Evidence of Aboriginal Networking: non-destructive pXRF characterisation of ground-edge hatchets from south-east South Australia

A Dissertation submitted by

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ABSTRACT

Differing patterns of distribution from source of local and exotic artefacts have been used to set up and modify theories and models of hunter-gatherer social/political networks. Stone hatchets are useful for testing these theories because they do not decay in time. In this research pXRF technology was used to compare 242 hatchets found in south-east South Australia with known local basalt sources, and with distant sources from Central Victoria and Mount Isa. Chemical analysis determined that the great majority of hatchets came from unknown sources of similar, distinctive, stone which, unlike the local basalts, were very low in most elements from Rb to Nb in the periodic table. This majority was similar, but not a match, to stone from Mt William in central Victoria.

From their distribution and frequency, this majority of hatchets was probably used as tools, but because they were found across three language areas, I conclude that they were also desirable exchange items. There was no apparent separation of useful and exchange hatchets, a difference from hunter-gatherer models which may have been a result of limited local stone sources.

My research also determined that three hatchets found in SESA originated in Mount Isa, extending the distance that Mount Isa hatchets are known to have moved from Lake Eyre/Flinders Ranges to south-east South Australia. One of these was distinctively shaped, matching a type of hatchet known to have originated in Mount Isa. Another three hatchets were determined to have originated near Mt Macedon in central Victoria. These six exotic hatchets were distributed evenly across the three language areas, showing no area with a concentration of power of acquisition.

I concluded that the distribution of SESA hatchets from source indicates a strong network between the three language groups, Ngarrindjeri, Bindjali and Buandig prior

to European settlement, a network which was highly interactive, evenly spread across Buandig land and the southern areas of their neighbours, and with no evidence of dominance by one group in any language area.

CERTIFICATE OF DISSERTATION

I certify that the substance of this dissertation has not been previously been submitted for any other degree, and is not currently being submitted for any other degree or qualification. I certify that the work is original, that any help in preparation and all sources used are acknowledged in this thesis.

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CHAPTER 1

INTRODUCTION

Figure 1 Area of SESA within southern South Australia and western Victoria. Inset of SESA within Australia

In this thesis I undertake non-destructive elemental characterisation using portable X-ray Fluorescence (pXRF) of a museum-curated set of Aboriginal ground-edge hatchets from south-east South Australia (SESA) and archived in the South Australian Museum. The purpose of the study is to determine the scale of movement of hatchets from geological origin to findspot. To do this, I compare elemental profiles of the hatchets with potential local and relatively close rock sources in SESA and western Victoria respectively, and with more distant rock locations in Queensland and central Victoria.

From the pattern of spread of items from source, I attempt to reconstruct aspects of the social network relevant to the movement of these hatchets. Underpinning this is the assumption that through the establishment of distance and direction from source of an artefact, I can evaluate the probable social networks that facilitated this movement (eg, evidence of limited movement of artefacts out of one area may be a product of a very different set of relationships in contrast to the movement of large numbers of items).

Aboriginal occupation of Australia is currently thought to extend back to more than 50,000 years (Hiscock 2008: Chapter 2). Evidence from rock art and occupation sites from this period indicates the development of an increasingly complex social organisation in relation to a demographic expansion into all parts of a highly resource diverse continent. Yet our evidence for the social importance of Aboriginal exchange is almost entirely dependent on a relatively brief and late window of historical accounts from the time of British colonisation (from 1788 AC). These accounts highlight the often elaborate and ritualised nature of Aboriginal meetings, as well as their scale, the geographic range of the participants and diversity of goods exchanged.

The study presented here is part of a larger project funded by the Australian Research Council (ARC) (Axe Exchange and Social Change) led by Drs Peter Grave (University of New England) and Val Attenbrow (Australian Museum) investigating movement of ground-edge hatchets in south eastern Australia. There were several known sources with which to compare SESA hatchets, with the aim of determining if there were patterns of distribution which might give information about Aboriginal trade, and thus the structure of the SESA social/political network.

1.1 Limitations and considerations relevant to my research

Early European accounts of Aboriginal culture are not necessarily disciplined or objective (Attenbrow et al 2012:47; see McCarthy 1939 and Roth 1897), and often the accounts are records of memories of the Aboriginals whose groups had been devastated by introduced diseases and displacement (McBryde 1979:117). Hunter-gatherer archaeology is further constrained by the scarcity and bias of the artefactual remains, typically only the lithic component survives, not the organic components (wood, bone and fibre), of the toolkit.

The ARC (Axe Exchange and Social Change) project of Peter Grave and Val Attenbrow was aimed at determining patterns of exchange of ground-edge hatchets as these changed through time in south-eastern Australia (Attenbrow 2013:2). In the Sydney Basin, there is the advantage of stratified finds from rockshelters (for example Attenbrow 2004; Hiscock and Attenbrow 1998), enabling a chronological comparison of tool collections. But the South Australian Museum collection of hatchets from SESA were all surface finds, so no chronological differences could be established. But, with some known sources, distance and direction of movement from source could be determined, and hence some trade/exchange patterns. SESA is a European concept. It is bounded by South Australia, whereas Buandig (the main Aboriginal group in this area) country extended to the Glenelg River which is in Victoria. This could affect findings of this research.

The stone axe of the Aborigines is correctly called a hatchet, because its handle was short and it used with one hand (Dickson 1976:33). Made from a wide variety of igneous and metamorphic rocks, the hatchets in this study all have a ground edge. A primary use was as a wood-working tool, with many purposes such as removing bark, notching trees, shaping wood, opening trees to extract food (Attenbrow 2004:241), though they were also used as weapons, to skin and butcher meat, as a hammer and as a pounder in preparing plants (Kononenko & Attenbrow 2015:2). There are regional differences in form, but these are not exclusive enough for a typology to exist for positive identification in place or time (Dickson 1976:35). With no confirmed typology to source hatchets, we are left with mineral or elemental variation to determine the numbers of hatchets coming from known sources.

A major drawback of conventional methods for determining mineralogy or elemental composition is that they involve destructive sampling of part of the artefact (for example Winterhoof 2007:147-148), but portable X-ray Fluorescence (pXRF) is not only non-destructive, it is also relatively rapid and flexible in terms of analytical requirements. PXRF performs elemental scans which produce net peak areas for a range of elements, which can be calibrated to ppm. It is particularly useful for elements in the range Rb-Nb of the periodic table, measuring these from under the stone surface, which avoids weathering problems. A number of studies have confirmed that pXRF can be sufficiently accurate to enable basalt artefacts to be assigned to specific geological origins with a high degree of confidence (Grave et al 2012; Williams-Thorpe et al 1999).

A particular problem for this research is that I am not a geologist, and can only guess at whether a stone is basalt or not. This restricts interpretation of results.

1.2 Interpretive frameworks

In Chapter 2 a review of the theoretical literature details a number of competing models of the socio-political structure of hunter-gatherer where exchange of information is accompanied by exchange of goods. The focus of my research is lithics, which is utilitarian but also can be a social or power status marker. Thus examination of the spread of lithics from source may determine if there are differences in the usage (sharing or exchange, prolific or rare) pattern between local, relatively close and distant sources. Such patterns can give information on the relationships between neighbouring groups.

1.3 Aims and questions

With the large number of SESA ground-edge hatchets in the South Australian Museum, there is the opportunity here to ask questions which address hypotheses arising from hunter-gatherer models.

1. Are there different proportions of hatchets from local and exotic sources?
2. What are the patterns of spread of the different sources?

The first hypothesis is that there will be a much higher proportion of locally sourced stone than exotic stone. The second hypothesis is that hatchets of highly valued (in social status terms) sources will be widely spread across the three language areas, because they were useful in maintaining networks, while hatchets of low value sources (used as tools alone and not used for social status markers) would be restricted in their spread, diminishing in numbers from source.

1.4 Structure of thesis

In presenting this research, the thesis will be structured as follows:

Chapter one: Introduction. This Chapter has set out the area of Aboriginal network and lithic exchange behaviour my research will investigate. Limitations and theoretical background were discussed very briefly, and questions and hypotheses presented.

Chapter two: Literature Review. This firstly examines hunter-gatherer theories and models, especially from more recent literature, pertaining to the whole world. Secondly it reviews Australian ethnological literature on Aboriginal exchanges, in particular the contribution of F.D. McCarthy. Thirdly it examines literature on Australian archaeological research into Aboriginal exchange, in particular the work of Isabel McBryde. Literature concerning the archaeological work that has been carried out in SESA follows, and the review is concluded with literature on the analytical methods that will be used in the research.

Chapter three: Methodology. This chapter describes the hatchet and source samples used in the research, and the scientific and mathematical methods used to gather and analyse data from the samples and sources.

Chapter four: Results. Here the results of the analyses are given, with tables, graphs and charts to support their explanation.

Chapter five: Discussion. In this Chapter, inferences are drawn from the results, and interpreted with reference to the research questions and hypotheses addressed above in this Introduction.

Chapter six: Conclusion. Here I will discuss the contribution of this research to our understanding of Aboriginal social/political networking and lithic exchange behaviour, and the implications of the conclusions. The thesis will finish with suggested directions for further research.

CHAPTER 2

LITERATURE REVIEW

Relevant literature is reviewed in this chapter. Firstly I will review literature, not specific to Australia, concerning archaeological hunter-gatherer theories and models, particularly literature that focuses on lithics. Next I will look at Australian and Pacific ethnological literature, then at Australian archaeology relevant to the models and issues of social networks, exchange, lithics and SESA. Literature relevant to my analytical methods will complete the review.

2.1 Hunter-Gatherer Theory

Modern hunter-gatherer societies are not merely a relict of ancient people, but neither are they irrelevant to our understanding of the structure of ancient societies (Jordan 2008:457). It has been through investigating modern hunter-gatherer societies in particular that archaeologists have formulated models of general hunter-gatherer structure.

In the past, ethnographic evidence based on observations of one or two societies was commonly used to make generalisations that were inadequate to explain the diversity that existed between hunter-gatherer societies (Jordan 2008:448; Winterhalder 2001). Subsequent hunter-gatherer studies of the 1950s and 1960s moved with more scientific methodology which sought underlying theoretical structures or models to generate hypotheses which could be tested, based on the assumption that 'societies subsisting on wild resources in similar environments would have similar organisation and similar features of culture' (Jordan 2008:450). For example, the "New Archaeology" developed a sub-discipline of ethno-archaeology, that combined ethnographic field studies with archaeological methodology (Jordan 2008:452), giving rise to behavioural ecology, a combination of cultural ecology and natural selection, which investigated the relationship between human populations and their socio-political adaption to the environment.

A 1966 conference – Man the Hunter – marked a watershed that first articulated the Optimal Foraging Theory (OFT) and the evaluation of behaviour in terms of its efficiency in extracting energy from the environment (Jordan 2008:454). A variant of this, the Central Place Forager Theory (CPFT), considered patterns of subsistence in an area surrounding residential sites, and the move to different sites when resources are depleted to the extent that the effort is not worth the energy gained (Winterhalder 2001:22). By comparing resource availability with relocation or settlement, testable predictions could be set up concerning responses to changes in resources (Winterhalder 2001:25). A third framework, named Encounter-Contingent, models the relationship between resources and a forager's decision of whether to acquire a tool or go on in the hope of a better item (Winterhalder 2001:14-15).). This model enabled behavioural predictions about the breadth of choices consequent on fluctuating changes in availability (2001:16-17).

To explain the relationship between resource availability and territoriality, Winterhalder considered the role of exchange and sharing (2001:26-29) where people share because there is no point in not sharing (2001:26). The reciprocal networking model has advantages of insurance against periods of resource shortages, access to more mates and group support (2001:27-28) where reciprocity, exchange with an expectation of a return, requires that participants remain in contact, with the roles of giver and receiver balanced and frequent.

A general weakness of these approaches was that they are reductionist, with subjective selection of variables thought to be critical and common. For OFT, the defining set of hunter-gatherer traits were egalitarianism, low population density, lack of territoriality, minimum storage and flux in band composition (Jordan 2008:450). For Winterhalder, all models could be reduced to four different characteristics: apparent underproduction, routine food sharing, egalitarianism and male/female division of labour (2001:13).

Baker and Swope (2004) argue that the characteristic of sharing and reciprocity is bound up with egalitarianism. Because some people are more skilled and energetic than others, there is an inequality in effort put in by individuals within a society to supply sufficient resources (2004:5). Too much effort would result in overproduction and depletion of resources, so to balance a necessary inequality of effort, individuals either share or give gifts if they produce too much, which sets up an obligation on the part of the receiver. A system of gift obligations most easily solves the problem of unequal production while resulting in an egalitarian society (Baker & Swope 2004:20).

While Baker and Swope suggest that the reciprocated gift is information about hunter type (2004:20), Fitzhugh et al (2011) take a much broader view. Their Information Network model of four layers, local, inter-group, regional and supra-regional, takes account of the temporal and spatial variation in information need with the cost of maintaining connections between the layers (Fitzhugh et al 2011:86). The information may be of changing socio-environmental factors essential to subsistence, or general local and traditional knowledge (Fitzhugh et al 2011:88-89). Highly connected networks transfer more information in multiple ways making them resilient in times of perturbations. Gatherings, exchange friendships, marriage and journeying to feasts, parties and trade fairs are means by which networks are connected (2011:86 and 91). At the local and inter-group level, these are relatively low-cost in terms of effort and resources, but much greater cost and effort is needed at the supra-regional level, where considerable distance may be involved (Fitzhugh et al 2011:92).

From their model, Fitzhugh at el identify four information strategies which they believe will result from different levels of environmental uncertainty coupled with the cost involved in maintaining information flow (2011:96-99, see their Figure 4.4). Using the varying geography, environment and culture of the Kuril Islands, they were able to test these strategies. Ease of physical connection (the cost of networking), and density of settlements (related to environmental uncertainty) were factors in determining the level and type of network connection (the culture) (Fitzhugh et al 2011:112-114).

Whallon's 2006 model linked variables of network frequency, information mobility and distance from source to utilitarian and non-utilitarian exchange. From German prehistoric data, lithics (utilitarian) were generally moved less than 200km from source while decorative shells (non-utilitarian) items were moved 200-600+km. Model B, where exchange of information and maintaining close connections was necessary for survival (2006:261), included a Frequent Network, between adjacent regions, and an Occasional Network between far distant regions (Whallon 2006:264).

The layered network model (Fitzhugh 2011:92 their Figure 4) is similar to a fractal pattern found by Hamilton et al (2007), where the ratio of number of members at one level to the next is the same across the whole system. Hierarchical levels of networks in 339 hunter-gatherer societies show that, though there is reduced person to person contact at the upper levels, these higher levels of network communication are as important as family levels for the information flow, which has 'profound implications' in our understanding of human society development (Hamilton et al 2007:2201).

Hill et al (2014) support Hamilton et al's conclusion. Their model of five levels of interaction was tested by counting annual interaction rates in two hunter-gatherer societies, one in Paraguay, the other in Tanzania. Of genetic, affinal and ritual (non-kin) relationships, ritual relationships were a strong predictor of inter-band connection networks (Hill et al 2014:7), increasing interaction rates more than family relationships, but I wonder if this is a consequence of Hills et al's methodology. Their method of acquiring knowledge of interactions was to count interactions between a subject and a randomly chosen person of the same sex (Hill et al 2014:2), which would underestimate the bias of increased interactions that naturally pertain to physically close family members.

More recent philosophical changes have moved away from strictly scientific reductionist approaches to re-incorporate ethnographic evidence into hunter-gatherer behaviour models and the relationship between belief systems (grounded in subsidence and ecological perspectives) and subsistence systems (Jordan 2008:458).

The above literature emphasises sharing or exchange of information as the primary motivation at all levels of the networks, but there are suggestions that, at least in poorly populated areas, the increased chance of gaining a marriage partner is also a prime motivation. Arranged marriages made up 85% of marriages of 190 hunter-gatherer societies from Africa, Asia and Australia, setting up obligations and reciprocal transactions which connected unrelated males, thereby reducing hostile relations and facilitating further alliances (Walker et al 2011:2-4). This was an interactive system, where marriage connections improved the information network, and this network improved the chances of marriage.

Many of the above investigations and conclusions were based on observation of modern or recent hunter-gatherer societies. To determine if exchange networking was a factor in ancient societies, archaeologists have looked for evidence in patterns of spread of lithics, because, unlike many exchanged items, stone tools remain in the archaeological record.

Hodder and Lane described four models (1982:217) of exchange which would result in particular patterns of spread of lithics varying in size and distance from source, though unfortunately there was not a distinct archaeological pattern for each model. However, in analysing the spread of British axes from source, they could discern decreasing lengths in some sources and not in others (1982:231), reducing possible models. The different patterns for different sources implied different social status, and ownership of a specific stone axe would give status and prestige because of its symbolic associations (1982:232). Hodder and Lane say that if it could be shown that transfer of axes` was controlled by an elite (elders), then the axes and associated symbolism would legitimate their status through links to the ritual process.

Hodder (1982) emphasised that economic, reductionist, formalist and substantivist investigations into exchange models are insufficient, that 'any adequate analysis of exchange systems must consider the way in which the way in which the symbolism of the artefact legitimates, supports and provides basis of power of interest groups' (1982:207). The power and status associated with special artefacts may be achieved by restricted access, and by the introduction of new high status items to replace ones which have filtered down the hierarchical social structure.

The problem with using lithics to investigate hunter-gatherer exchange systems is that even if the stone is correctly sourced, this does not tell us how the stone moved from source to findspot, whether it was moved directly or by exchange (Close 2000:50). However, an investigation into flaked Neolithic artefacts found differences between numbers of sandstone and fine-grain rocks, one was common and one was rare. Inferring direct procurement if a stone is very common at a site, Close (2000:73) suggested a different procurement practice for the two stone types.

Binford, from observations of Nunamiut of Alaska, concluded that the procurement of raw materials is embedded, occurring incidentally with subsistence tasks, that very rarely is a trip made for the ‘express and exclusive purpose’ of getting a raw material (1979:259). However, this conclusion was based on only one society which was extreme in characteristics of diet, logistics and storage (Binford 1979:255-256), a society with a huge domain and no contact at that time with other groups. Other archaeologists disagree with his conclusion. Hertell and Tallavaara (2011) looked at flint found in Mesolithic sites in Finland, to determine if exotic stone was a result of high mobility, as Binford claims, or exchange. Exchange explains why lithics found at one site originated from two different distant sites (Hertell and Tallavaara 2011:31). Their model of long-distance networking would result in an assemblage of a small amount of exotics among a larger set of local lithics (Hertell and Tallavaara 2011:23), a model which enables predictions applicable to my research. They agree with Hill et al (2014) and Walker et al (2011) above, that long-distance contacts improve mate availability for low population societies (Hertell and Tallavaara 2011:32).

In describing lithic acquisition, Duke and Steele define direct procurement as procurement and use from a geological source, and indirect as procurement by exchange (2010:813). They tested the hypothesis that direct embedded procurement characterises abundant high-quality raw materials, and direct special-purpose characterises poorer and sparser lithics by investigating the distance that stone moved in eastern and western Palaeolithic Europe (2010:814-816). From a broad scale and simplified geological map, there was an inverse correlation between stone quality and distance from source (Duke & Steele 2010:823), that is, stone quality affected procurement, results consistent with, though not conclusive of, special purpose procurement (Duke & Steele 2010:825).

Gould and Saggers (1985) also questioned Binford's embedded procurement theory. Of the Australian Western Desert Puntutjarpa, there is 'plenty of evidence' (ethnographic) describing special-purpose trips made by men only to procure stone, only sometimes associated with visits to sacred (men's) sites (Gould & Staggers 1985:120). From analyses of Puntutjarpa adzes, local chert of a high quality dominated, but there was a significant proportion of exotic stone of a poorer quality. From this, and ethnographic evidence, came the Exotic Stone Hypothesis which states that long-distance ties, maintained by special-purpose lithic procurement journeys, characterise hunter-gatherer societies that live in an environment of uncertain resources (Gould and Saggers 1985:122). This pattern of a lower, though significant proportion of exotic stone compared to local stone, was not found at a second rockshelter at James Range East in the Central Desert, which they explain by determining that here, the exotic stone was of a higher tool quality than the local (Gould and Saggers 1985:132). Interestingly, there was an increase in exotic stone in both sites over the last 200 years (since colonisation), which, according to the Exotic Stone Hypothesis, indicates a higher level of social networking (1985:132).

