estructurales de la vegetacion arborea en tres ambientes de una selva con Araucaria en Misiones, Argentina." *Floresta* 38 (4): 743-756.

Ripley, B.D. 1976. "The Second-Order Analysis of Stationary Point Processes" *Journal of Applied Probability* 13 (2): 255-266.

Riris, P. 2010a. "Expanding the Taquara/Itarare Model: Feasting and Social Complexity in the Southern Brazilian Highlands." *Reinvention: a Journal of Undergraduate Research* 3 (1). Available: www.warwick.ac.uk/go/reinventionjournal/issues/volume3issue1/riris.

Riris, P. 2010b. *Predictive modelling in Misiones Province, Argentina using GIS: a case study of the Taquara/Itararé tradition.* Department of Archaeology: University of Exeter, Exeter. Unpublished MA dissertation.

Riris, P. and I. Romanowska. 2014. "A Reconstructed Reduction Sequence for Curved Bifacial Stone Tools From the Eastern La Plata Basin, Argentina" *Lithics* 35.

Rizzo, A. 1967. "Primeras noticias sobre excavación estratigráfica de una gruta en 3 de Mayo: Garuhapé, Misiones". *Anales de Arqueología y Etnología* 22: 77-92

Rizzo, A. 1968. *Un yacimiento arqueológico en la provincia de Misiones: la gruta de Tres de Mayo*. Facultad de Filosofía, Letras y Ciencias del Hombre: Universidad Nacional del Litoral, Santa Fe. Unpublished Ph.D. dissertation.

Rizzo, A., A, Figini, S. Salceda and E. Tonni. 2006. "Ocupación Humana Holocénica en el Noreste de la Mesopotamia: la Gruta 3 de Mayo (Gurahapé, Misiones, Argentina)" *Folia Histórica del Nordeste* 16: 131-137.

Robrahn, E. 1989. *A ocupação pré-colonial do vale do Ribeira do Iguape, SP: os grupos ceramistas do médio curso.* Faculdade de Filosofia, Letras e Ciências Humanas: Universidade de São Paulo, São Paulo. Unpublished MA dissertation.

Robrahn-González, E. 1996. "Os grupos ceramistas pré-coloniais do Centro-Oeste brasileiro" *Revista do Museu de Arqueologia e Etnologia* 6: 83-122.

Rodrigues, A.D. 1999. Macro-Jê. In: Dixon, R.M.W. and Aikhenvald, A.Y. (Eds.), *The Amazonian Languages*. Cambridge: Cambridge University Press. 165-206.

Rodriguez, J.A. 2001. Nordeste prehispánico. In: Berberian, E.E. and A.E. Nielsen (Eds.), *Historia Argentina Prehispanica, Volume 1*. Córdoba: Editorial Brujas, 693-736.

Rodriguez, J.A. 2005. "Human occupation of the eastern La Plata Basin and the adjacent littoral region during the mid-Holocene." *Quaternary International* 132 (1): 23-36.

Rogge, J.H. 2004. "*Fenômenos de Fronteira: Um Estudo da Situações de Contato Entre os Portadores das Tradições Cerâmicas Pré-Históricas no Rio Grande do Sul*." Programa de Pós-Graduação em História: Universidade do Vale do Rio Dos Sinos, São Leopoldo. Unpublished PhD dissertation.

Rogge, J.H. 2006 Pesquisas Arqueológicas em São Marcos, RS. In: *Anais do V encontro do Núcleo Regional Sul da Sociedade de Arqueologia Brasileira – SAB/Sul*. Rio Grande, Brazil. 20-23 November.

Rogge, J.H. and M.V. Beber. 2013. “Arqueologia das estruturas subterrâneas do sul do Brasil” *Revista Tempos Acadêmicos* 11: 146-162.

Rohr, J.A. 1966. “Pesquisas arqueológicas em Santa Catarina, os sítios arqueológicos do município de Itapiranga” *Pesquisas, Antropologia* 15: 21-60.