Newlander (2012) investigated paleoarchaic chert, fine-grained volcanic and obsidian stone tools and sources in the Great Basin in Nevada, USA. Obsidian and one chert type moved over 200km from source (2012:309), the obsidian being used for projectile points to which it was not suited (Newlander 2012:315), suggesting that these two stones were procured through non-utilitarian mobility or exchange. The spread from source of the three types of stone support a multi-tiered model of mobility and intergroup interaction in paleoarchaic Nevada:- the common chert distribution reflects procurement during local subsistence activities, the fine-grained volcanic spread reflects annual or territorial ranges, and the spread of exotic chert and obsidian indicates an extended social network maintained through non-utilitarian mobility or exchange (Newlander 2012:316). Whether it was exchange or procurement through long-distance movement into another territory, the resulting social interaction indicates a network.

2.2 Australian Ethnographic Literature

The literature above reviews models of hunter-gatherer social networks that share information and ritual and marriage relationships between groups at each level of a multi-layered world. There is ethnographic evidence of these networks and exchange in Australia, though we cannot rely on historical records (Hiscock 2008). In the first chapter of Archaeology of Ancient Australia, Hiscock argues that Aboriginal culture was not static in time or place, and that people from different areas had different social structure and rules because groups responded to their continually changing environment in ways which suited their group culture. People who recorded behaviours assumed that these behaviours and the underlying social structure were Australia-wide (Stanner 1965:3-5). There was short and long-term temporal and spatial variation because Aboriginal groups varied in size with fluctuations in rainfall and hence food resources.

Added to this were the immense changes to Aboriginal society that happened with European colonisation, consequent on displacement and plagues of smallpox and other diseases. These diseases removed huge numbers of people, and unequally, because more females died than men (Hiscock 2008:15). Hiscock suggests that the social structures responded to this radical change by moving towards a more patriarchal society, with an increased need for exchange of necessary goods, and increased desire for status goods requisite to a patriarchal/hierarchical society. Even excluding these problems, the bulk of the first hand descriptions are limited in the land mass of Australia that they cover: - there is little information on the culture of Aborigines whose lands were first colonised by the Europeans and considerable information of the desert peoples whose arid lands were undesirable for their settlement. Such a consequence is inevitable, but it means that we are in danger of applying interpretations of patterns of behaviour from poorly resourced areas about which we have considerable knowledge, to areas about which we know less. The physical area of my research, southeast South Australia, was good land for European settlement because it is well-watered (for Australia), does not have extreme weather and the soil is suitable for farming. Hence it was settled quickly, and the Aboriginal people were as quickly displaced.

In other words, in using ethno-historical sources, we are not researching Aboriginal exchange networks that have been in place for thousands of years, but a behaviour pattern which was in place around 1800, but may have developed as recently as 1000+ years ago, or even after colonisation.

There were many observers of Aboriginal peoples in the years after colonisation who wrote accounts of what they saw. These descriptions have been quoted, collated, summarised and been used to draw conclusions about Aboriginal behaviour. There are first-hand descriptions of the gathering of many people from neighbouring tribes, and of the ceremonies and exchange that accompanied these gatherings. Many of these are of the far north and outback Queensland which were settled later, but, despite the collapse of networks of south and eastern Australia when colonisation occurred (Attenbrow et al 2012:47), there are also descriptions of gatherings and exchange from southern and eastern Australia. These suggest that exchange patterns varied in degree and spatially between

Aboriginal groups. Examples of variation are seen in the Kurnai of eastern Victoria who were socially/politically isolated from the rest of Victoria (McBryde 1978:363), in contrast to the clans around Lake Eyre who exchanged extensively (McBryde 1997), or groups within western Victoria who preferentially engaged in exchange with some neighbouring groups, but not others (McBryde 1984b:279).

The ethnological literature of F.D. McCarthy

Probably the most well-known observer and recorder of first-hand Aboriginal life in Southeastern Australia was A. W. Howitt who wrote ‘Tribes of South Eastern Australia’ in 1904. His descriptions of barter and trade routes (Howitt 1904:710-721) are fascinating. However, this literature review will start with F. D. McCarthy, whose papers in Oceania 1939, based on and collated many early observations of Howitt and others, are extensively used and quoted as a source for Aboriginal behaviour and archaeology. Because this research is of ground-edge hatchets found in south-east South Australia (SESA), any details which may be relevant to this are included.

McCarthy (1939c:178) names particular meeting places for exchange of goods in Queensland (citing Roth 1897: sect.224), in outback South Australia (citing Horne and Aiston 1924:20), and near Melbourne (citing Howitt 1904:710-720). In central NSW, stone source sites were meeting places used long before Europeans arrived. There are detailed descriptions of exchanges at early gatherings along the NSW coast and Victoria, and early records of meeting places (McCarthy 1939a:408). One meeting place, described by Jessop (1862:244) as a trade centre, was at Noarlunga, south-east of Adelaide, close to the area of this research (McCarthy 1939b:88).

Notice of a proposed ceremony was sent by messenger, with a verbal communication of where and when it would be held, and perhaps what would be exchanged (McCarthy 1939c:177). McCarthy quotes Hale and Tindale (1934:122-123), Howitt (1904:328-330); Love (1936:191-193) and Roth (1897:sect 224) with descriptions of these meetings, and the manner of the exchange carried out between individuals, and quotes Daisy Bates on the numbers of people who attended (Bates 1938:167), and the distance travelled to join a gathering (Bates 1938:121-122) (McCarthy 1939a:437).

It had been noted by observers that items exchanged were not of equal value, nor necessarily in short supply, and often were quickly exchanged on to someone else, thus it was understood by the earliest observers that social intercourse, not economics and necessity, was the motivating force in trade (McCarthy 1939c:174-175). The reason for meeting was barter, so that 'the opportunity is taken' to settle grievances and cement relationships, achieving peace by substituting exchange for fighting between groups to obtain raw materials (McCarthy 1939c:174-175). Elkin (1931:197-198) described the exchanges in South Australia from the northeast to the south coast, though not to the southeast, who says that the exchange of women and gifts was a means of expressing and cementing friendships, symbolical or obligatory, not merely an economic transaction (McCarthy 1939a:426).

'Magical power' was attributed if an item was from a distant source (McCarthy 1939c:173-174), and reciprocity was essential (McCarthy 1939c:179). The trade routes, or Trunk Trade Routes (McCarthy 1939b:98), were limited by the weight of objects, by a conservative unwillingness to use different items and in particular, by the physiography of the country (McCarthy 1939c:175-176). The central route through the deserts, connecting northern to southern Australia, followed the water courses. Along this route Flinders

Ranges Parachilna red ochre travelled over 300 miles to Queensland, NSW and Alice Springs. Boomerangs from outback Queensland (McCarthy 1939b:82, citing Horne and Aston 1924:74), the narcotic pituri from the centre, shells from the north-west and axes from Mount Isa travelled this route to Lake Eyre. McCarthy's description of trade in northern Australia and Queensland is detailed (1939a:410-425), a demonstration of just how much has been recorded and is known about these areas. Ground-edge axes were also traded along a northerly east-west route into Western Australia (McCarthy 1939c:174).

McCarthy (1939a:427) writes, from a personal communication with Tindale, that trade routes in South Australia were focussed around the southern end of this route at the Parachilna Gorge ochre source. However, Lake Eyre was a major node, a place where routes started or ended. Traded goods went along the 'main trunk route' to Port Augusta, along Spencers and St Vincents gulfs to the mouth of the Murray River and the Coorong (McCarthy 1939b:101). Victorian stone axes moved into South Australia either via Lake Hindmarsh in north-western Victoria through Pinnaroo lands to Talem Bend and Mannum, or, an alternative route, close to the coast from the Glenelg River to the Coorong through SESA (McCarthy 1939 IXB:427-8). McCarthy (1939 IXA:410) quotes Basedow (1929:362) as stating that 'the southeast tribes of South Australia used to receive their supplies of stone axe heads from the hill tribes of what is now Victoria'.

McCarthy's papers, based on first-hand reports of exchange and networking, have been covered in some detail because they summarise early observations. His ethnological data supports hunter-gatherer theories and models which include sharing, reciprocity and networking at neighbour and far-distant levels for non-economic reasons.

2.3 Australian Archaeological Literature

This review now looks at literature which describes archaeological research relevant to Australian Aboriginal networking and exchange. One should start with Hiscock's warnings.

Hiscock (2008: Chapter 4) describes the variety of culture that existed across Australia, emphasising that it was not a single culture. The temporal and physical introduction and spread of stone tools, backed artefacts, small tools and ground-edge hatchets prove that there was no one Aboriginal culture, but a multiplicity of them through time and space. In their paper on the introduction of backed artefacts, Hiscock and Attenbrow (1998) argue that it is easy to read wrong conclusions from archaeological data, and that archaeological exploration must carefully consider all variables. Accepting that research for one physical and temporal area cannot be transposed onto another time and place, and that it is difficult to determine if all variables are covered, this review will now consider literature relevant to the research conducted here.

2.3.1 The work of Isabel McBryde

One of the most quoted and influential researchers into Australian Aboriginal trade and exchange is Isabel McBryde, who carried out archaeological research into stone axe quarries and exchange patterns in Victoria, New South Wales and Lake Eyre Basin. Her Victorian and New South Wales work was based not on desert cultures, but on land similar to that of SESA, thus it also has the disadvantage that Aboriginal people had been quickly displaced, so descriptions of their life and social structure come from memories of Aboriginal people who were living in the area prior to colonisation and early European settler. McBryde wrote many papers and contributed to several books describing her research, presenting ideas and theories in different contexts, so here her work and ideas will be reviewed, referring to the different papers which describe these, rather than going through the papers individually.

The status of stone is dependent on source

In 1972, Binns and McBryde published the results of their investigation of movement of axes from source across a large region of northern NSW, using axes from private and museum collections. They categorised them according to petrology, which required a sample cut from artefacts to make thin sections, and type of hatchet (1972:3). There were many well-known stone axe sources within this region, including quarries and cobbles in river beds (1972:74), some of which were shown to be sources of their categorised groups. This enabled analysis of patterns of spread from source. The directional spread indicated trade routes. It was also apparent that some stone was used only locally, not for exchange or trade (1972:97).

In 1972, McBryde began her research into the Mount William greenstone quarry because, for an early settled area, it had unusually good ethnographic evidence of its role in Aboriginal society at the time of colonisation (1979:117). The quarry was still being used in the 1830s, and there are historical records of the last traditional owners describing controlled acquisition of the stone (McBryde 1984b:270-273; McBryde 1984a:148; McBryde and Watchman 1976:164). Mt William stone was documented as a very highly valued stone which was traded to New South Wales and South Australia (McBryde 1986:79; McBryde and Harrison 1981:200).

McBryde and Watchman tracked the pattern of spread of stone from at least ten quarries in the three Victorian greenbelts (McBryde 1979:117; McBryde and Watchman 1976:164-165). The central belt, in Kulin country, includes Mt William and Mt Camel, and the western belt, closest to SESA, runs from the Grampians down to the coast. The belts are Cambrian greenstone, narrow ridges with outcrops of altered and metamorphosed basic igneous rocks (McBryde and Watchman 1976:166). Mt William stone was often indistinguishable, even with petrographic analysis, from that of near-by Mt Camel, (McBryde and Harrison 1981:189), but XRF on powdered samples of source stone and hatchets did separate them.

However, stone from the eastern and western greenstone belts in Victoria were separable by visual analysis, because they were distinct rock types. The Glenormiston-Ararat part of the western belt is basalt, tuff and chert, - Berrambool quarry near the Hopkins River is a distinctive albitized microporphyritic basalt, Baronga, west of Ararat, contains altered dolerite, while Mt Dryden and Jallukar (in the Grampians) have outcrops of trachyte, dacite and syenite porphyry (McBryde and Watchman 1976: 166-168).

McBryde and Watchman divided the findspots area in Victoria into quadrats based on a 1:250,000 map, then into 50km distances (McBryde1978:359-360). By counting artefacts from different stone sources found in these areas, they could determine in which directions hatchets from each quarry were more used, more distantly traded, and in which directions. From their map of distribution from each quarry, hatchets from the central greenstone belt were widely dispersed, those from the western Victorian Hopkins River region less so, and those from the eastern belt and Geelong only distributed locally (McBryde 1979:118-119; McBryde 1984b:268; McBryde and Watchman 1976:170-171). However, stone did not spread equally in all directions, especially from the central belt, and stone from Berrambool was not found in adjacent lands to the northwest (1984b:269) though it moved south and west. Relevant to my research, their map of distribution of hatchets (McBryde and Watchman 1976:173), as well as McBryde's later chart of distances from source (1984b:270) show that stone from Berrambool and Baronga was commonly used 300km from source. McBryde and Watchman believed Berrambool hatchets reached South Australia, but their lack of samples from South Australian sites prevented their doing more than suggesting this as possible (McBryde and Watchman 1976:171). One hatchet from Mt William, now in Canberra, was found at Millicent in SESA (McBryde and Harrison 1981:200).

McBryde (1997) found the same distinction between useful and high status quarries of grindstones from Lake Eyre. Of the Lake Eyre grindstone quarries, several had suitable stone, but some quarries were more worked, exchanged and highly regarded than others (McBryde 1997:593-595). There were two types of quarries, smaller quarries casually used by locals to produce grindstones that were not traded, and larger ones of which the access was controlled by men, and this access was traded to outsiders. Also, there were different patterns of spread of grindstones associated with these two types of quarry usage (McBryde 1997:595).

McBryde's exchange patterns and network theories

In her writings, McBryde describes a layered network of exchange. There is the simplest layer of exchange, the casual daily swapping of articles within the close group, usually involving low status non-endurable items, gifts of flora and fauna, food or clothing (McBryde 1997:589-590).

The second layer, more elaborate or formal, was between neighbouring groups and language groups, where gatherings were organised at particular meeting places for ceremonies and rituals. These formal exchanges were to mark the end of a conflict, to seal important social or political deals between individuals or groups and to gift sponsors at initiations and marriage ceremonies (McBryde 1987:268; McBryde 1997:591-592). Goods and services were exchanged between neighbouring peoples who spoke related languages, at ceremonies and rituals which cemented relationships between these groups. These formal exchanges required high status artefacts, status conferred by the importance of the place of origin in Dreaming mythology, the spiritual or symbolic nature of the raw material and the status of the maker (McBryde 1997:589-592). With reference to lithics and status, there was no technological necessity for greenstone for axes, so source must have been important to exchange value (McBryde 1978:357-358).

To understand which factors were important in networking at this level, McBryde looked at the spread of stone from source. In Victoria, the position of rivers, geology and population did not explain why greenstone moved in some directions and not others (McBryde 1978:362; McBryde1986:79; McBryde and Harrson1981:189), but there was remarkable correlation between artefact spread and language boundaries (McBryde 1986:84). The same factor was relevant in the distribution of grindstones around Lake Eyre, where the connecting network of culture and ceremonies was between the peoples who lived predominantly north and south, who spoke related languages and shared customs and beliefs, distinct from groups of the east and west (McBryde 1987:256).

The third and spatially widest exchange level involved long-distance exchange through organised excursions to special meeting places (McBryde 1987). Along the channel country this involved the long-distance movement of pituri, shells and hard stone hatchets to Lake Eyre (the last coming from Cloncurry/Mount Isa), none of which were available in that area (McBryde 1997:602-604). Hatchet heads followed a route from the Selwyn ranges, near Mount Isa, south to Birdsville in one movement, from where it was exchanged to move further south to Kopperamana, east of Lake Eyre (McBryde 1987:260).

From here, it moved east, rather than south. Of interest to this study, McBryde also says that the Lake Eyre people obtained hard volcanic stone from ‘distant quarries in the southeast’ as well as from the Mount Isa district (1987:265).

Although hatchet stone went no further south than Lake Eyre, expeditions of men of several different groups, all from north of Lake Eyre, walked for two months almost 500km to the Flinders Ranges to obtain red ochre from Pukardu Hill (McBryde 1987:259). This Parachilna ochre was prized above closer sources, and Dreamtime stories told of its formation and importance (McBryde 1987). The grinding stones and ochre from the Flinders were not obtained for their usefulness, they were acquired, then kept for further barter, and increased in value as they were exchanged further from source (McBryde 1987:262).

This network layer of long-distance single-move exchange system involved organised production for organised exchange. The production could be called commercial, because it was carried out for exchange, not for personal use. It involved controlled access to the source, complex routes of removal long distances from sources (McBryde 1997:604), and possibly mass production of goods (Hiscock 2005; McBryde 1997:594).

Through her papers, McBryde considers reasons for exchange networks, questioning whether economics (scarcity), technological or social (spiritual or status value) factors are the motives behind exchange (McBryde 1997:588), and concludes that there are symbolic reasons, indicative of political, social and ceremonial connections between peoples that are the real motivation.

The people of SESA were not desert people, and possibly did not require this complex network for survival, but they lived in lands similar to the central Victorian groups who did network, maintaining particular cultural relations with their neighbours.

McBryde's work supports hunter-gatherer models of sharing and exchange of local and exotic stone, with layers of networking and a distinction between the procurement methods of local and exotic stone. The non-economic motivation for networking also supports these models, but McBryde includes a dimension of choice in who will be networked. Following this detailed review of her work, other literature relevant to this research is examined briefly.

2.3.2 Other Australian and Pacific archaeological literature on exchanges and networks

Pertinent questions which have become issues in Australian archaeology network models are: Is there evidence to support layered networks? Was long-distance movement of lithics a result of high mobility or exchange? Is there evidence to suggest whether it is the quality or source of a lithic that gives it high value/status? McBryde is typical in that she explored physical evidence, included ethnographic evidence, and discussed causes and social structure, but there are other contributions to these questions and underlying models.

From archaeological sources (Geneste et al 2012; Morwood and Trezise 1989:81), it is known that ground-edge axes were produced during the Pleistocene in north-west and north-east Australia. While they first appeared in the south east nearly 4000 years ago, they only became common in these areas during the last one or two thousand years (Attenbrow 2010:102), and they were never made in Tasmania or parts of southern Western Australia (Smith 2013:291; Hiscock 2008:Chapter 1). Large gatherings occurred 25,000 to 30,000 years ago, the size of which would have required economic and social organisation (Hiscock 2008:123), where items would have been formally exchanged.

Mulvaney (1976:86) in his chapter on Australia's deserts mapped the long distance route joining north to south central Australia, along which pituri and stone from Cloncurry travelled south to the Flinders Ranges, from where grindstones and ochre travelled north (Mulvaney 1976:90). Gift-giving was a common factor in most ceremonial meetings, but economic motives are insufficient to explain the rituals and social factors associated with the exchange, which is better described as 'reciprocal gift exchange' (Mulvaney 1976:75).

One point of particular interest to this research is Mulvaney's positioning on a map of a ceremonial centre north of Casterton on the western side of the Glenelg River in far western Victoria (1976:76). Less than 50 km. from SESA, this is inside Buandig country.

In 1951 Berndt, and Berndt and Berndt in 1988, described different types of socio/political/judicial meetings of several tribal groups in Arnhem Land (1951:174; 1988:121-130). These also were hierarchical, one level was local, the next was between neighbouring cultures and the widest spread was the long-distance movement of goods.

Paton's 1994 model of exchange was based on his research into procurement and exchange of stone artefacts in northern Australia. He points out that in Australia it is the degree of cultural homogeneity that is most striking, which raises the question of how such homogeneity is formed and maintained. Paton says that 'very sophisticated information crucial to the operation of a society can be conveyed across great distances' by artefact exchange and distribution (Paton 1994:172). Paton argues that the value of the exchange is not the usefulness of the item, but its trade value, basing this on the fact that exchanged items were not used, rather they were exchanged further, discarded or deliberately broken (Paton 1994:176-177). However the sources of stone were important, because of their associations with mythology related to particular quarries (Paton 1994:177) Access to important quarries was highly controlled, restricted to a few men, so that the Dreaming was properly managed, and no danger came to the community. The Dreaming myths and knowledge were related to the rock, and were carried with the stone along the Dreaming tracks, which could be hundreds of km long (Paton 178). Paton concludes that the real value of the artefacts lies in the socially indispensable messages they help communicate. This comes back to the need of hunter-gatherer communities to survive times of stress by relying on their wide social ties and mores which govern ownership rights and symbols of vital information about creation myths.

Paton shows that exchange was ritual, socially significant. He saw no economic role in the exchanges, however he does not consider whether the role of exchanged items has changed since European occupation. It is possible/probable that, prior to European occupation, exchange had a useful (economic) role as well as an important socially ritualistic one.

Smith (2013:270-271) describes layers of exchange in networks in Central Australia from Arnhem Land to Lake Eyre. At one level, there was interpersonal exchange between kin or exchange partners, where reciprocity was an integral part of the exchange, which was carried out at ceremonial gatherings, resulting in many small transactions of goods, ceremonies and social behaviours. The next level was formal exchange between neighbouring language peoples, a political economy, used so each group could establish and maintain their place within the wider area. These exchanges were usually of prestige items, and rarely of food. Goods could be transferred a long distance by going from one group to the next along a series of jumps. The last layer of exchange is the single move, long-distance transfer of four special items, red ochre, pituri, grinding stones and stone axe heads (Smith 2013:270-271). From ethnographic evidence, these were carried over 400km by large groups of men who exchanged large quantities of one of these desirable items for another (Gould and Saggers 1985:120; Smith 2013:267).

This long-distance trade route started 1500-1000 years ago with grindstones and axe heads, and later included pituri and ochre (Smith 2013:298). It was limited to the branches of rivers along the eastern side of the arid desert region, where particular desirable items were available at either end of the route. Ethnological and scientific sources of evidence suggest high levels of population coupled with shortages of food in this region as well as a social structure dominated by older men (Smith 2013:298). These older men monopolised women and resources, and organised the long-distance trade. Smith (2013:300) believes that this trade route was a recent consequence of a ‘spiralling demand’ for high status exchange goods, instigated by these men to maintain their elite position.

Smith concludes (2013:300) that the elaborate long-distance trade system through Lake Eyre is unique in the world of hunter-gatherers, but evidence of these exchange networks relies on ethnological evidence, and archaeological evidence is needed (2013:272).

This social structure change may answer the question of why some sources have higher desirability than others. The desire of an elite group to maintain their position has been a reason for their creating artificial demand for an item in many societies, not just hunter-gatherer. While some quarries did have superior stone or ochre, and consequently were a highly desired source, other sources, for example the Parachilna quarry in the

Flinders Ranges, may have been manipulated by Dreaming mythology to be more desirable (McBryde 1997:592).

Ken Mulvaney (2005:304) describes an exchange pattern on the Barkley Tablelands in Northern Territory in which sandstone for grinding seeds, silcrete for knives and blades, and ribbonstone for tula adzes were exchanged. Milling the grass seeds that grew on the tablelands required grinding stones that only came from the Ashburton Range to the west. There was a familiar pattern – one Ashburton quarry was worked far more than others, despite there being no difference in stone quality. The exchange network developed in this difficult country to allow survival, but evolved into a complex social structure which, to stay in place and be able to adapt to changing conditions, came to require and rely on high status items from special Dreaming places (Mulvaney 2005:311-313). When a group had plenty of resources (food and water), they shared them at gatherings, setting up an obligation that ensured them of a return. Exchanged gifts from special places associated with the Dreaming, its mythology and song-lines, cemented this network. This system is unlikely to be more than 'several thousand years old', based on linguistics, and the spatial distribution of the skin terminology as described by McConvell (1996) (Mulvaney 2005:311-13).

Mulvaney refers to a 1991 unpublished report by Mulvaney and Pickering which states that stone axes from Mount Isa reached the Barkley Tablelands (2005:307).

Brumm (2010) also described restricted access to the very high status stone from the Mt William quarry in Victoria. Mt William was on the border between two clans, and both of these exerted control of the quarry. Only one member of a clan, a particularly strong individual, was in control of and permitted to work the quarry, and people came and exchanged for the stone rather than for access to the quarry.

The role of this clan chief devolved from father to son, but the son had to prove his worth before he became chief (2010:184). This was done by demonstrating exceptional skills in communication through song and dance with the spirit world, songs and dances often communicated over long distances, Brumm argues that one particularly strong myth, the Falling Sky, was associated with Mt William stone, making this stone exceptionally significant in the Dreaming (2010:191). The myth involved a need for axes to hold up the sky to the northeast over the mountains of the Great Dividing Range.

However, Hiscock (2013) shows the malleability and continual evolution and changing of the Dreaming in response to changing situations. He argues that the development of this particular myth with its emphasis on Mt William axes were a response to European settlement and the desire of the elders to maintain their powerful position.

Miles Robson (2012) also argues that social factors were behind exchange, but questions the emphasis on ethnographic evidence, looking at archaeological evidence of stone axe heads in museums. The falloff patterns of finds of polished and unpolished axes in the United Kingdom from source, and the falloff patterns in Victoria of greenstone from different quarries are similar. There was a pattern of gradual falloff as indicative of local trade (a lower level of network), and an uneven extensive trade (strong in some directions and not others) as indicative of formal bulk exchange (a higher level of network) (Robson 2012:99-101). Local exchange was not restricted by the weight of the axe heads, but for long-distance bulk trade, smaller or a narrower range of sizes of heads were produced. From these distribution patterns, axe heads from Mt William and Mt Camel were made for the bulk trade, while heads from the western belt were made for local exchange, a difference which indicates that social relations rather than resources influenced the distribution.

Hiscock (2005) studied a very large quarry at Lake Moondara I, one of many quarries in the Cloncurry/Mt Isa area. There was a massive number of axe roughouts (an estimated 800,000), and from measured cores and flakes at three stages of their production, evidence of a standardised technique as well as standardised final products, indicative of mass production for mass trade (Hiscock 2005:290). Average measurements of the hatchets at the final stages of their production indicate the standardised ground-edge hatchet as 9.7+/- 1.8cm length, 9.3+/-1.7cm width, and 4.1+/-0.7cm thickness (2005:291). In his final discussion, Hiscock argues that this standardised production and trade in a non-hierarchical, non-commercial society means that we need to relook at theories on prehistoric trade. It shows that 'standardised large-scale production for trade does not indicate socio-political structures of a hierarchical nature' with a centralised authority, and, from the other side of the argument, not only commercial trading systems show standardisation (2005:298).

Attenbrow et al (2016) analysed provenance of stone tools and their distance from source. They compared 121 mafic, ground-edged artefacts found in the Sydney Basin with 368 geological samples in the central coast region of NSW. They found that hatchets were mostly from local sources, some of which were commonly used, while other sources were not utilised (2016:16). These locally made stone hatchets were tools, without power or symbolism, not acquired by exchange or ceremoniously (2016:6). European settlement would have changed the status of hatchets, their value as a tool would be diminished because of available alternatives, but their social power and symbolic value would remain. Attenbrow et al found that the distances from source that hatchets were moved was less than along the central desert routes or other regions of south-eastern Australia and concluded that this was because the Sydney Basin region was a populous, well-watered and fertile land (2016:23).

Winterhoof (2007) looked at variation in size and shape of Samoan basalt adzes, and spatial and temporal variation of production in conjunction with the socio-political organisation. Chemical analysis separated sources, signs of intensification, and increased and more efficient production (Winterhoof 2007:155-166), revealing two types of production centres, and two types of adzes. One type of production centre was not common, but it was large, and the manufactural process was controlled, producing high quality standardised adzes for non-local trade. This allowed wealth accumulation by the elite owners of the quarry. The second type of production centre was much more frequent, these were small and independent, producing more varied axes to be used as work tools (Winterhoof 2007:187-189).

Tibbet (2002) also considered spatial variation in size and type of stone axes from their source. He measured Mt Isa axes found at different places away from their source. He argued that similarly large sized axes at Glenormiston and Kopperamanna indicate that these were trade centres, and the small axes found at Boulia indicate that this was not a trading place (2002:24). He noted that smaller axes were found at other places along possible exchange/trade routes, but that these, contrary to Renfew's model of down-the-line reciprocity, did not diminish in size with distance from the source at Mt Isa. From this, he argues that there is no evidence of down-the-line reciprocity in the Lake Eyre Basin (2002:27).

These studies investigated aspects of the hunter-gatherer models concerned with sharing and exchange, differentiating between local and exotic items, layers of networking and the motivation behind these. They also describe different production or procurement methods for different layers of hierarchical networks.

2.3.3 Literature on archaeology on SESA prior to European colonisation

This section of the review concerns literature on the archaeology related to the Aboriginal occupation of this area prior to European colonisation.

Lake Eyre, named in the trade routes above, is in the arid region of South Australia, north of SESA. A closer region to SESA in which sites have been excavated is the Roonka Valley to the north-east of Adelaide on the lower reaches of the Murray River. Pretty (1977) excavated three sites in this area, and was able to date levels at Roonka Flat. There were no complete ground-edge hatchets, but from the latest level, which was related to the last 4000 years, there were traces of fine-grained volcanic stone characteristic of material used for making axes, implying that this was a production site (Pretty 1977:306). Evidence for temporal changes in burial practices, decoration and site usage in the last 4000 years, suggested cultural rather than technological reasons for change in these areas (Pretty 1977:319-320).

Bednarik (1994:45) refers to enormous chert deposits, as well as nodules of chert lying on the shoreline and further inland in south SESA, near Cape Northumberland which became available, quarried and used, during the Holocene. However, chert is suitable for flaked rather than ground tools. Along the south coast, Bird and Frankel (2001) excavated Malangine and Koongine caves. These had been used for about 2000 years at the end of the Pleistocene, then again during the last 1000 years of the Holocene (Bird and Frankel 2001:73). There was no evidence of ground stone (Bird & Frankel 2001:60). All the stone was flint, quarried from outcrops in the caves or nearby, or from poor quality nodules from the beach.

There is little ethnographic literature on the Aboriginal people who lived in SESA. Christina Smith (1880) described five tribes of Aborigines who lived near her station, and named what she believed were their lands. She says the largest group was the Booandik, who occupied lands from the mouth of the Glenelg River (in Victoria) to Rivoli Bay south of Robe, and that other tribes occupied the land between Lacepede Bay (north of Robe) and Bordertown (1880:ix). Smith (1880:x) says justice was administered at corroborees by old men, with the loudest and strongest group winning the dispute. While she does not explicitly refer to modes of exchange, when describing marriage customs she mentions gifts of food given to parents (Smith 1880:3). This is the only allusion to exchange in her book, which, apart from description of customs of marriage and kin, and language, is a depressing catalogue of stories of individuals who have had their culture completely removed.

Horton's map of Aboriginal languages areas shows three peoples in SESA (Horton 1996); the Buandig who covered most of the area, occupying the land along the coast from Robe to the Glenelg River, extending inland about 40km; the Ngarrindjeri who lived along the Coorong, their lands extending south to approximately Robe; and the Bindjali who lived east of the Ngarrindjeri, and north of the Buandig. However, there is an area between these three groups that Horton does not assign to anyone. This includes the upper Glenelg, but goes north to approximately Naracoorte and west past Penola (Figure 2 Southeast South Australia area of research, showing language areas as defined by Horton.).

It is not simply that the language boundaries at the time of European settlement are uncertain, there is also no way of knowing how long they had been in existence. It is probable that language boundaries moved even during the few thousand years since ground-edge hatchets were used in south eastern Australia.

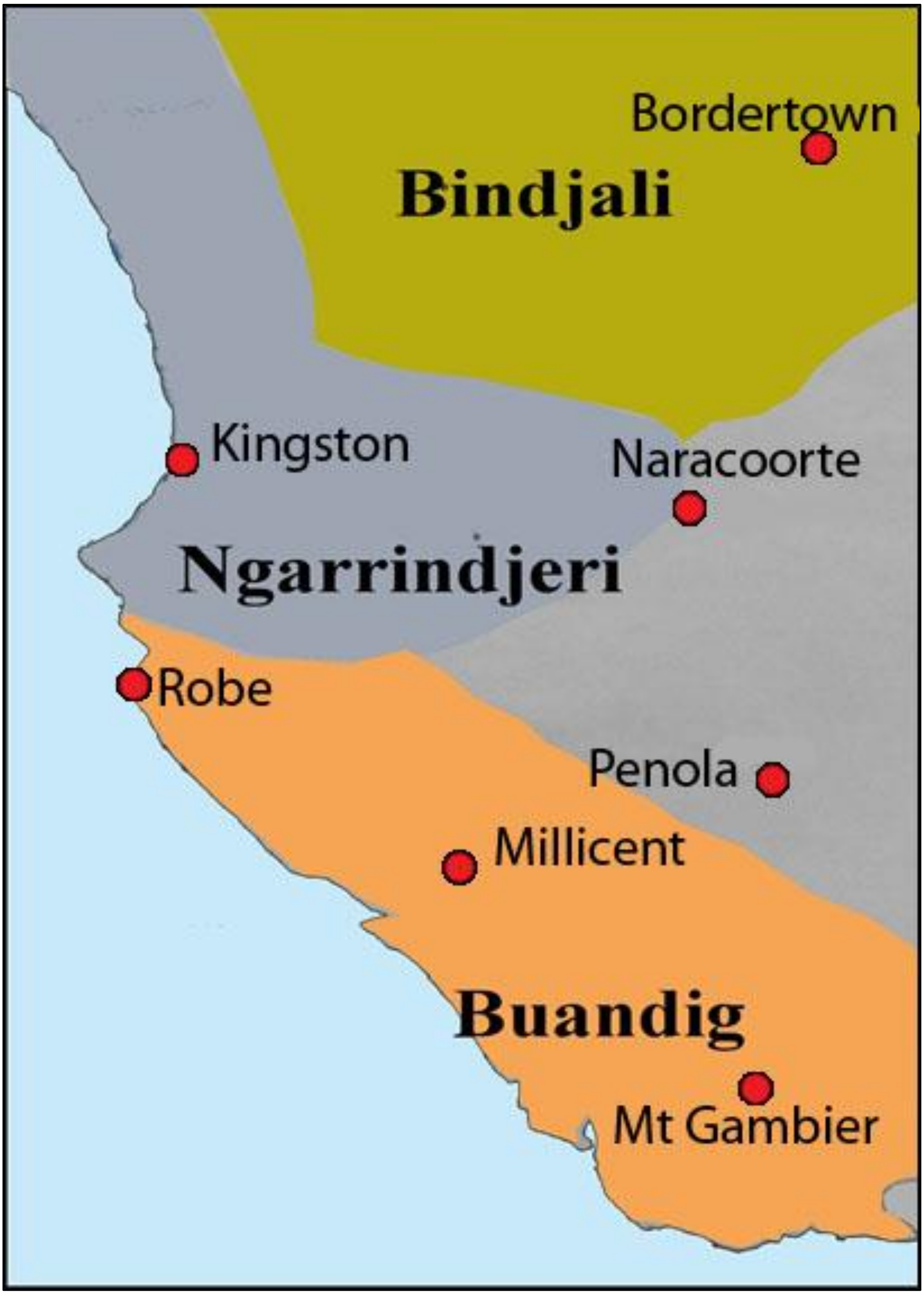

Figure 2 Southeast South Australia area of research, showing language areas as defined by Horton.

From literature on hunter-gatherer models, archaeology and ethnology, this review will now address literature on the scientific and mathematical techniques which were used in this research.

2.4 Literature on elemental analysis of stone

In attempting to source stone artefacts, archaeologists have used petrographic analysis and elemental analysis. Unfortunately petrographic and most accurate forms of elemental analysis require destruction of at least part of the artefact, which is undesirable for museum collection pieces. This review starts with literature on analyses which utilised destructive methods for elemental characterisation in research aimed at sourcing stone or artefacts.

2.4.1 Literature on elemental analyses using destructive techniques

Petrographic analysis of stone tools always involved taking thin sections and was particularly destructive (eg Binns and McBryde 1972), but elemental analysis has also been destructive. For example, to differentiate different sources of greenstone, McBryde and Watchman ground slices of sources and hatchets (1976:167) for analysis by XRF, and then produced biplots of Y against Sr and Y against Zr to separate two sources of artefacts.

Peter Rickwood et al (1983) using samples of basalt from sites in the Blue Mountains near Sydney, Australia, tested thin slices with different techniques to produce the best possible results over a wide range of elements. The study used PCA to model fifteen elements, iteratively removing one element at a time, and reanalysing the reduced dataset, in order to establish which elements were the most useful differentiators. For his study, Rickwood found Sc, V, Ni, Y and Zr to be the most decisive elements in separating the Blue Mountains basalts (Rickwood et al 1983:134).

2.4.2 Literature on elemental analyses using non-destructive XRF

Using non-destructive Energy Dispersive XRF, Mills et al (2010) analysed over 800 basalt artefacts and 34 ‘ecofacts’ found in one midden at one site on Kaua’i, a Hawaiian island. Comparing these with 34 adzes from the Kaua’i museum, pebbles from another canyon and Kaua’i basalt, they divided the tools into expedient and formal, the formal being adzes, the expedient being scrapers, files, drills, etc. Their analysis used trace elements from Rb to Nb, as well as Ba, Ni and Cu. This study used a combination of biplots of select elements characteristic of different basalt flows (eg Zr against Sr) and multivariate methods (Principal Components Analysis) to use the full range of measured elements for characterisation (2010:3390-3391). This combination of techniques enabled them to conclude that local basalt was used for expedient tools, but there was multiple production of formal adzes from more distant quarries.

Jones et al (1997) also used non- destructive XRF to elementally characterise artefacts from eastern Nevada in USA with a range of lithologies (basalts, andesite and other igneous stone). To determine which elements were most useful in sourcing the artefacts, they experimented with using ten major elements and six trace ones on prepared and unprepared stone, using ratios of major elements (using Al as the normalising factor) and trace elements (using Sr as the normalising factor). Several ratios of major elements, in particular Si and Al, could distinguish sources, but also, ratios of trace elements Rb/Sr and Zr/Sr were found to be equally effective (Jones et al 1997:937). Discriminant function analysis of ratios of major elements correctly sourced most of their artefacts. Ti and Zr were shown to be unaffected by weathering, and Y, Nb and Cr were also useful differentiators (Jones et al 1997:941-942). They concluded that ‘source attribution by fully non-destructive means may simply be a matter of restricting study to a smaller group of less mobile elements’ (Jones et al 1997:942).

2.5 Use of pXRF and mathematical methods

In 1991, changes to XRF methods of cooling and excitation produced an instrument which was physically and legally portable across national and international borders (Forster et al 2011:389). Further improvements in resolution and sensitivity resulted in a technique that is useful and comparable with XRF. While pXRF is less sensitive, and is suitable for a smaller range of elements than XRF, its portability, non-destructive technique and speed of use make it very useful (Forster et al 2011:390). As such it has been successfully used in the following research.

Olwen Williams-Thorpe et al (2004) used pXRF when sourcing bluestone axe-heads in Britain. Fe and Rb, and Ba, as well as Zr, Nb, Y and Sr, were needed to determine atypical rocks. In 2010, Williams-Thorpe et al, again using pXRF, compared eleven axe-heads with two known stone sources. From biplots of Ti against Zr, Nb against Zr, and Y against Zr, used because these are more immobile, they could associate axes with known quarries, as well as identify as yet unknown sources (Williams-Thorpe et al 2010:111).

Colby Phillips and Speakman (2009) used pXRF to source obsidian in the Kuril Islands. Biplots of Rb against Sr, and Zr against Sr separated sources, and enabled them to successfully differentiate proportions of use of several sources of non-local stone. Nazaroff et al (2010) tested portable XRF against laboratory XRF measurements of Mayan obsidian and found that while the pXRF was internally consistent, the results were not statistically the same as those from the laboratory XRF, but could still provide reliable source differentiation using Sr, Zr and Rb.

Forster et al (2011) testing several ceramic matrices to determine which elements were more accurately measured by pXRF, found that low counts and coarse matrices were unreliably measured, and required many more replicates to produce satisfactory results (2011:394). Low counts, surface interference and minerology affected pXRF accuracy, but, using PCA on elements Fe combined with Th and Rb-Nb, unaltered ceramic groups could still be correctly classified (Forster et al 2010:398).