Rohr, J.A. 1968 “Achados arqueológicos em Itapiranga” *Pesquisas, Antropologia* 18: 49-65.

Rohr, J.A. 1971. “Os sítios arqueológicos do planalto catarinense, Brasil” *Pesquisas, Antropologia* 24: 1-54.

Roosevelt, A.C. 1991a. Determinismo Ecológico na Interpretação do desenvolvimento Social Indígena da Amazônia. In: Neves, W. (Ed.), *Origens, Adaptações e Diversidade Biológica do Homem Nativo da Amazônia.* Belém: Museu Paraense Emílio Goeldi, 103-141.

Roosevelt, A.C. 1993. “The Rise and Fall of the Amazon Chiefdoms” *L’Homme* 33 (126-128): 255-283.

Roosevelt, A.C. 2009. “A historical memoir of archaeological research in Brazil (1981-2007).” *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas* 4 (1): 155-170.

Roosevelt A.C., M.L. Dacosta, C.L. Machado, M. Michab, N. Mercier, H. Valladas, J. Feathers, W. Barnett, M.I. Dasilveira, A. Henderson, J. Sliva, B. Chernoff, D.S. Reese, J.A. Holman, N. Toth and K. Schick. 1996. “Paleoindian Cave Dwellers in the Amazon: The Peopling of the Americas” *Science* 272: 373-384

Roper, D.C. 1976. “Lateral displacement of artifacts due to plowing.” *American Antiquity* 41 (3): 372-375.

Roth, B.J. and H.L. Dibble. “Production and Transport of Blanks and Tools at the French Middle Paleolithic Site of Combe-Capelle Bas” *American Antiquity* 63 (1): 47-62.

Rozen, K.C. and A.P. Sullivan. 1989. “Measurement, Method, and Meaning in Lithic Analysis: Problems with Amick and Mauldin's Middle-Range Approach” *American Antiquity* 54 (1): 169-175.

Sack, R.D. 1983. “Human Territoriality: A Theory” *Annals of the Association of American Geographers* 73 (1): 55-74.

Sack, R.D. 1986. *Human Territoriality: Its History and Theory*. Cambridge: Cambridge University Press.

Sakamoto, Y., M. Ishiguro and G. Kitagawa. 1986. *Akaike Information Criterion Statistics*. Tokyo: KTK Scientific Publishers.

Saldanha, J.D.M. 2005. *Paisagem, lugares e cultura material: Uma arqueologia espacial nas Terras Altas do Rio Grande do Sul.* Faculdade de Filosofia e Ciências Humanas: Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre. Unpublished MA dissertation.

Scheel-Ybert, R. 2001. “Man and Vegetation in Southeastern Brazil during the Late Holocene” *Journal of Archaeological Science* 28: 471-480.

Scheinsohn, V. 2003. “Hunter-Gatherer Archaeology in South America.” *Annual Review of Anthropology* 32 (1): 339-361.

Schiffer, M.B. 1972. “Archaeological context and systemic context.” *American Antiquity* 37 (2): 156-165.

Schiffer, M.B. 1988. “The Structure of Archaeological Theory.” *American Antiquity* 53 (3): 461-485.

Schiffer, M.B., A.P. Sullivan and T.C. Klinger. 1978. “The Design of Archaeological Surveys.” *World Archaeology* 10 (1): 1-28.

Schimmel, A. 1967. “Nuevas noticias sobre la arqueologia Misionera” *Runa* 10 (1-2): 383-388.

Schlanger, S.H. 1991. "On Manos, Metates, and the History of Site Occupations." *American Antiquity* 56 (3): 460-474.

Schlanger, S.H. 1992. Recognizing Persistent Places in Anasazi Settlement Systems. In: Rossignol, J. and L. Wandsnider (Eds.), *Space, Time, and Archaeological Landscapes.* New York: Plenum Press. 91-111.