Forster and Grave (2012) used pXRF on obsidian artefacts and geological specimens from Turkey and, from distribution patterns, found that sources used in central Anatolia were different from those used around Van in eastern Turkey. Principal component analysis of FeO3, Rb, Sr, Y, Zr and Nb determined five distinct clusters (2012:734).

Grave et al (2012) also analysed 76 ground-edge hatchets from three localities within the Sydney area, and 40 non-vitreous basalts of various ages from the same area. Data was in Net Peak Areas, not calibrated, so ratios and normalising processes were used to remove instrument variation (Grave et al 2012:1683). Ni, Cu and Rh were not considered useful because their net peak counts would be lowered by the instrumentation. From experiments with ratios of several elements, the set of elements which best distinguished basalts was Sr, Zr and Nb. However, the basalts needed to be rich in these three elements (2012:1685), Nb-depleted hatchets could not be sourced.

Newlander (2012:309) used pXRF as well as XRF and LA-ICP-MS, and found that each technique replicated the same structure of sources and artefacts in his datasets, even when the absolute values differed.

Shackley (2010) warned archaeologists to be careful and scientific in their use of pXRF. He said (2010:19) ‘if you are using a pXRF in archaeology you must analyse standards periodically and publish the results to establish validity’, because internal consistency is not enough. Empirical calibration is needed and at least one international standard should be included (Shackley 2011:13). The test samples must be sufficiently large, bigger than 10mm and thicker than 2mm for valid pXRF measurement (Shackley 2010 and 2011).

This review of elemental analytical literature shows that using a combination of the trace elements in the range Rb-Nb is most effective at sourcing correctly, though including a major element such as Fe or Ti or Si may be useful. PXRF is not reliable with these lighter surface elements, but is particularly accurate with heavier trace elements in the range Rb-Nb, measured from deeper within the sample. Its non-destructive technique make it highly desirable, as do the ease and comparative speed of use. Hence this research, using pXRF will use these elements to produce clusters which may represent sources.

2.6 Additional information from literature

As a final note, there are a couple of intriguing brief references in early ethnological writings to stone from Victoria being taken into SESA.

N.B. Tindale (Records SAM, reproduced from NB Tindale's *Aboriginal Tribes of Australia* (1974) Notes on Bunganditj) refers to a stone axe factory site near Harrow, between SESA and the Grampians. In his information on the Bunganditj tribe of SESA, he describes their land as going east to the Grampians – an area not included in Horton's map of the equivalent Buandig. Tindale's language boundaries are now considered less satisfactory than Hortons, but Harrow, less than 70km from SESA, is inside Tindale's Bunganditj country.

As quoted from McCarthy above, H. Basedow (1929:362) refers to hill-tribes of Victoria supplying stone to the tribes of south-eastern South Australia. Unfortunately, he does not give any more direction than this, nor does he give the source of this information. He does go on to say that the outcrops of stone were the property of a limited number of men, passed hereditarily, and was traded with surrounding districts, which is similar to McBryde's ethnological evidence of Mt William.

2.7 Conclusion to literature review

From this review, it can be seen that recent theories and models of hunter-gatherer behaviour focus on the structure and functioning of socio/political networks, with the ultimate aim of understanding their purpose. Sharing, reciprocity, exchange of both information and goods, and methods of procurement are major factors in maintaining a hierarchy of levels of networking, and it is through examining patterns of spread of goods that we may gain understanding of the structure. This research analysed mafic hatchets and known basalt sources within or within 100km of the find region and sources over 300km from SESA. Hence a model which postulates patterns of different frequencies for close and far distances from source is one that this research can address.

Studies of the spread of stone from source use the extent of movement, the direction and ratio of tool dimensions with distance from source to support models of exchange. This research includes dimensions of hatchets, and if there are patterns of movement from source, then it may be possible to compare these with models described above. It must be strongly acknowledged however, again from the literature, that these patterns of exchange have been fluid through time, and especially have altered since European settlement.

From this Chapter, archaeological and analytical methods to be used in addressing the questions and hypotheses formulated in the Introduction can be determined. The next Chapter will describe the methodology of this research.

CHAPTER 3

HATCHETS, SOURCES AND METHODOLOGY

Consequent on a review of the literature relevant to this thesis (Chapter Two), the methodology was determined. In this chapter, the artefacts and sources used in the research, the technique of measuring the elements in these, and the statistical analyses used are described.

3.1 Hatchets

The ARC Project investigated basalt hatchets using PXRF from southern Queensland and the Sydney region. South Australian Museum (SAM) Hindmarsh Store holds 242 ground-edged hatchets all provenanced to the small region of south-east South Australia (SESA) which were available for PXRF analysis. This area does not include land in Victoria west of the Glenelg River, a region similar in geology to SESA. The SAM hatchets were all weighed, measured, photographed and analysed using PXRF in the Hindmarsh Store.

From Figure 3 it can be seen that finds are not evenly spread across the whole area of SESA. They are concentrated in the south with another large group of finds from around Bordertown. This may reflect the European farming of land since settlement as much as it is a result of variation of Aboriginal land occupation and actual variation in hatchet production, use and abandonment.

Figure 3 Southeast South Australia, showing names and locations of all hatchet findspots

Typical hatchets are shown in Figure 4, and rare or unusual, in type of shape or stone, are shown in Figure 5.

Figure 4 A sample of typical hatchets used in this research, from clusters 8, 10, 9 and 5.

Figure 5 Unusual or rare shaped hatchets from SAM

3.2 Sources

SESA is mostly sand formations and swamps, with limestone east of Naracoorte and south of Mt Gambier. In the north, west of Bordertown, there are small protrusions of igneous rocks, almost all granites and quartz (Figure 6). In the south, there are protrusions of igneous rock in the south, though basalts are only shown at Mt Schank (Figure 7).

However, there are references in the literature to local stone sources: Bednarik describes sources of siliceous rocks near the coast south of Kongorong, and chert, a sedimentary stone more suited to flaking than edge grinding, near Cape Northumberland, which have evidence of pre-historic quarrying (1994:45). Frankel and Sterne refer to beach cobbles of flint along the coast of SESA as a source of stone tools, but their investigation only describes chipped or flaked tools (2011:66). Tindale mentions a stone 'axe' source close to Harrow, less than 50 km to the east of SESA (Figure 1). However, Horton places this outside Buandig lands (though Tindale does not), and there are no known basalt/stone hatchet quarries near Harrow (pers. comm. David Taylor geologist with Victorian Geological Survey).

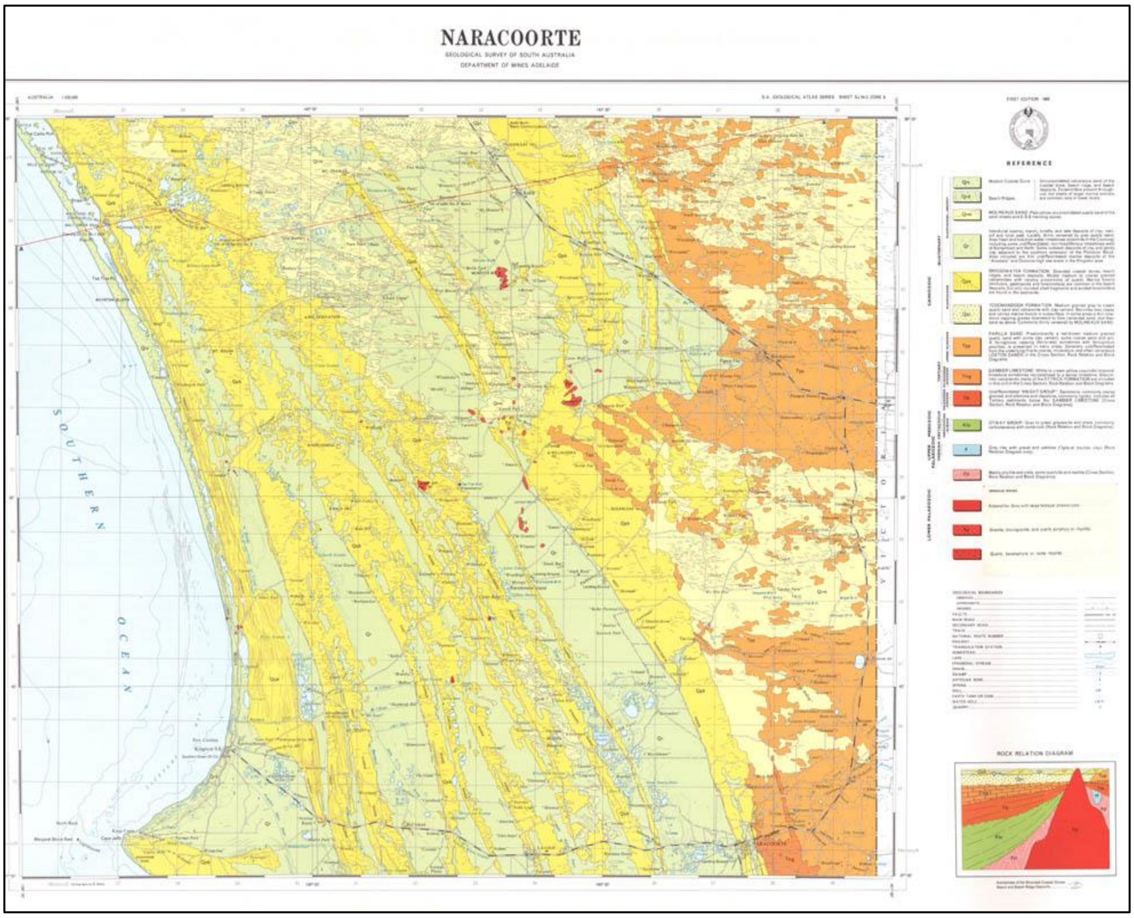

Figure 6 Geological map of northern SESA, Naracoorte region

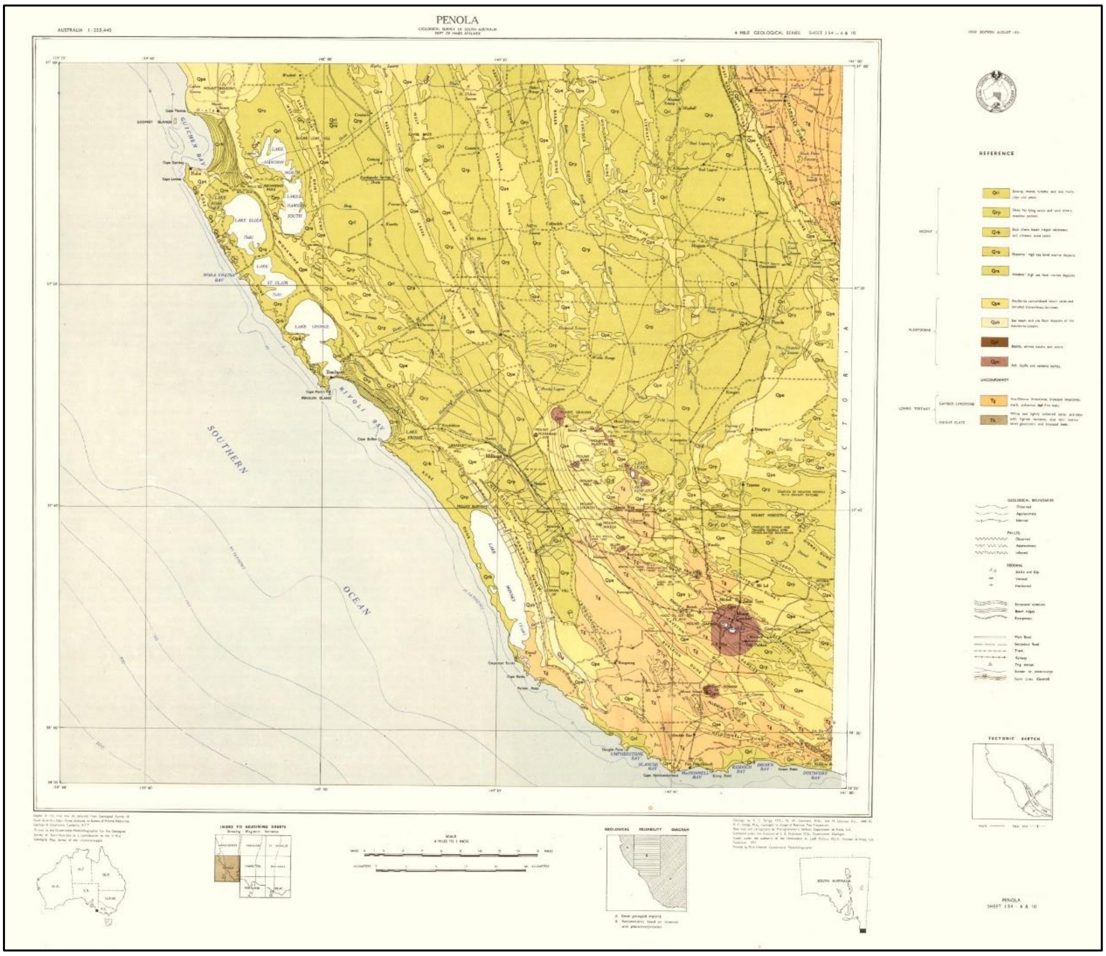

Figure 7 Geological map of southern SESA, Penola region

Basalt source samples were collected in 2013 by Grave, Attenbrow and Walker from Mt Gambier, Mt Schank, Mt Muirhead, The Bluff, Mt Graham and Mt Watch in SESA (Figure 8), none of which are known as Aboriginal quarries, These sites covered known extrusions of the Newer Volcanic Province of southeast Australia, active during the Holocene, though some were active up to 40,000 years ago in the late Pliocene or early Pleistocene (Irving and Green 1975:56). In western Victoria basalt samples were collected from Mt Eccles, Harman's Rd near Mt Napier, Mt Rouse and Mt Shadwell (Figure 8). Peter Hiscock supplied stone samples from Lake Moondara in the Cloncurry-Mount Isa region, and further samples of stone axes and sources from

Mount Isa, Mt William and central Victoria came from the Archaeological Collection of the Australian Museum in Sydney.

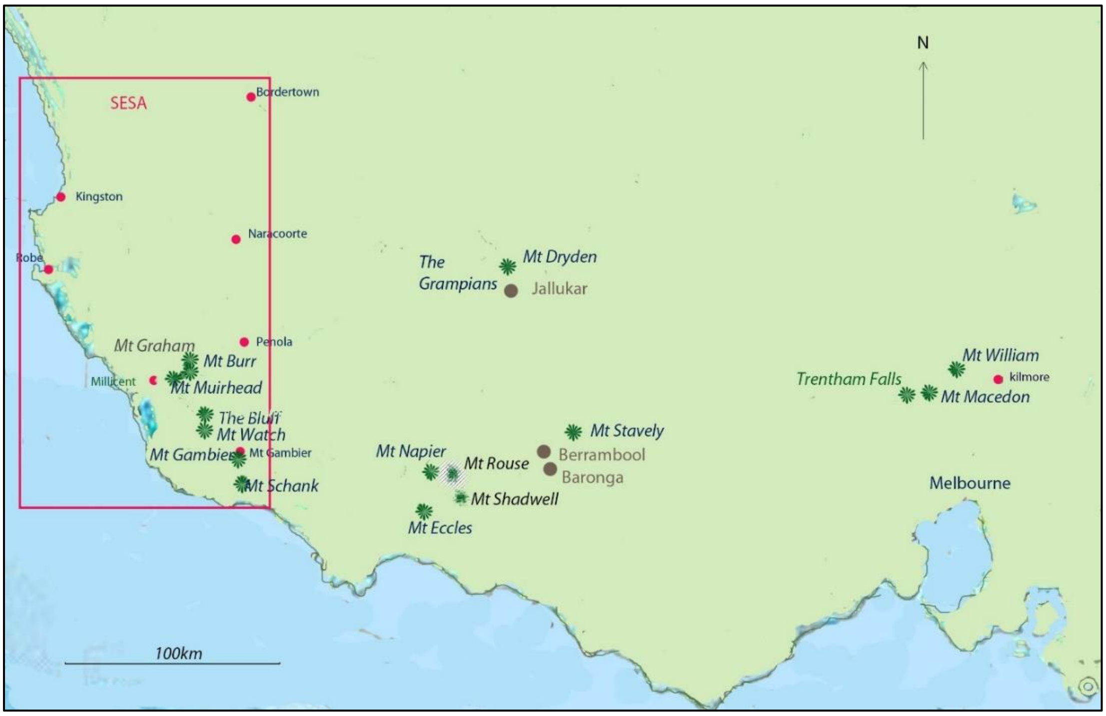

Figure 8 Basalt sources from SESA and Victoria named in this research

Stone other than basalt was not collected partly because this project was part of a larger project addressing basalt hatchets in Eastern Australia. But also there was no other known source of suitable hatchet stone in the region.

The Victorian Geological Survey also provided elemental data on various stone samples collected across Victoria. These were not tested with pXRF (though some had been tested with XRF). Since different techniques are best suited to measuring particular ranges of elements, and pXRF's range is the deeper elements, it was questionable whether matches between this data and SESA hatchets would be found, but it was considered worth trying. The Victorian geological survey data had been calibrated into ppm and many samples included the elements Rb-Zr.

I am not a geologist, and am unable to name stone type or more than guess at whether the source was river stone, a beach cobble or quarried. Several hatchets looked like river stones, but most were too irregular (Figures 4 and 5).

3.3 Methodology: instrumentation and setup

All hatchets and source material for this research were analysed using the same pXRF instrument, a Bruker Tracer III SD (serial number T3S1240), equipped with a rhodium tube, and peltier-cooled Silicon detector with a resolution of approximately 170eV FHWM at the Mn Kα peak at 5.9keV (at 1000 counts per second) over an area of $7mm^2$. Analyses were conducted at 40 keV, 15 mA, using a 0.076 mm copper/0.0305 mm aluminium/0.006 mm titanium filter in the X-ray path.

In Adelaide, the instrument was positioned upright so that hatchets could be placed on the snout of the instrument flush with the X-ray window. They were tested for 180 seconds three times, with the window aimed at a different part of the hatchet for each test. Bruker software S1PXRF produced count rates. All hatchets were tested in June 2014.

The source samples were tested with the same instrument at the Australian Museum in Sydney or in the archaeology laboratories of the University of New England in Armidale, maintaining the same settings. Each sample was characterised by a minimum of three replicate analyses at different areas of the sample.

3.4 Methodology: analytical and statistical techniques

A basalt calibration file for the UNE instrument was produced by Peter Grave working with Bruker, using nearly 90 basalt samples from SESA, western Victoria, the Sydney Basin, NE New South Wales and SE Queensland. This file was used to convert raw net peak area counts to quantitative values (parts per million or ppm). This restriction to one instrument with its calibration file gives internal consistency, but not the external confirmation that Shackley (2010) advises. However, a preliminary measurement of 28 of the 242 hatchets, using a different pXRF instrument in 2013, gave data which, when compared with results from 2014, showed strong correlation of most elements, in particular, those in the range Rb-Nb. Also, the neat separation of the sources, tested at different times, supports the validity of the data.

From the literature review, decisions were made on which elements to use in analyses, and which analytic techniques to use. PXRF of non-destructive material is unreliable for lighter elements (Forster et al 2011), except under vacuum conditions, so these elements were not included. Elements from Rb to Nb were considered, because they were used by Forster and Grave (2012) in testing obsidian, and various combinations of these were used by all the other researchers as described in Chapter 2. The South Australian Museum hatchets produced a very high number of zero readings of Nb, which made using ratios with this element as a divider unsustainable (Grave et al 2012). Also, the high number of zero readings of Nb, Y and Zr meant that these elements were useful for initial separation but for finer distinction of some groups, analysis of clusters with low ppm might be unreliable (Forster et al 2011). So elements Rb, Sr, Y, Zr, and Nb were chosen for initial separation, then selected groups of clusters were more closely examined. For examination of clusters without the largest two clusters (which contained most of the extreme low values), elemental comparison was possible.

The statistical packages JMP 11 and JMP 12 was used in all analyses. It enables clustering, principal component analyses, discriminant analysis, 3D graphs and biplots. Excel 2013 was used for producing tables and charts.

3.5 Methodology: procedure of analyses

3.5.1 Analyses of sources

Firstly, the stone sources were analysed by clustering using Ward's method with five elements, Rb to Nb, to establish that there were distinct groups to which the hatchets could be compared. PCA of five elements Rb-Nb were used to produce a biplot of the first two components. Discriminant analysis was used to test the degree of separation. Ten clusters were chosen because this separated sources and was a manageable number.

PXRF data for the sources and hatchets were combined into one dataset. Clustering, using Ward's method, of elements Rb-Nb was used to determine 10 clusters, to match the number of source groups, as well as being a manageable number. There is no suggestion that there are exactly ten geological areas from which the hatchets were sourced. It is more than probable that some of these clusters include hatchets from different sources, and that one source area has been separated into multiple clusters. But for ease of communication, these ten clusters will be referred to as the SESA Clusters 1 to 10 throughout this research. Principal Component Analysis (PCA) of these elements produced a biplot of the first two components.

For each SESA Cluster, known sources and hatchets were counted, and averages and standard deviations of the ppm of the five elements Rb-Nb calculated using the hatchets only. These averages and standard deviations were produced to allow elemental differences between the clusters of hatchets to be discerned.

To address the first question presented in the Introduction, (Are there different proportions of hatchets from local and exotic sources?) SESA Clusters associated with local and exotic sources were examined. SESA Clusters were selected according to whether they were associated with local, none or exotic sources.

The very low readings of several elements in the range Rb-Nb of the two largest clusters (which because of their numbers were most likely to be locally sourced), suggested that all of these elements needed to be included in analysis to maximise elemental and graphical separation of clusters. So SESA Clusters associated with local sources and the two largest clusters were analysed further with PCA of five elements Rb to Nb, producing biplots of the first two Principal Components. These two largest clusters were also compared with data from the Victorian Geological Survey.

Next, SESA Clusters associated with exotic stone were analysed by elemental comparison, using elements Rb, Sr and Zr to produce three dimensional graphs. Firstly the three SESA Clusters associated with Mount Isa were examined, though for these a further test was used. Variation from the Mean for the elements Fe, Rb, Sr, Y, Zr and Nb, were charted, using the formula

$V = \frac{mean - x}{SD}$, for instances where similar sources and artefacts were particularly close. Fe was included in these charts because its ppm of all hatchets and sources were sufficiently large that its readings could be useful. These were compared with two Australian Museum hatchets, found at Lake Eyre and Coopers Creek, because their distinct shape had been recognised as similar to one singular and distinctive SESA hatchet. Lastly, the SESA Cluster associated with exotic stone from central Victoria was examined by three dimensional graphs of elements Rb, Sr and Zr.

3.5.2 Relationship between numbers of artefact finds from each SESA Cluster and language groups in SESA

In addressing the second question (What are the distribution patterns for the different sources?), data was examined to determine if there was a discernible pattern of source use associated with the Aboriginal language groups in SESA (cf McBryde 1986:84).

There are three Aboriginal language groups in SESA (Figure 2 Southeast South Australia area of research, showing language areas as defined by Horton.). According to Horton, Buandig covered most of the study area, from Robe to the Glenelg River, going from the coast at least 40km inland. Ngarrindjeri lived along the Coorong, from the mouth of the Murray River to near Robe where their lands met the country of the Buandig. The Bindjali lived inland to the north of the Buandig, However, there is a large undefined area between the Buandig and the Bindjali, which includes Penola. However, Tindale says this undefined land was part of Bunanditj (Buandig) lands. Accepting Buandig and Bunanditj as different spellings of the same Aboriginal language group name, the area allocated to this group by Horton and Tindale differ.

The area of SESA in which hatchets were found in this research included most of Buandig country, excepting only the small area west of the Glenelg which is now part of Victoria. The southern part of Bindjali lands, which included Bordertown and land to the south, was also included, as was the southern part of Ngarrindjeri lands which extended from the coast to near Naracoorte. In my analysis, Penola has been included in Buandig land but Naracoorte has been treated separately because it is on the border of two or three languages.

The numbers of hatchets in each language area and in each cluster were very uneven, making it impossible to determine patterns or draw inferences from raw numbers. However, using a ratio of number of all hatchet finds in each language area against the total number of finds, the number of finds which would be expected in each cluster for each language area, if each cluster source was used evenly across SESA, could be determined.

For example, the ratio of finds for Buandig is 171/242, because 171 hatchets of the total 242 were found in Buandig country. 4 Buandig hatchets were clustered in SESA Cluster 1. Thus the expected number of hatchets in SESA Cluster 1 for Buandig would be

$$x = 4 * \frac{171}{242} = 2.83$$

This produced a table of expected numbers of finds for each cluster which could be compared with the actual number of finds. Any substantial differences could be attributed to language boundaries and networking.

Maps showing findspots of hatchets from local, the two large and the exotically associated SESA Clusters were produced. These differences between the expected and actual numbers, combined with these findsite location maps, provided information on the spread of each SESA Source, which in turn could give evidence of the networking between the three language groups.

This Chapter has described the methods used to analyse the data gathered in this research. The next Chapter shows the results of these analyses.

CHAPTER 4

RESULTS

This Chapter presents the results of the analyses. Firstly, the sources are analysed alone, then these were combined with the hatchets for analysis.

4.1 The sources

Using JMP, the sources were grouped into ten clusters using Ward's clustering algorithm for elements Rb to Nb, hence referred to as Source Clusters 1 to 10. Appendix A shows the ppm of elements Rb-Nb for all the sources, and the Source Cluster No. of each source.

PCA of sources using elements Rb-Nb gave a plot of the first two PCs shown in Figure 9Figure 9. These five elements separated the sources very well (Figure 9). The density or spread of the clustering varied between sources. In particular, sources from Mount Isa and Lake Moondara (Source Clusters 3 and 4) split into two groups (blue diamonds and orange X) not exactly aligned with those two names, while those from Mt William (green triangle) were all very close. The basalts collected from SESA and western Victoria split into five distinct clusters, and two sources from central Victoria (Mt Macedon and Ramsey Rd) were isolated in the top right quadrant. One cluster combined one source from central Victoria (Daylesford) with Mount Watch which is part of the Newer Volcanic region of South Australia.

Discriminant analysis carried out on these clusters using these five elements produced no mismatches, confirming the accuracy of the clustering (Appendix B) . Variation in Rb separated the Mount Isa district sources into two clusters.

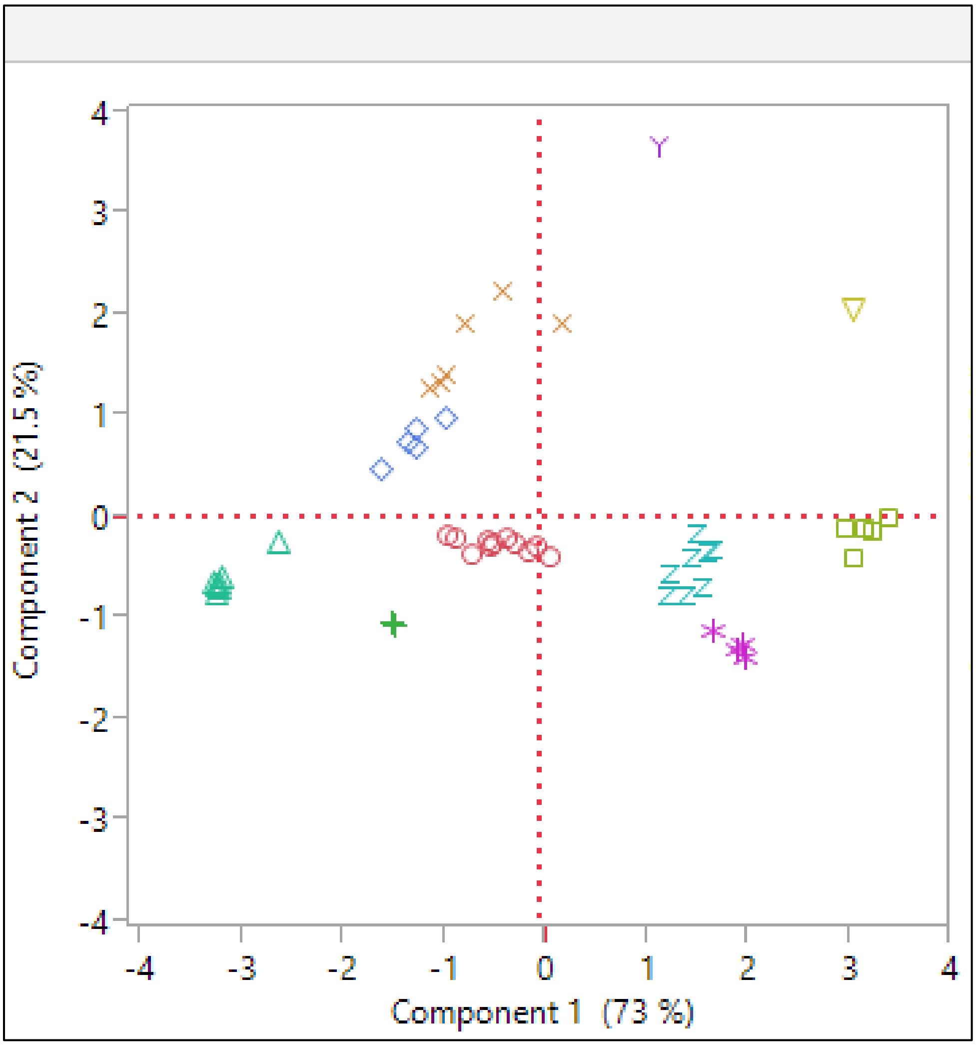

Figure 9 Sources only, clustered using 5 elements, PCA using 5 elements, graph of the first 2 components. Mt William (green triangle), Mount Isa/Lake Moondara (blue diamond, orange X), local volcanic (red circle, yellow/green square, purple star), Mount Watch and Daylesford in central Victoria (blue Z), two single outliers from Mt Macedon and Trentham Falls in central Victoria (Y and inverted triangle).

4.2 Analysis of combined artefacts and sources

Appendix C shows the names of the hatchet findspots, as well as the weights and dimensions of the 242 SESA hatchets. The calibrated pXRF data of these hatchets (Appendix D) and the sources (Appendix A) were combined. Ward's method for the five elements Rb-Nb was used for clustering, and ten clusters were chosen as being manageable while still a large enough number to distinguish different sources. These are referred to as SESA Clusters 1 to 10. Using these elements, PCA produced a graph of the first two components (Figure 10) which shows that most of the sources (coloured symbols) are separated from the mass of hatchets (black dots).

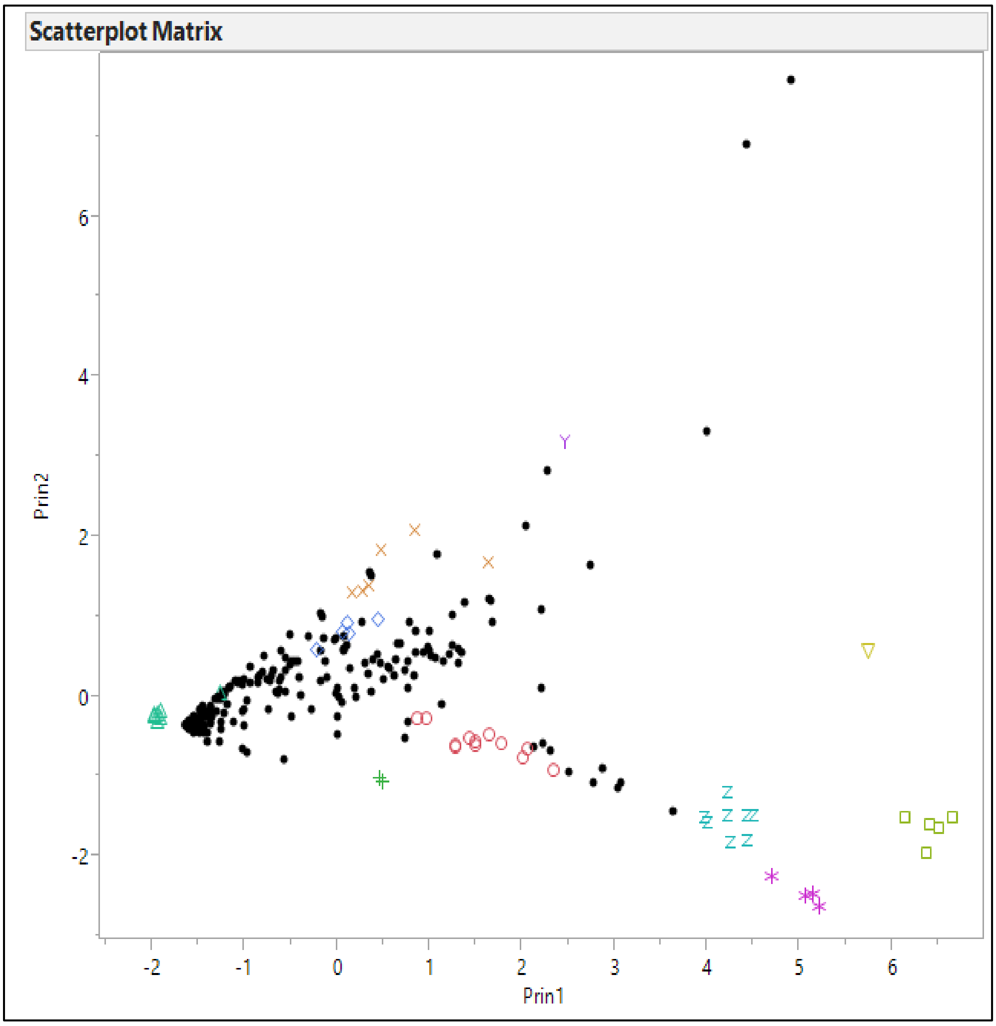

Figure 10 Combined sources and SAM hatchets. PCA of 5 elements, graph of the first 2 PCs. SAM hatchets are black and sources are coloured as in Figure 9 . Mt William (green triangle), Mount Isa/Lake Moondara (blue diamond, orange X), local volcanic (red circle, yellow/green square, purple star), Mount Watch and Daylesford in central Victoria (blue Z), two single outliers from Mt Macedon and Trentham Falls in central Victoria (Y and inverted triangle).

Table 1 details the numbers of hatchets and any sources in each SESA Cluster, as well as the names of the sources (if any) associated with each SESA Cluster. The average ppm of Rb, Sr, Y, Zr and Nb and standard deviation of each SESA Cluster, calculated using hatchets only, are shown in Table 2.

Table 1 Numbers of artefacts, and numbers and names of sources (if any) associated with each SESA Cluster. The colour of SESA Clusters of artefacts on following figures.

SESA Cl	No. Artefacts	No. Sources	Total	Names of known associated sources	Artefact graph colour
1	4	12	16	Western Vic, Mt Muirhead	red
2	9	4	13	Mt Gambier, Condah, Daylesford	dark green
3	3	1	4	Mt Macedon	dark blue
4	13	1	14	Mt Isa blank	orange
5	25	5	30	Lake Moondara	purple
6	2	0	2		black
7	1	17	18	Mt Watch, Mt Schank, West Vic	yellow
8	105	7	112	Mt William	pale blue
9	16	5	21	Mount Isa	pink
10	64	0	64		pale green

Table 2 SESA Clusters, showing average and standard deviations of elements Rb-Nb of each cluster, calculated using only the hatchets, not the sources

Cl	av Rb	SD Rb	av Sr	SD Sr	av Y	SD Y	av Zr	SD Zr	av Nb	SD Nb
1	20.28	7.85	421.06	120.34	17.31	4.62	122.53	27.75	4.03	8
2	28.25	4.6	533.47	110.35	23.52	2.63	186.32	17.51	33.19	5
3	99.46	2.4	227.88	144.93	39.07	15.47	194.59	37.97	7.39	0.65
4	31.49	15.04	294.73	53.99	31.98	4.12	163.59	43.97	2.48	1.17
5	36.72	8.6	329.69	67.74	20.36	2.66	101.47	24.49	0.45	0.41
6	252.79	15.51	85.82	24.57	55.59	4.29	93.83	1.87	12.08	0.68
7	16.99		444.19		28.97		280.65		59.62	
8	0.66	1.32	66.87	30.3	4.75	1.57	0.47	2.77	0	0
9	8.53	9.93	143.54	50.53	26.93	2.87	50.51	24.06	0.71	1
10	6.17	7.84	154.86	94.16	15.14	4.2	23.63	28.04	0.04	0.19

From these tables, the largest SESA Cluster, No. 8, is heavily depleted of all of the testing elements Rb-Nb, and the other large cluster, SESA Cluster 10 is low in these comparative to other SESA Clusters.

4.3 Local sources and matching hatchets – SESA Clusters 1, 2 and 7

The first question this research addressed was the comparative use of local and exotic stone.

The high number of local sources and low numbers of hatchets in SESA Clusters 1, 2 and 7 shows that little of the newer basalts, from Mt Gambier, Mt Schank and western Victorian volcanoes, was used, even though these sources were geographically close, and in most cases, easily available (Table 1).

In Figure 11, one hatchet is elementally close to Mount Watch sources, four to Mt Eccles and eight to either Mt Gambier or western Victoria. However, no hatchets were close to basalts from Mt Schank, Mt Muirhead, The Bluff or Mt McIntyre which are within SESA. The result was unexpected – intuition and archaeological theory says that people would use more of their closest sources than they did of distant sources. It is noticeable that the Source Cluster which combined Daylesford with Mount Watch is here separated in SESA Clusters.

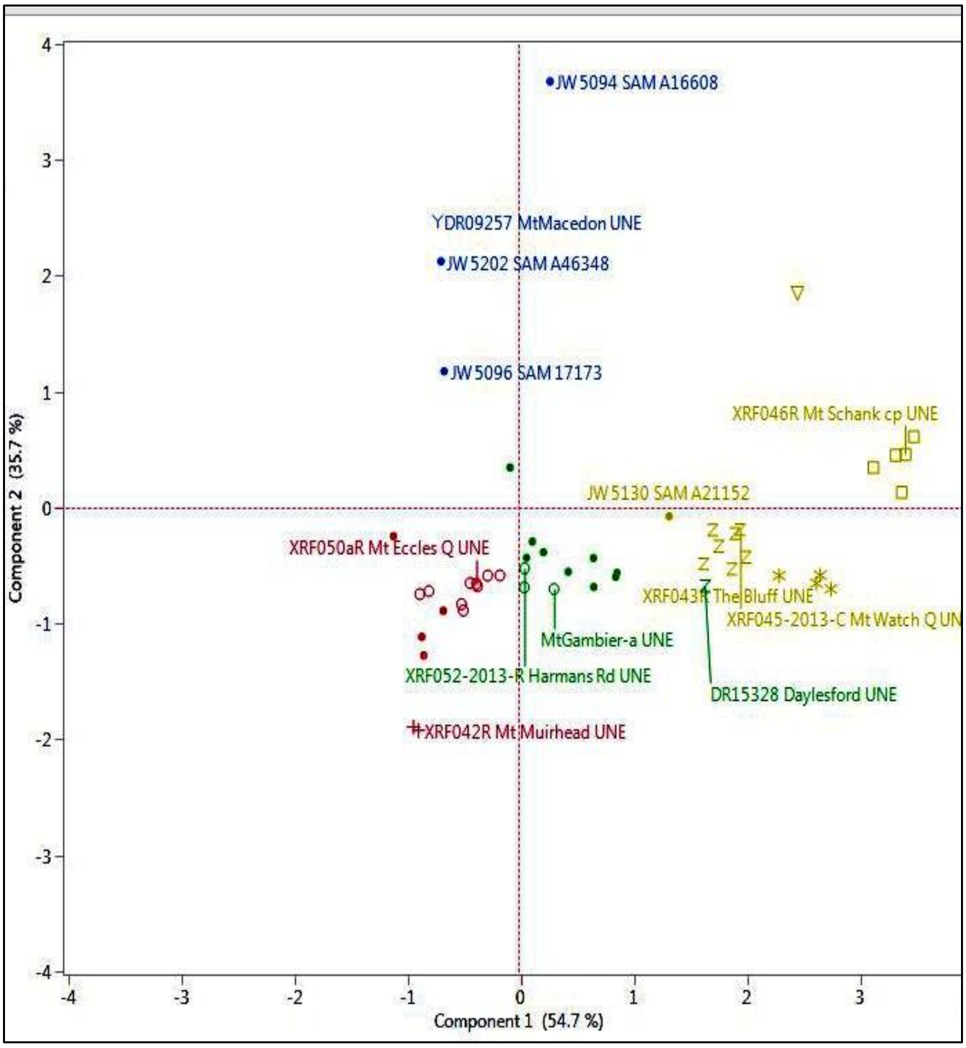

Figure 11 PCA of local sources and associated hatchets using 5 elements. Graph of the first 2 PCs. Showing SESA Clusters 1 (red), 2 (dark green), 3 (dark blue), 7 (yellow) with hatchets as dots, and sources as +, O, Y and Z. SESA Cluster 6 was removed because its extreme outlying position strongly compressed the remaining structure. Sources close to hatchets are labelled. Source Cluster 8 (Marked by Z) which combined Daylesford and Mount Watch is now separated into SESA Clusters 2 and 7.