Schmitz, P.I. 1957. "Um paradeiro guarani no alto Uruguai." *Pesquisas (Antropologia)* 1:122-142.

Schmitz, P.I. 1987. "Prehistoric hunters and gatherers of Brazil." *Journal of World Prehistory* 1 (1): 53-126.

Schmitz, P.I. (Ed.). 1991. *Arqueologia do Rio Grande do Sul.* 1st ed. São Leopoldo: Instituto Anchietano de Pesquisas.

Schmitz, P.I. (Ed.). 2006a. *Arqueologia do Rio Grande do Sul*. 2nd ed. São Leopoldo: Instituto Anchietano de Pesquisas.

Schmitz, P.I. 2006b. O mundo da caça, da pesca e da coleta. In: Schmitz, P.I. (Ed.), *Arqueologia do Rio Grande do Sul*. 2nd ed. São Leopoldo: Instituto Anchietano de Pesquisas. 13-30.

Schmitz, P.I. 2010. "Caçadores antigos no Vale do Rio Caí, RS." *Pesquisas, Antropologia* 68: 79-108.

Schmitz, P.I. and I.I.B. Becker. 1991. Os primitivos engenheiros do Planalto e suas estruturas subterrâneas: a tradição Taquara. In: Schmitz, P.I. (Ed.), *Arqueologia do Rio Grande do Sul*. São Leopoldo: Instituto Anchietano de Pesquisas. 251-293.

Schmitz, P.I. and I.I.B. Becker. 2006. Os primitivos engenheiros do Planalto e suas estruturas subterrâneas: a tradição Taquara. In: Schmitz, P.I. (Ed.), *Arqueologia do Rio Grande do Sul*. 2nd ed. São Leopoldo: Instituto Anchietano de Pesquisas. 65-100.

Schmitz, P.I. and J.P. Brochado. 1972 Datos para uma secuencia cultural del Estado de Rio Grande do Sul, Brasil. *Gabinete de Arqueologia 2*. Porto Alegre: Universidade Federal do Rio Grande do Sul.

Schmitz, P.I., and J.H. Rogge. 2004. "Dados e reflexões para o sistema de assentamento de populações ceramistas do Planalto do Rio Grande do Sul." *Revista de Arqueologia* 17: 101-115.

Schmitz, P.I., A.S. Barbosa, A.S., A. Jacobus and M.B. Ribeiro. 1989. *Arqueologia nos Cerrados do Brasil Central*. São Leopoldo: Instituto Anchietano de Pesquisas.

Schmitz, P.I., J.H. Rogge, A.O. Rosa, M.V. Beber, J. Mauhs and F.V. Arnt. 2002. "O projeto Vacaria: Casas subterrâneas no planalto rio-grandense" *Pesquisas, Antropologia* 58: 11-105.

Schmitz, P.I., J.H. Rogge and A.O. Rosa. 2007. "Arqueologia do planalto sul-rio-grandense: as casas subterrâneas de São Marcos" *História Unisinos* 11 (2): 267-270.

Schmitz, P.I., J.H. Rogge, R.V. Novasco, N.M. Mergen and S. Ferrasso. 2013a. "Rincão dos Albinos: Um Grande Sítio Jê Meridional" *Pesquisas, Antropologia* 70: 65-131.

Schmitz, P.I., J.H. Rogge, R.V. Novasco, N.M. Mergen and S. Ferrasso. 2013b. "Boa Parada: Um lugar de casa subterrâneas, aterros-plataforma e 'danceiro'" *Pesquisas, Antropologia* 70: 133-135.

Schofield, A.J. 1987. "Putting Lithics To the Test: Non-Site Analysis and the Neolithic Settlement of Southern England." *Oxford Journal of Archaeology* 6 (3): 269-286.

Schriever, B.A., M.S. Taliaferro, and B.J. Roth 2011. "A tale of two sites: Functional site differentiation and lithic technology during the Late Pithouse period in the Mimbres area of Southwestern New Mexico." *Journal of Anthropological Archaeology* 30 (2): 102–115.