4.4 Unsourced stone: investigation of SESA Clusters 6, 8 and 10.

SESA Cluster 6, with two hatchets which are not related to any sources (Table 1), stands out as extraordinarily different from all other hatchets and sources. These two hatchets are extremely high in Rb, and much lower than average in Sr (Table 2)

SESA Clusters 8 and 10 (which are the largest clusters) have 105 and 64 artefacts respectively. SESA Cluster 8 includes Mt William sources, whereas hatchets in SESA Cluster 10 were not matched to any sources. Hatchets and sources in these two clusters have negligible Nb, and SESA Cluster 8 is also very low in Rb and Zr (Table 2). However, the ppm of these elements in Cambrian metamorphosed basalt of Mt William in SESA are even lower, and their complete separation from SESA hatchets is shown by the biplot graph (Figure 12).

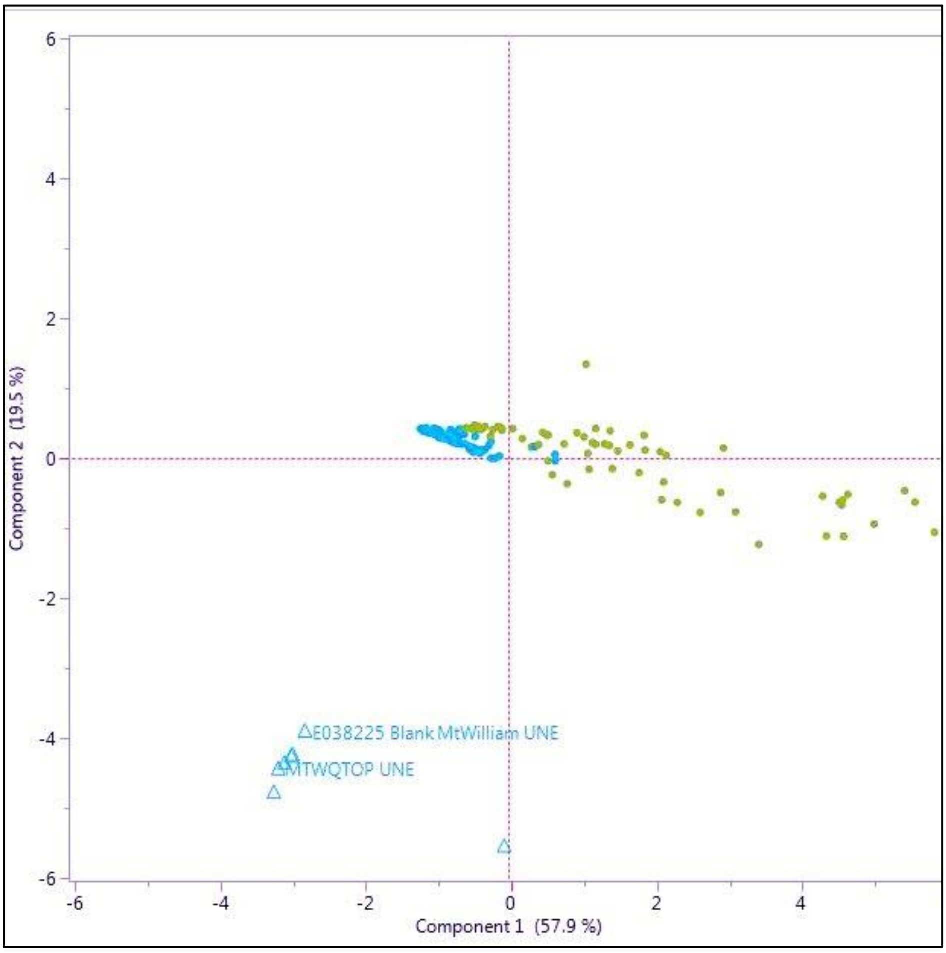

Figure 12 PCA of 5 elements, graph of the first 2 PCs. Showing SESA Clusters 8 and 10 and Mt William sources. SESA Clusters 8 (pale blue) and 10 (pale green) with Mt William sources as triangles. This shows the complete separation of Mt William stone from SESA Clusters 8 and 10.

Thus SESA Cluster 8 consists of two sub-clusters, one is Mt William sources and other is the 105 SAM hatchets. Given the difference between these SESA Clusters 8 and 10 and the other sources, and the elementally close yet different Mt William stone, it is possible that these two clusters are Cambrian volcanics, but from another area in Victoria, probably western Victoria since this is closest to SESA.

Another set of potential source data was available from the Victorian Geological Survey (VGS). This was combined with SESA Clusters 8 and 10 and analysed using only Rb-Zr, because Nb was not available for many samples taken by the Victorian geological survey. Principal Component Analysis of this data provided over 90% eigenvalue in the first two components, but this was using only four elements, which would result in high eigenvalues due to the small number of variables. A Clustering (Appendix E) and a scattergram of the first two PCs of this large dataset (Figure 13) shows only a small overlap of hatchets and sources.

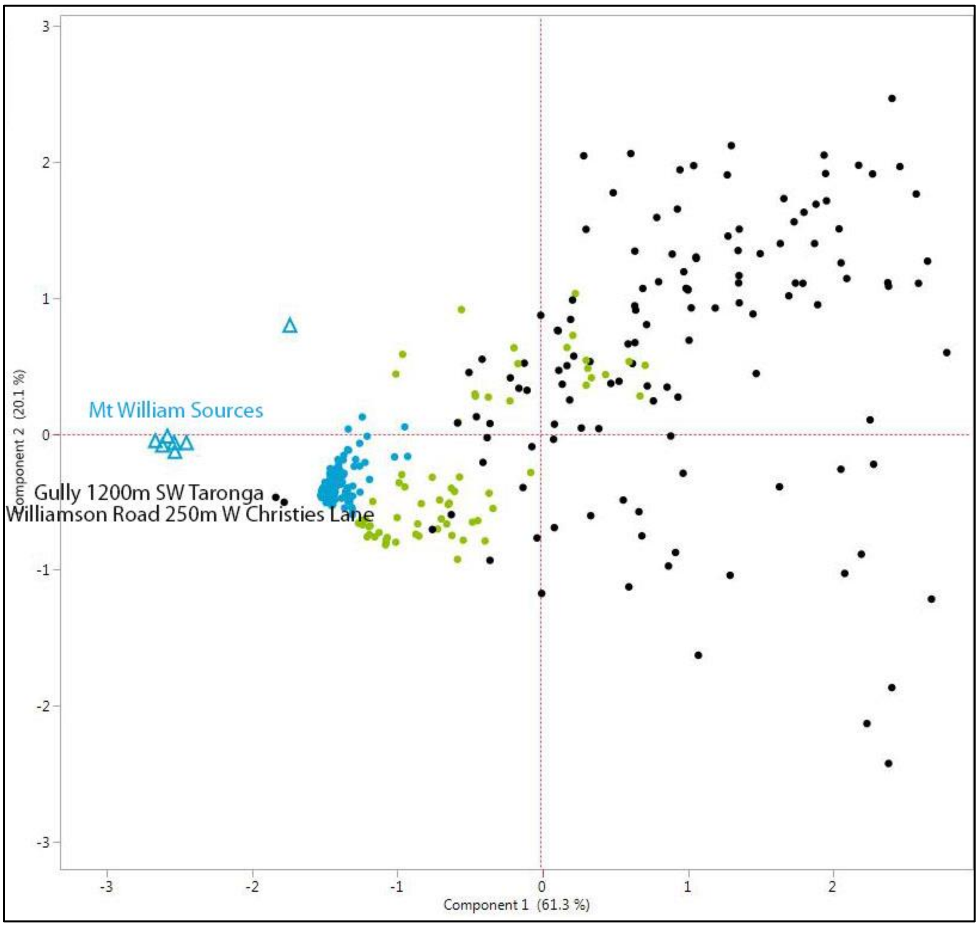

Figure 13 PC analysis using 4 elements, graph of the first 2 PCs. Showing SESA Clusters 8 (pale blue) and 10 (pale green) with Victorian Geological Survey data (black.)

It is clear that most of the hatchets are not associated with most of these sources. Only two western Victorian sources closely matched SESA Cluster 8 (see

Appendix E). One was andesite breccia and serpentinite from Williamson Road, near Mt Stavely, which is over 150km from SESA, but close to the known Aboriginal quarry at Berrambool. The second VGS source associated with hatchets in SESA Cluster 8 was Mt Dryden meta-andesites, which is further away from SESA than Williamson Road.

As these analyses which compare the SAM data with VGS data are based on only four elements, they must be treated with reservation.

4.5 Exotic stone: SESA Clusters 4, 5 and 9, with matches to Mount Isa sources.

The Mount Isa district sources were elementally far more widely distributed than other sources, making it difficult to match the Mount Isa sources with each other, let alone with the hatchets. Consequently, because of the importance of the possibility of stone or/and hatchets having been moved from Mount Isa to SESA, these clusters were examined closely. Elemental comparison was possible because these clusters, unlike SESA Clusters 8 and 10, had significant ppm of most elements between Rb and Nb. Three dimensional graphs of elements Rb, Sr and Zr were the most effective in separating the three clusters, so these were used for elemental comparison graphs.

A triplot graphs of SESA Clusters 4, 5 and 9 using elements Rb, Sr and Zr shows overlap of sources with some hatchets (Figure 14).

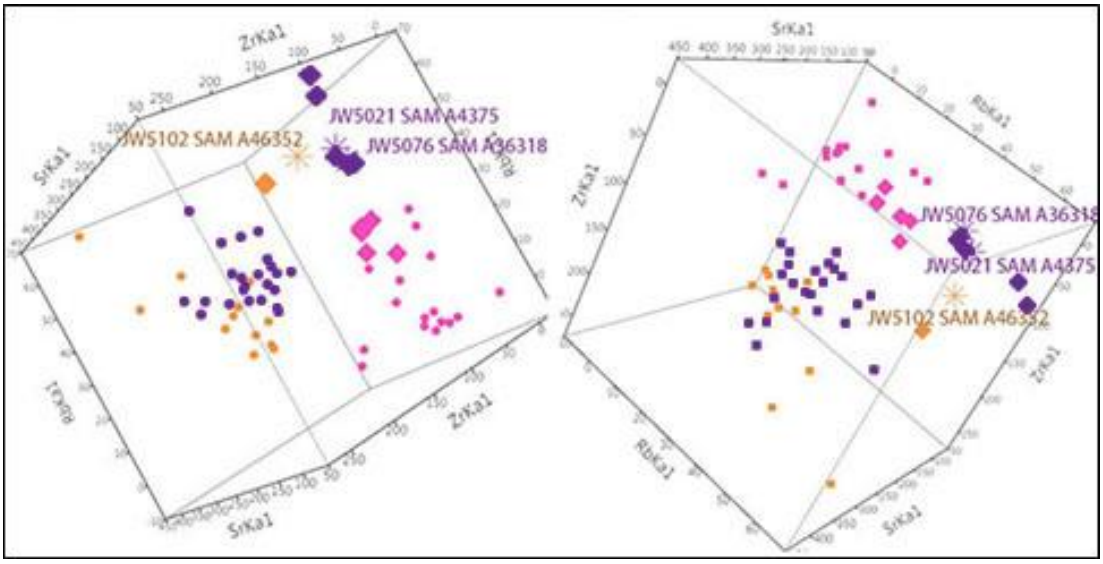

Figure 14 Triplots of Rb, Sr and Zr of SESA Clusters 4 (orange), 5 (purple) and 9 (pink). Hatchets are shown as dots, with Mount Isa/Lake Moondara sources as diamonds in the same cluster colours. Three SAM hatchets closely associated with these sources are shown as stars in the same SESA Cluster colours

The triplots of SESA Clusters 4 and 5 only (Figure 15), enables a clearer distinction of sources and hatchets, and shows close matches with three hatchets (SAM A46352 (JW 5102), SAM A4375 (JW 5021) and SAM A36318 (JW 5076)) with Mount Isa region sources, in particular, with Lake Moondara sources.

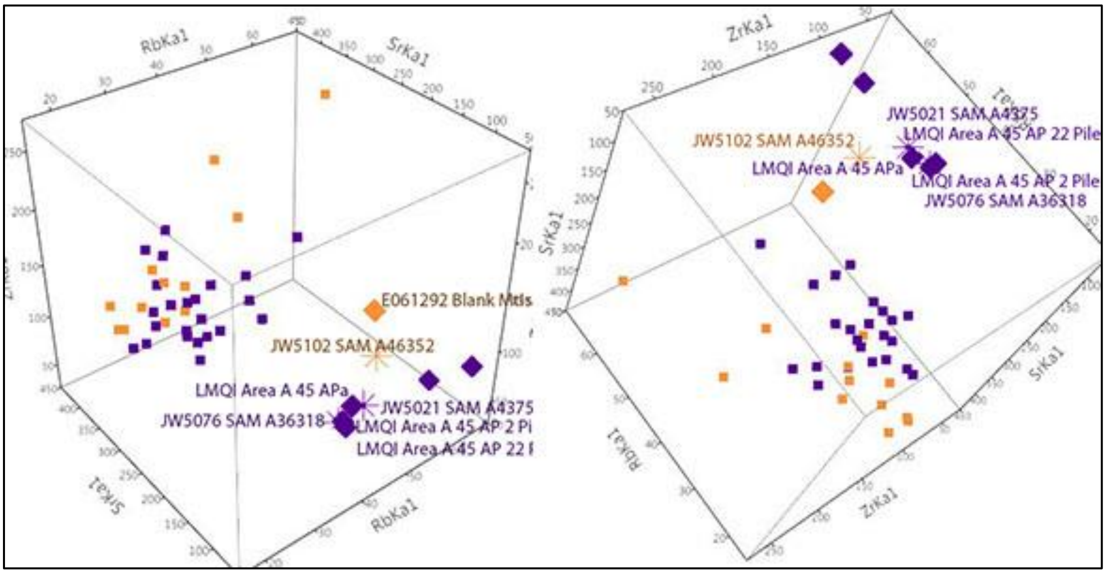

Figure 15 Triplots of Rb, Sr and Zr of SESA Clusters 4 (Orange) and 5 (Purple). Hatchets are shown as small squares, and Mount Isa/Lake Moondara sources as

diamonds in the same colour as the SESA Source with which they are associated. Hatchets associated with sources are labelled, as are the relevant sources.

SAM A46352 (JW 5102) is a 400gm waisted, or tanged and shouldered hatchet, the only one of this shape in the SAM SESA collection (Figure 16). It was found in the Stewart Ranges in the north-west of SESA, in Ngarrindjeri country.

Figure 16 SAM hatchet A46352 found at Stewarts Range in SESA, weight 400.26gm, length 9.1cm, width 8.6cm, and thickness 3.9cm

SAM A4375 (JW 5021) is a small hatchet (180gm), found at Tarpeena, in Buandig country (Figure 17)Figure 17.

Figure 17 SAM hatchet A4375 found at Tarpeena in SESA, weight 180.17gm, length 5.9cm, width 6.15cm, and thickness 3.4cm.

SAM A36318 (JW 5076) (Figure 18) which is a larger tool (508gm), was found at Naracoorte, on the boundary point between the three language areas (Figure 2Figure 18).

Figure 18 SAM A36318, found at Naracoorte in SESA, weight 508.69, length 13.25cm, width 8.1cm, thickness 3.75cm

The triplots of Mount Isa sources and SESA Clusters 4 and 5 hatchets (Figure 15), shows SAM A4375 and SAM A36318 are very close to Lake Moondara sources LMQI Area A 45 APa UNE, LMQI Area 45 AP 2 Pile and LMQI Area 45 AP 22 Pile. The third hatchet SAM A46352, is also close to LMQI Area A 45 APa UNE. This is the very distinctive hatchet SAM A46352 which typologically matches two hatchets found at Cooper's Creek and Lake Eyre. These analyses strongly support the conclusion that these three SESA hatchets were made from Mount Isa district stone.

Closer examination of SESA Cluster, 9, a triplot of Rb, Sr and Zr, clearly separates the hatchets from sources (Figure 19), indicating that there are really two distinct clusters, with a conclusion that the hatchets are probably not associated with these Mount Isa sources.

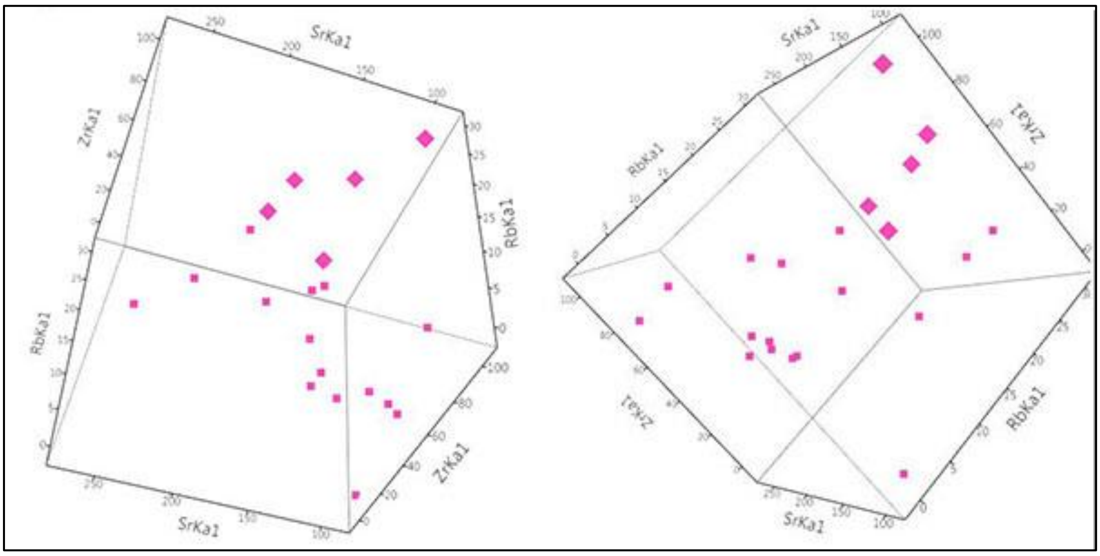

Figure 19 Triplots of Rb, Sr and Zr showing SESA Cluster 9 as small squares, with Lake Moondara/Mount Isa sources as large diamonds. This shows the separation of the hatchets from these sources, indicating two sub-clusters.

As a further analysis, patterns of variation from the Mean for six elements, Fe and Rb-Nb, of the three SESA hatchets of interest were compared with Mount Isa district sources using the formula

$$V = \frac{X - x}{SD}$$

The waisted hatchet, A46352 was compared with five sources (Figure 20). The inclusion of Fe, Y and Nb show that this hatchet is closer to CV E061292b Blank MtIsa than the triplot graphs of three elements shows.

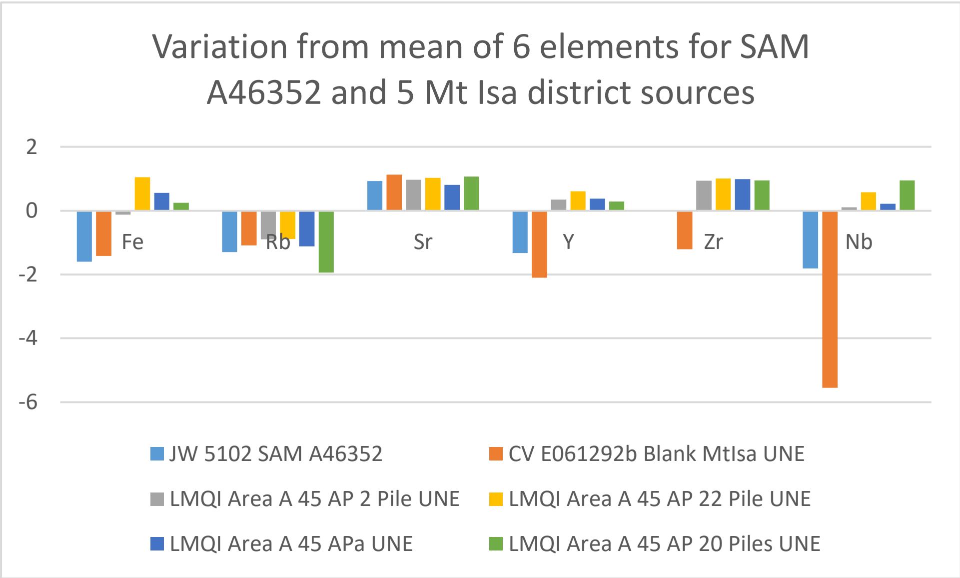

Figure 20 Histogram of variation from the mean of 6 elements, calculated using averages and standard deviations of SESA Clusters 4, 5 and 9. Comparison of A46352 with 5 Lake Moondara and Mount Isa sources.

Similarly, the other two hatchets, A4375 and A36318, were compared with Lake Moondara sources (Figure 21). The inclusion of Fe and Y show that these two hatchets probably came from different quarries, though the similarity of element pattern supports Mount Isa/Lake Moondara district as sources for these two hatchets.

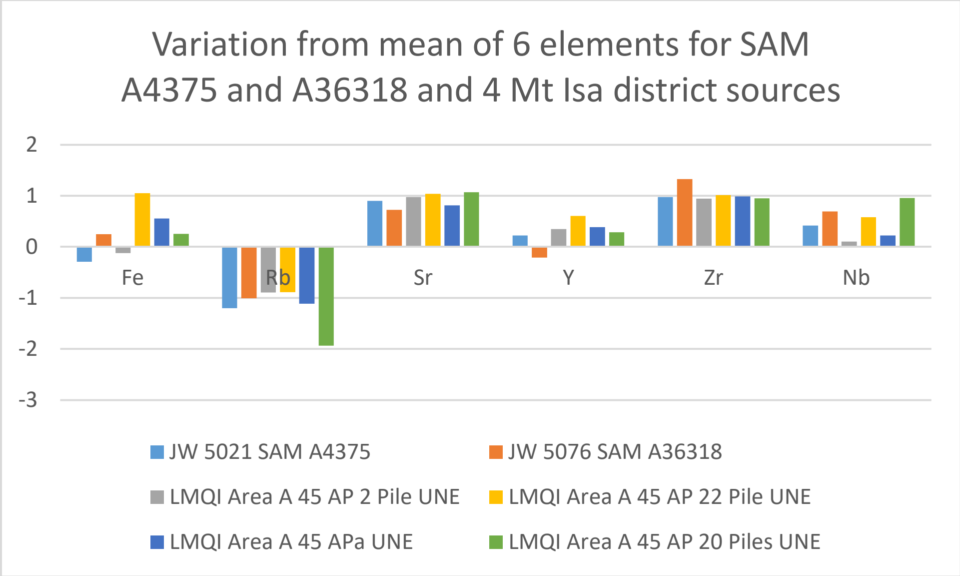

Figure 21 Histogram of variation from the mean of 6 elements, calculated using averages and standard deviations of SESA Clusters 4, 5 and 9. Comparison of A4375 and A36318 with 4 Lake Moondara sources.

SAM A46352 (JW 5102) is similar in shape to hatchets found at Lake Eyre and Coopers Creek (see McCarthy et al 1946:49, Figs. 266 and 267) held in the Australian Museum (AM Registration Numbers E0361676 and E050645b respectively). These were included in this analysis when the similarity was recognised by Mark Moore of UNE and Val Attenbrow of AM .

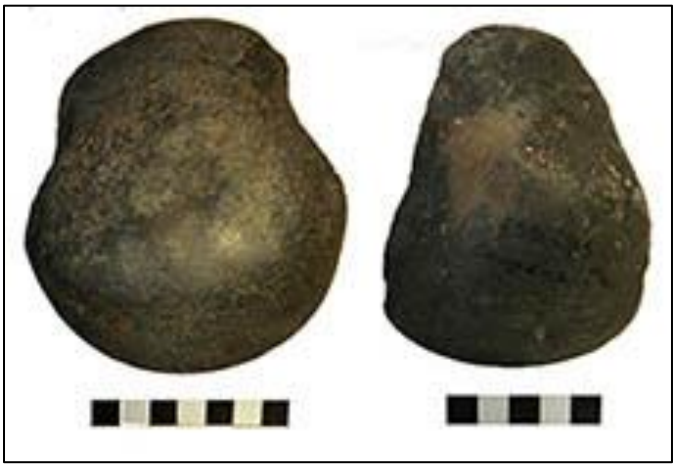

Figure 22 Two hatchets from AM. Left ID 9513 EO36167 from Lake Eyre (11.34cm long, 10.42cm wide, 3.765cm thick). Right ID 9515 EO50645b from Coopers Ck (10.08cm long, 7.997cm wide, 3.476cm thick).

These two hatchets (Figure 22Figure 22) were tested with the same pXRF machine and their results combined with SESA Clusters 4 and 5, including the three SAM hatchets A46352, A4375 and A36318. A triplot graph of Rb, Sr and Zr aligned the two AM hatchets with Mount Isa/Lake Moondara sources, supporting the conclusion that these hatchets came from this area (Figure 23Figure 23). In this graph sources from SESA Cluster 9 (pink) are included, because these sources from Mt Isa aligned more closely with the two AM hatchets than sources from SESA Clusters 4 and 5.

A comparison of variation from the mean of Fe, Rb, Sr, Y, Zr and Nb shows that these five hatchets probably did not come from the same quarry (Figure 24).

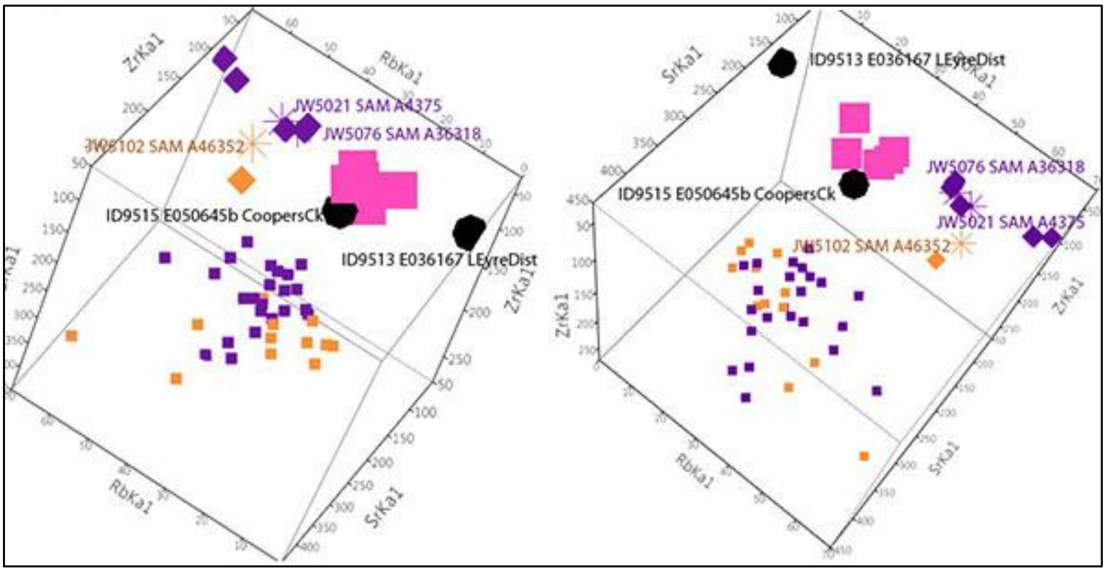

Figure 23 Triplots of Rb, Sr and Zr of SESA Clusters 4 (orange) and 5 (purple), and sources of SESA Cluster 9 (pink). Two AM hatchets (black) similar in shape to A46352 are included.

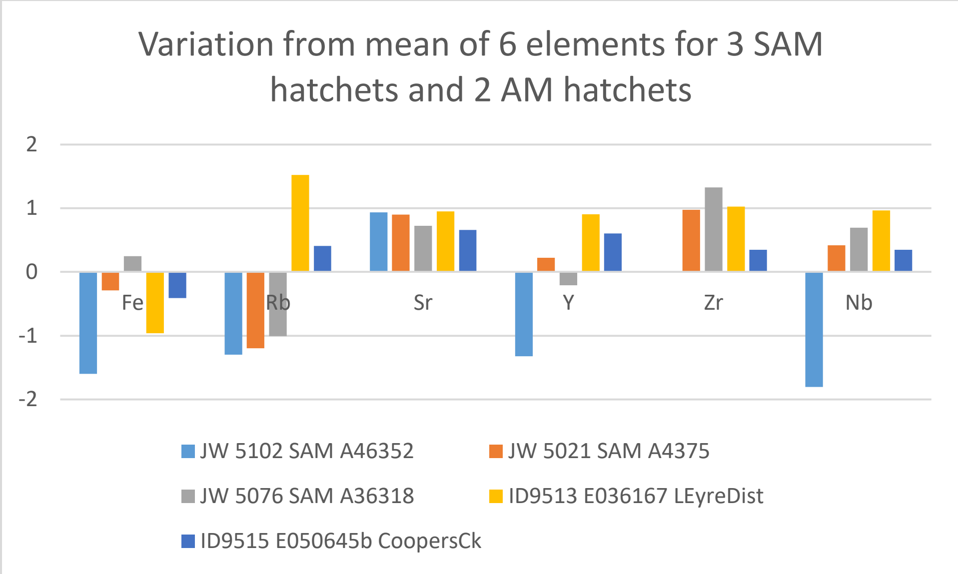

Figure 24 Histogram of variation from the mean of 6 elements, calculated using averages and standard deviations of SESA Clusters 4, 5 and 9. Comparison of three SAM hatchets and two AM hatchets found at Coopers Ck and Lake Eyre, believed to have originated in Mt Isa district

Hiscock (2005) provides measurements for the standardised ground hatchets (retouched flakes that have been ground) produced at Lake Moondara Quarry 1. By comparison with his measurements (Table 3), only A46352 of the three SESA hatchets fits neatly within his range of standardised hatchets, while, of the AM hatchets, the Lake Eyre one is within the range, and the Coopers Creek one is only a little thinner than the standard.

Table 3 Hiscock's standardised hatchets from Lake Moondara, compared with three SESA hatchets believed to be from Mount Isa

Hatchet size	Length (cm)	Width (cm)	Thickness (cm)
standardised	9.7+/-1.8	9.3+/-1.7	4.1+/-0.7
A46352	9.1	8.6	3.9
A4375	5.9	6.15	3.4
A36318	13.25	8.1	3.75
EO36167	11.34	10.42	3.765
EO50645b	10.08	7.997	3.476

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4.6 Stone matched with central Victorian sources – SESA Cluster 3

Three hatchets in SESA Cluster 3, which are associated with Mt Macedon in central Victoria over 300km from SESA (Figure 8), clearly separated from other hatchets and sources. In Figure 11, SAM A46348 (JW5202) is closest to Mt Macedon source, but A17173 (JW5096) and A16608 (JW5094) are comparatively close to this source, being clearly separated from other hatchets and sources. These hatchets and Mt Macedon have comparatively high ppm for most elements, but especially Rb, a pattern which separates them from other hatchets and sources (Table 2).

4.7 Language groups, hatchets and sources

The second question that this research addresses, (What are the patterns of spread from the different sources?) investigates the pattern of source usage for the three language groups who inhabited SESA prior to European settlement. Such investigations can reveal exchange networks through the distribution of stone source materials being either confined to or extending beyond one language area. The difficulty with interpreting these figures for SESA is that most hatchets were found in Buandig country, and most of the SESA Clusters have low numbers of hatchets.

However, Table 4, which shows the hatchets found in the three language areas and Naracoorte, and Table 5, which shows the number of hatchets which would be found in these if there was an even spread of finds, enables examination for anomalies.

Table 4 Numbers of hatchets found in three language areas and Naracoorte

SESA Cl	Buandig	Ngarrindjeri	Bindjali	Naracoorte	Total
1	3	0	1	0	**4**
2	9	0	0	0	**9**
3	1	1	1	0	**3**
4	11	2	0	0	**13**
5	22	0	0	3	**25**
6	1	0	1	0	**2**
7	1	0	0	0	**1**
8	65	20	16	4	**105**
9	13	2	1	0	**16**
10	45	11	8	0	**64**
	171	**36**	**28**	**7**	**242**

Table 5 Expected numbers of hatchets of each SESA Cluster that would be found in each language area if they were evenly spread across the landscape (see Chapter 3 for method of calculation)

SESA Cl	Buandig	Ngarrindjeri	Bindjali	Naracoorte	Total
1	2.83	0.6	0.46	0.12	**4**
2	6.36	1.34	1.04	0.26	**9**
3	2.12	0.45	0.35	0.09	**3**
4	9.19	1.93	1.5	0.38	**13**
5	17.67	3.72	2.89	0.72	**25**
6	1.41	0.3	0.23	0.06	**2**
7	0.71	0.15	0.12	0.03	**1**
8	74.19	15.62	12.15	3.04	**105**
9	11.31	2.38	1.85	0.46	**16**
10	45.22	9.52	7.4	1.85	**64**
Total	**171**	**36**	**28**	**7**	**242**

Also, maps of the findspots for the different SESA Clusters show the pattern of spread (Figure 25, Figure 26, Figure 27). Sites with a single find are a small dot. Where multiple finds were made at one site, a larger dot is accompanied by the number of finds. The sole hatchet of SESA Cluster 7 (JW 5130 SAM A21152) which was found at Millicent is not shown on these findspot maps.

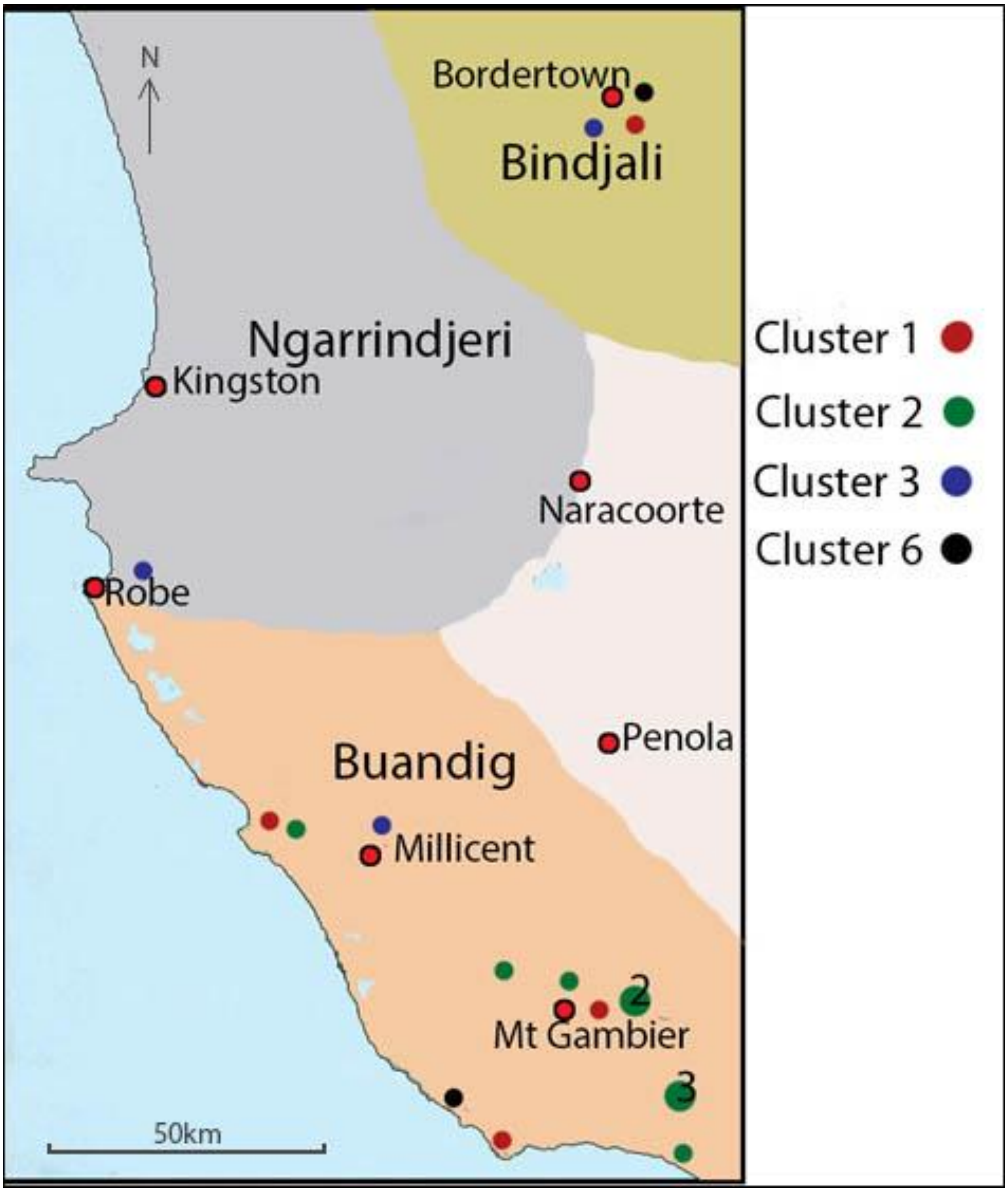

Figure 25 Findspots of SESA Clusters 1, 2 3 and 6 in Bindjali, Ngarrindjeri and Buandig country. Where multiple finds were made, a larger dot is accompanied by the number of finds.

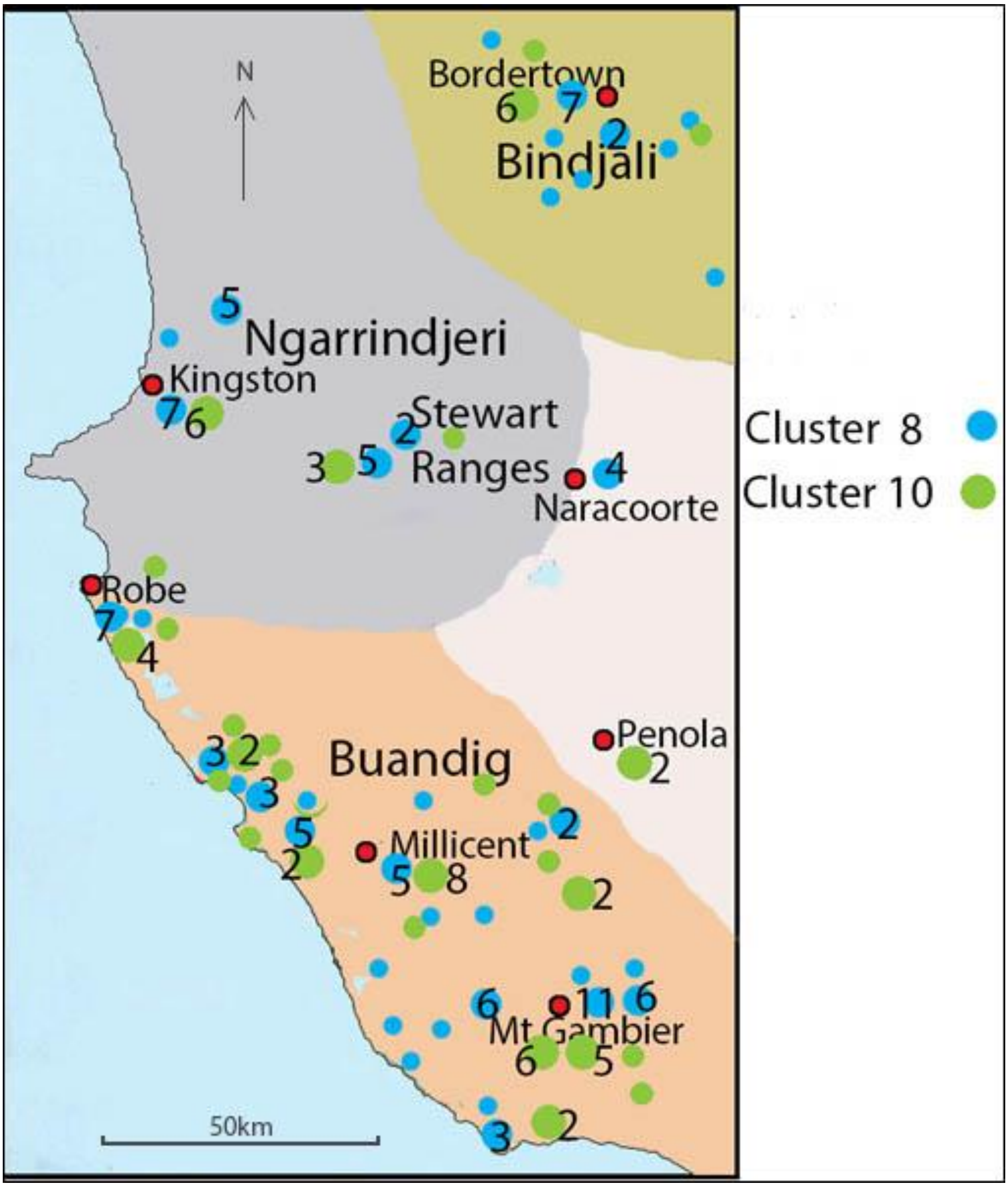

Figure 26 Findspots SESA Clusters 8 and 10 in Bindjali, Ngarrindjeri and Buandig country. Where multiple finds were made, a larger dot is accompanied by the number of finds.