Schwarz, G.E. 1978. "Estimating the dimension of a model" *Annals of Statistics* 6 (2): 461-464.

Sempé, M.C. and M.A. Caggiano. 1995. 'Las culturas agroalfareras del Alto Uruguay (Misiones, Argentina)' *Revista do Museu de Arqueología e Etnología* 5: 27-38.

Serrano, A. 1937. "Arqueologia brasileira: Subsídios para a arqueologia do Brasil meridional." *Revista do Arquivo Municipal de São Paulo* 36: 398-405.

Serrano, A. 1940. "Los sambaquís y otros ensayos de arqueología brasileña." In: *Anais do Terceiro Congresso Rio-Grandense de História e Geografia*. Porto Alegre: Imprenta Riograndense.

Serrano, A. 1972. *Líneas fundamentales de la arqueología del litoral. Una tentativa de periodización.* Córdoba: Universidad Nacional de Córdoba.

Shekhar, S., M.R. Evans, J.M. Kang and P. Mohan. 2011. "Identifying patterns in spatial information: a survey of methods" *WIREs Data Mining and Knowledge Discovery* 1: 193-214.

Shiner, J.I. 2004. *Place as Occupational Histories: Towards an Understanding of Deflated Surface Artefact Distributions in the West Darling, New South Wales, Australia*. Department of Anthropology: University of Auckland, Auckland. Unpublished PhD dissertation.

Shott, M.J. 1986. "Technological Organization and Settlement Mobility: An Ethnographic Examination." *Journal of Anthropological Research* 42 (1): 15-51.

Shott, M.J. 2005. The Reduction Thesis and Its Discontents: Overview of the Volume. In: Clarkson, C. and L. Lamb (Eds.), *Lithics "Down Under": Australian Perspectives on Lithic Reduction, Use and Classification*. Oxford: BAR International series 1408. 109–25.

Shott, M.J. and M.C. Nelson. 2008. Lithic Reduction, Its Measurement, and Implications: Comments on the Volume. In: Andrefsky, W. (Ed.), *Lithic Technology: Measures of Production, Use and Curation.* Cambridge: Cambridge University Press. 23-48.

Silva, F.A. 1999. "As Cerâmicas dos Jê do Sul do Brasil e os seus Estilos Tecnológicos: Elementos para uma Etnoarqueologia Kaingang e Xokleng." *Revista do CEPA* 23 (30): 57-73.

Silver, H. 2007. *The process of social exclusion: the dynamics of an evolving concept.* CPRC Working Paper 95. Department of Sociology: Brown University.

Simões, M.F. 1972. "Índice das fases arqueológicas brasileiras 1950-1971." *Publicações Avulsas do Museu Paraense Emílio Goeldi* 18: 3-75.

Soja, E.W. 1971. *The Political Organization of Space.* Association of American Geographers: Commission on College Geography.

Soja, E.W. 1980. "The Socio-Spatial Dialectic." *Annals of the Association of American Geographers* 70 (2): 207-225.

Stahl, P.W. 2002. "Paradigms in paradise: Revising standard Amazonian prehistory." *Review of Archaeology* 23 (2): 39–51

Steinberg, J.M. 1996. "Ploughzone sampling in Denmark: isolating and interpreting site signatures from disturbed contexts." *Antiquity* 70 (268): 368-392.

Stern, N. 1993. "The Structure of the Lower Pleistocene Archaeological Record: A Case Study From the Koobi Fora Formation." *Current Anthropology* 34 (3): 201-215.

Stevaux, J.C. 2000. "Climatic events during the Late Pleistocene and Holocene in the Upper Parana River: Correlation with NE Argentina and South-Central Brazil" *Quaternary International* 72: 73-85.

Steward, J.H. (Ed.). 1946a. *The Handbook of South American Indians. Volume 1: The Marginal Tribes*. Washington D.C.: Smithsonian Institution.

Steward, J.H. (Ed.). 1946b. *The Handbook of South American Indians. Volume 2: The Tropical Forest Tribes*. Washington D.C.: Smithsonian Institution.

Stewart, K., S. Turner, S. Kelley, C. Hawkesworth, L. Kirstein and M. Mantovani. 1996. "3-D, ^{40}Ar-^{39}Ar geochronology in the Paraná continental flood basalt province." *Earth and Planetary Science Letters* 143: 95- 109.

Stoyan, D. and H. Stoyan. 1994. *Fractals, random shapes and point fields*. Chichester: John Wiley & Sons.

Strahler, A.N. 1957. "Quantitative Analysis of Watershed Geomorphology." *Transactions, American Geophysical Union* 38 (6): 913–921.

Strand, E.K., A.P. Robinson and S.C. Bunting. 2007. "Spatial patterns on the sagebrush steppe/Western juniper ecotone" *Plant Ecology* 190: 159-173.

Strathern, M. 1991. *Partial Connections*. Savage, MA: Rowman & Littlefield.

Sullivan, A.P. 1995. "Artifact Scatters and Subsistence Organization." *Journal of Field Archaeology* 22 (1): 49-64.

Sullivan, A.P. (Ed.) 1998. *Surface Archaeology*. Albuquerque: University of New Mexico Press.

Tainter, J.A. 1998. Surface Archaeology: Perceptions, Values, and Potential. In: Sullivan, A.P. (Ed.), *Surface Archaeology*. Albuquerque: University of New Mexico Press. 169-179.

Tainter, J.A. and G.J. Lucas. 1983. "Epistemology of the Significance Concept." *American Antiquity* 48 (4): 707-719.

Taylor, J., R. Francovich and H. Patterson. 2000. Cultural Depositional Processes and Post-Depositional Problems. In: R. Francovich and H. Patterson (eds.), *Extracting Meaning from Ploughsoil Assemblages.* Oxford: Oxbow. 16-28.

Thomas, D.H. 1975. Nonsite Sampling in Archaeology: Up the Creek Without a Site? In: Mueller, J.W. (Ed.), *Sampling in Archaeology*. Tucson: University of Arizona Press.

Thomas, J. 2004. *Archaeology and modernity*. London: Routledge.

Tobler, W. 1993. *Three Presentations on Spatial Analysis: Non-Isotropic Modeling, Speculations on the Geometry of Geography, and Global Geographical Analysis*. Santa Barbara: NCGIA Technical Report TR-93-1.

de la Torre, I. and R. Mora. 2005. *Technological Strategies in the Lower Pleistocene at Olduvai Beds I & II*. Liège: Études et Recherches Archéologiques de l'Université de Liège.

Trigger, B.G. 2006. *A History of Archaeological Thought*. Cambridge: Cambridge University of Press.

Urban, G. 1998. A história da cultura brasileira segundas línguas nativas. In: Carneiro, M.C. (Ed.), *História dos Índios no Brasil*. São Paulo: Companhia das Letras, 87-102.

Vanzetti, A., M. Vidale, M. Gallinaro, D.W. Frayer and L. Bondioli. 2010. "The iceman as a burial" *Antiquity* 84, 684- 692.

Verhagen, P. and K. Jeneson. 2012. A Roman Puzzle: Trying to Find the Via Belgica with GIS. In: Chrysanthi, A., P. Murrieta Flores and C. Papadopoulus. *Thinking Beyond the Tool. Archaeological Computing and the Interpretive Process.* Oxford: Archaeopress. 123-130

Veiga, J. 2000. A retomada da festa do Kikikoi no P.I. Xapecó e a relação desse ritual com os mitos Kaingang. In: Motta, L.T., F.S. Noelli and K. Tommasino (Eds.), *Uri e Wãxi: Estudos Interdisciplinares dos Kaingang*., Londrina: Editoria da UEL. 261–292.

Venables, W.N. and B.D. Ripley. 2002. *Modern Applied Statistics with S.* 4th ed. New York: Springer.

Vialou, A.V. 1984. "Brito: o mais antigo sítio arqueológico do Paranapanema, Estado de São Paulo" *Revista do Museu Paulista* 29: 9–21

Vialou, A.V. 2009. "Tecnologia lítica no planalto brasileiro: persistência ou mudança" *Revista de Arqueologia* 22 (2): 35-53.

Villagran, X.S., D. Klokler, P. Nishida, M.D. Gaspar, and P. DeBlasis. 2010. "Lecturas Estratigráficas: Arquitectura funeraria y depositación de residuous en el Sambaquí Jabuticabeira II" *Latin American Antiquity* 21 (2): 195-216.

Viveiros de Castro, E.B. 1996. "Images of Nature and Society in Amazonian Ethnology." *Annual Review of Anthropology* 25: 179-200.

Wachnitz, G.A. 1984. *Prehistoria Altoparanaense Preguarani*. Misiones: Imprenta Seyfried.

Wagner, G., K. Hilbert, D. Bandeira, M.C. Tenório and M.M. Okamura. 2011. "*Sambaquis* (shell mounds) of the Brazilian coast" *Quaternary International* 1-2: 51-60.

Walker, J.H. 2011. "Amazonian Dark Earth and Ring Ditches in the Central Llanos de Mojos, Bolivia." *Culture, Agriculture, Food and Environment* 33 (1): 2–14.

Walker, J.H. 2012. "Recent Landscape Archaeology in South America." *Journal of Archaeological Research* 20 (4): 309-355.

Wandsnider, L. 1992. The Spatial Dimension of Time. In: Rossignol, J. and L. Wandsnider (Eds.), *Space, Time, and Archaeological Landscapes.* New York: Plenum Press. 257-280.

Wandsnider, L. 1996. "Describing and Comparing Archaeological Spatial Structures." *Journal of Archaeological Method and Theory* 3 (4): 319 – 384.

Wandsnider, L. 1998a. Landscape Element Configuration, Lifespace, and Occupation History: Ethnoarchaeological Observations and Archaeologial Applications. In: Sullivan, A.P. (Ed.), *Surface Archaeology*. Albuquerque: University of New Mexico Press. 21-39.

Wandsnider, L. 1998b. Regional Scale Processes and Archaeological Landscape Units. In: Ramenofsky, A.F. and A. Steffen (Eds.), *Unit Issues in Archaeology: Measuring Time, Space, and Material.* Salt Lake City: University of Utah Press. 87-102.

Wandsnider, L. 2004. Solving the Puzzle of the Archaeological Labyrinth: Time Perspectivism in Mediterranean Surface Archaeology. In: Alcock, S. and J. Cherry (Eds.), *Side-by Side*. Oxford: Oxbow Press. 46-68.

Wandsnider, L. and E. Camilli. 1992. "The Character of Surface Archaeological Deposits and Its Influence on Survey Accuracy." *Journal of Field Archaeology* 19 2: 169-188.

Wells, E.C., G.E. Rice and J.C. Ravesloot. 2004. "Peopling Landscapes between Villages in the Middle Gila River Valley of Central Arizona." *American Antiquity* 69 (4): 627-652.

Werdelin, L. and M.E. Lewis. 2013. "Temporal Change in Functional Richness and Evenness in the Eastern African Plio-Pleistocene Carnivoran Guild." *PLOS ONE* 8 (3): e57944. DOI:10.1371/journal.pone.0057944

Whallon, R. 1973. "Spatial Analysis of Occupation Floors I: Application of Dimensional Analysis of Variance." *American Antiquity* 38 (3): 266-278.

Whallon, R. 2006. "Social networks and information: Non-"utilitarian" mobility among hunter-gatherers." *Journal of Anthropological Archaeology* 25 (2): 259–270.

Wheatley, D. 1996. Between the lines: the role of GIS-based predictive modelling in the interpretation of extensive survey data. In: Kammermans, H. and K. Fennema (Eds.), *Interfacing the past (CAA95 proceedings)* Leiden: Leiden University Press. 275-292.

Wheatley, D. and M. Gillings. 2002. *Spatial Technology and Archaeology: the archaeological applications of GIS.* London: Taylor & Francis.

Wheatley, D. 2014. Connecting landscapes with built environments: visibility analysis, scale and the senses. In: Paliou, E., U. Lieberwirth, and S. Polla (Eds.), *Spatial analysis and social spaces: interdisciplinary approaches to the interpretation of prehistoric and historic built environments.* Berlin: De Gruyter. 115-134.

White, G.G. and T.F. King. 2007. *The Archaeological Survey Manual*. Walnut Creek: Left Coast Press.

Wiegand, T., F. Jeltsch, I. Hanski and V. Grimm. 2003. "Using pattern-oriented modeling for revealing hidden information: a key for reconciling ecological theory and application" *Oikos* 100: 209-222.

Wiegand, T. and K.A. Moloney. 2004. "Rings, circles, and null-models for point pattern analysis in ecology" *Oikos* 104: 209-229.

Wiegand, T. and K.A. Moloney. 2013. *Handbook of Spatial Point-Pattern Analysis in Ecology*. Boca Raton: CRC Press.

Wildesen, L.E. 1982. "The Study of Impacts on Archaeological Sites." *Advances in Archaeological Method and Theory* 5: 51-96.

Wood, J. 1996. *The Geomorphological Characterisation of Digital Elevation Models.* Department of Geology: University of Leicester, Leicester. Unpublished PhD dissertation.

Wood, J. 1998. Modelling the Continuity of Surface Form Using DEMs. Paper in: *8th International Symposium on Spatial Data Handling, Vancouver, Canada, July 11-15th.*

Wood, W.R. and D.L. Johnson. 1978. "A survey of disturbance processes in archaeological site formation." *Advances in Archaeological Method and Theory.* 1: 315-381.

Wüst, I. 1983. *Aspectos da ocupação pré-colonial em uma área do Mato Grosso de Goiás*. Museu de Arqueologia e Etnologia: University of São Paulo, São Paulo. Unpublished MA dissertation.

Wüst, I. 1998 "Continuities and discontinuities: archaeology and ethnoarchaeology in the heart of the Eastern Bororo territory, Mato Grosso, Brazil." *Antiquity* 72 (277): 663–675.

Yarrow, T. 2006. Perspective Matters: Traversing Scale through Archaeological Practice. In: Lock, G. and B.L. Molyneaux (Eds.), *Confronting Scale in Archaeology: Issues of Theory and Practice.* New York: Springer. 77-87.

Zech, M., R. Zech, H. Morrás, L. Moretti, B. Glaser and W. Zech. 2009. "Late Quaternary environmental changes in Misiones, subtropical NE Argentina, deduced from multi-proxy geochemical analyses in a palaeosol-sediment sequence." *Quaternary International* 196 (1-2): 121-136.

Zedeño, M.N. 1997. "Landscapes, Land Use, and the History of Territory Formation: An Example from the Puebloan Southwest." *Journal of Archaeological Method and Theory* 4 (1): 67-103.

Zeidler, J.A. 1995. Archaeological survey and site discovery in the forested neotropics. In: Stahl, P.W. (Ed.), *Archaeology in the lowland American Neotropics: Current Analytical Methods and Applications.* Cambridge: Cambridge University Press. 7-41.

Zucchi, A. 1973. "Prehistoric human occupations of the western Venezuelan llanos" *American Antiquity* 38 (2): 182-190.

Zvelebil, M., S.W. Green and M.G. Macklin. 1992. Archaeological Landscapes, Lithic Scatters, and Human Behaviour. In: Rossignol, J. and L. Wandsnider (Eds.), *Space, Time, and Archaeological Landscapes.* New York: Plenum Press. 193-226.