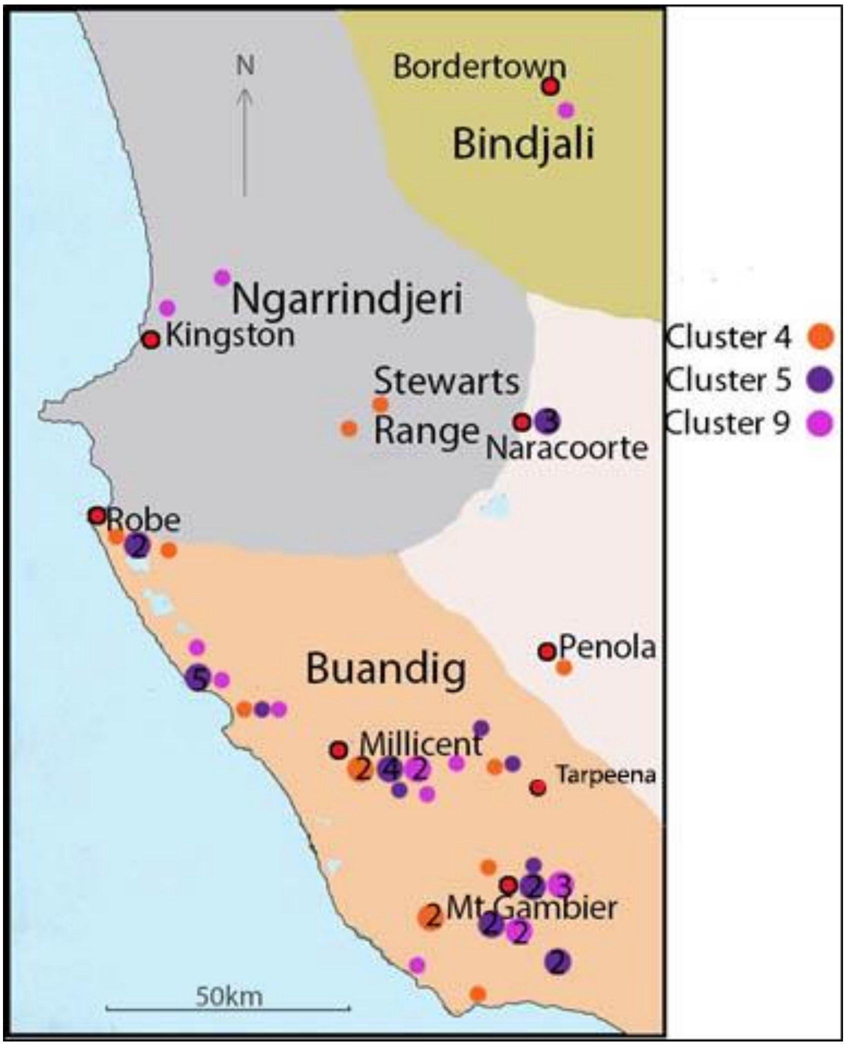

Figure 27 Findspots SESA Clusters 4, 5 and 9 (related to Mount Isa sources) in Bindjali, Ngarrindjeri and Buandig country. Where multiple finds were made, a larger dot is accompanied by the number of finds.

From Tables 4 and 5, the obvious anomaly of expected values is SESA Cluster 8, the most commonly used unknown source. There are higher than expected numbers of finds of this source in neighbouring language areas, coupled with lower than expected in Buandig country. The high numbers from this source indicate a highly used and/or desirable stone, while the disproportionate numbers in neighbouring language areas (Table 5), and the well-spread find sites (Figure 26) indicate it was shared or exchanged beyond language boundaries. Similarly, SESA Cluster 10 findsites were well-spread (Figure 26), indicating that it too was a desirable stone shared or exchanged across language boundaries. There is evidence here of a strong network extending beyond language boundaries.

No hatchets from SESA Cluster 5 (which was associated with Lake Moondara) were found in Ngarrindjeri or Bindjali land, though there were three finds at Naracoorte, and two at Robe on the boundary of Buandig country (Figure 27). The 20 hatchets which were determined above (see Figure 19) to be a separate cluster within SESA Cluster 9 were not exchanged into Ngarrindjeri or Bindjali land (Figure 27). On this basis it could be suggested that the source of this sub-cluster of SESA Cluster 9 is in Buandig country.

SESA Cluster 2 is a relatively small cluster of hatchets, (9), found only in Buandig country, and associated with Mt Gambier and Western Victorian sources (Figure 25Figure 25). The low number of finds, and the lack of movement into neighbouring language areas indicate a low status for this local volcanic stone.

The other differences between expected and found numbers are low or the number of finds was so low that it is difficult to draw conclusions from them. However, the three finds in SESA Cluster 3 associated with Mt Macedon in central Victoria were from each of the three language areas. Similarly, the three hatchets concluded to have come from Mount Isa were found in Ngarrindjeri country, Naracoorte and Buandig country. Both of these exotic stone patterns show a disproportionately even spread across the language areas.

The results presented above will be discussed in the following Chapter with reference to the questions posited in the introduction, and models of hunter-gatherer socio/political structure.

CHAPTER 5

DISCUSSION

In this Chapter, the results which were presented in the preceding Chapter are discussed in relation to the questions and hypotheses outlined in Chapter 1 and derived from the literature review of interpretive frameworks in Chapter 2.

1. Are there different proportions of hatchets from local and exotic sources?
2. What are the distribution patterns of the different sources?

5.1 Proportions of local and exotic sources

5.1.1 The use of local stone

The expectation was that most of the SAM SESA hatchets would have been made from local basalts because Aboriginal people would have utilized nearby sources. Major usage should have left clear evidence of stone availability and acquisition. There are few basalt sources in this area, and the volcanoes which could supply basalt are obvious, because, although not high, they rise from dominantly level ground, and can be easily seen from a distance. It was from these volcanoes, in particular their basalt sources indicated by retired Principal Geologist with the South Australian government, Malcolm Sheard, that my local source stone was collected.

Results show that use of these few physically obvious sources was unexpectedly low, only 14 of 242 hatchets were made from local basalt sources. It is possible that stone for these few hatchets was collected, as Binford's embedded procurement model argues (1979:259), during other routine activities. However, the low numbers do not support models which postulate heavy use of local stone for tools, because it was not used extensively, nor do they support the theory of special procurement for exchange (compare Mills et al 2010), because these few hatchets were not spread far from their local source. Why did people make so little use of the obvious volcanic sources? The logical answer is that the basalt was unsuitable for making hatchets. The volcanoes around SESA are part of the Newer Volcanic Province of southeast Australia, active during the Holocene, though some were active up to 40,000 years ago in the late Pliocene or early Pleistocene (Irving and Green 1975:56). According to Malcolm Sheard (pers.comm. 2014), these new basalts are extremely hard, and much older, altered, basalts would more likely be chosen for grinding into tools as they are still hard enough to be useful. Unfortunately, the only basalts in SESA are part of these Newer Volcanic region.

Models postulating large proportions of locally used stone (Close 2000; Robson 2012; Duke and Steele 2010; McBryde and Harrison 1981; Mills et al 2010) can only be supported by this research if the low numbers of known locally sourced hatchets are offset by prolific unknown local source(s). From the data generated in the present study, any large proportion of local stone must be SESA Clusters 8 and 10, stone of unknown source, though similar to Mt William. Their very low ppm of all elements in the range Rb-Nb completely separates them from all of my known sources except Mount William (Table 2). However, further analysis of SESA Cluster 8 shows the complete separation of Mt William stone from the rest of this cluster, indicating that not one of the SAM hatchets are made of Mt William greenstone (Figure 12). The outlying but very similar elemental composition suggests that these two SESA Clusters come from the same or several quarries possibly within a small area of western Victoria, of a stone similar to Mount William stone.

Mt William stone is part of the central greenbelt of Victoria, an altered Cambrian basalt, around 500 million years old. Being similar, though distinct, the western greenbelts of Victoria are a possible source for the hatchets of unknown sources in SESA Cluster 8. McBryde and Watchman (1976) names three Aboriginal quarries in the western belt; Berrambool, south of Mt Staveley, Jallukar near the Grampians, and Baronga further south on the Hopkins River (McBryde and Harrison 1981:184). However, these greenbelt quarries would not have been part of Buandig land according to Horton, or even according to Tindale who believed their land stretched into Victoria to the Grampians.

Also unfortunately, these sources are 100 – 200 km away from SESA, which does not fit the definitions of a local source in the hypotheses of McBryde and Harrison (1981:195) or Gould and Saggers (1985:121). The western Victorian greenbelt probably was an exotic source of highly valued stone for hatchets of social status value. While it is likely that there were hatchets from these sources in SESA, they would have been rare, high status, items, not the majority of found hatchets. This is supported by a match of a few SESA hatchets with data provided by the Victorian Geological Survey for Mt Stavely and Mt Dryden (Appendix E). However, because of the differences in the method of measurement between my study and the Victorian Geological Survey, the limited elements that could be used for comparison, and my lack of knowledge of Victorian geology, I am not at all confident in asserting that the association between Mt Stavely and Mt Dryden and SESA hatchets is valid.

The extensive use and distribution of hatchets from SESA Sources 8 and 10 show that they were made of superior and valued stone (a fact supported by its similarity to the highly prized Mt William greenstone). The large numbers suggest direct procurement (Close 2000:73), though there are no obvious local quarries, while the obvious desirability of the stone in an area of poor stone resources also suggests direct procurement, not necessarily from a close source (Duke and Steele 2010:823; Gould and Saggers 1985:122).

The references in literature described above in Section 3.2 Methodology to possible local stone sources do not solve the problem of the most commonly used stone in SESA. The sources at the moment are unknown or unrecognised as Aboriginal quarries.

These results do not support models which separate local heavily used quarries from special quarries used exclusively or predominately for exchange stone (McBryde 1997:594; Robson 2012; McBryde and Watchman 1976; Mills et al 2010). From their dominance and distribution, hatchets from SESA Clusters 8 and 10 must have been both commonly used tools, and valued exchange goods (compare McBryde and Harrison 1981; Mills et al 2010). Furthermore, the distribution of SESA Cluster 10 hatchets across Buandig and into neighbouring countries is similar to the distribution of SESA Cluster 8 hatchets (Figure 26Figure 26), showing no separation into two sets of quarries based on one set for local tool use and a second set for exchange (McBryde 1997:593-595; Winterhoof 2007:187-189; Duke and Steele 2010; Gould and Saggers 1985:120; Mills et al 2010).

Several models (Hodder and Lane 1982; Paton 1994; Tibbet 2002) used variation in dimension from source as a factor in determining type of exchange. With the great number of hatchets related to unknown sources, it is not possible to analyse the data in this way. If the ratio of distance to dimension was always clear-cut, then it might be possible determine possible directions or areas of source. But research does not show a direct relationship between dimension and distance from source (McBryde and Harrison 1981:204); Hodder and Lane 1982:232; Tibbet 2002:25). Till the major sources of SESA hatchets are known, investigation into models which include ratios of dimension to distance from source cannot be investigated with data from this research.

One consequence of using a high valued stone for local tools is that, if a social/political network is to be maintained at a higher level, other higher status items are required. According to models requiring high status, and therefore exclusivity, there would have been a further need for very highly prized exchange items (Smith 2013:270; Winterhoof 2007:190), which may have been satisfied by more exotic stone (in this case, from Mount Isa or Mt Macedon), or non-lithic items.

5.1.2 The use of exotic stone

Hunter-gatherer models, for example, the Exotic Stone Hypothesis, argue that poorly resourced areas will acquire exotic stone (Gould and Saggers 1985:122). A small number of exotic stone hatchets were found in the SAM collection, a proportion in line with this hypothesis (Hertell and Tallavaara 2011:23). The close association of hatchets with Mount Isa basalt was exciting, with three hatchets probably coming from this district. From Figure 15, SAM hatchets A4375, A36318 and A46352 match sources from Lake Moondara. The last of these is especially interesting because typologically it is distinctive. Described as waisted, or as tanged and shouldered, it is the only hatchet of this type in the SAM SESA collection. Others of the same style, found at Coopers Creek and Lake Eyre, are now in the Australian Museum in Sydney. A46352 is the only one of the three SESA hatchets which fits very neatly within the size range of Hiscock's standardised hatchet production, supporting his theory of standardised production for distance trade (Hiscock 2005; McBryde 1984b:270-273; Robson 2012:101; Sassaman et al 1988:90; Winterhoof 2007:187-189). The other two SESA hatchets match the elemental composition of Lake Moondara sources very closely, but, because they are not near the standardised size range, they probably were not made by regulated production.

While it is impossible to know how stone or hatchets moved from northern Queensland to SESA, there are several possible explanations (Close 2000:50) (eg, carried by one group of traders, or moved by exchange from one community to its neighbour, or it could have been a combination of these two).

From ethnographic literature, there are many descriptions of trade routes through the channel country aligning the deserts of central Australia, connecting Mount Isa to Lake Eyre and/or the Flinders Ranges (McBryde 1987; D.J. Mulvaney 1976; McCarthy 1939; Smith 2013; Tibbet 2002). McCarthy (1939:101) adds that the main trunk route, after reaching the Flinders Ranges, went south to the coast near Port Augusta, along the coast to the mouth of the Murray River in the Coorong, and on to the Glenelg River through what would have been Buandig country (Figure 28). All ethnographic sources named above agree that the main north-south long-distance route, where items were carried by a single group of men, finished at either Lake Eyre or the Flinders Ranges. Whether the move to the Flinders Ranges was via one or two long-distance stages with different groups of men, from the Flinders Ranges to SESA required further exchange which, since there are no ethnographic descriptions of further long-distance moves, probably was achieved by movement from each group to a neighbouring one.

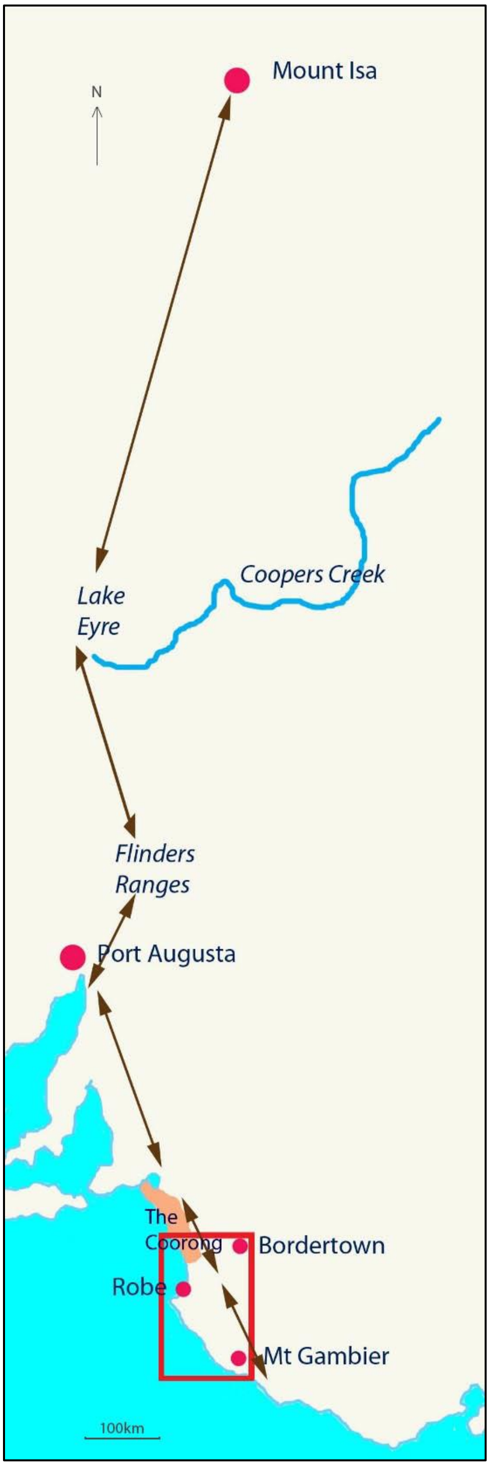

Figure 28 Map of central and south central Australia, showing the exchange route between Mount Isa and SESA, undetailed between Mt Isa and Lake Eyre, but including the southern section as described by McCarthy 1939b:101. SESA is defined by red rectangle.

McCarthy's southern route is supported by at least one artefact determined in this research to have come from the Mount Isa district. The Coorong was part of Ngarrindjeri lands that extended from the mouth of the Murray River to just north of Robe. One of the hatchets, the distinctively shaped A46352 (Figure 16), was found in Stewart Ranges, within the south east of their lands (**Error! Reference source not found.**). This is 16km from Naracoorte, on the border between Ngarrindjeri, Bindjali and Buandig lands where another hatchet, A36318 Figure 18), matching Lake Moondara stone, was found. The third hatchet A4375 (Figure 17Figure 17) was found at Tarpeena, 67km south-east of the Stewart Ranges, in Buandig country (Figure 27). Thus, of the three hatchets determined to have originated in the Mount Isa district, one was found within the land of the Coorong people, and a second was found at the edge of their land. This is despite the fact that the great majority of hatchets, 171 of 242, were found in Buandig country. It is supporting evidence of a route through the Coorong into lands further east and south.

The great distance that these hatchets moved does not support direct procurement through mobility, and a second set of exotics from a different direction also support exchange as the means of procurement in SESA (Hertell and Tallavaara 2011:31). Three SESA hatchets, A16608, A46348 and A17173, came from Mt Macedon, about 400km east in central Victoria, land of the Kulin speaking Woiworung people. It is not suggested that these hatchets were moved in a single step because there is no ethnological evidence of single-step long-distance trade in this area. But there is evidence of meeting places throughout Victoria where items were exchanged (McBryde 1984a:139; McCarthy 1939a:408; Mulvaney 1976:76), so they could have moved formally from one community to its neighbour, and then to the next, etc, gaining status as they moved further from their source (McBryde 1987:262; Smith 2013:300). The three Mt Macedon hatchets were found at Millicent (Buandig) in the south, Keilira Station near Kingston (Ngarrindjeri) in the west and at Nalang near Bordertown (Bindjali) in the north of SESA. This distribution across language areas also supports movement of individual items from one gathering place to the next rather than an organised long-distance exchange between two language areas.

Another outlying cluster deserves some discussion. The two outlier hatchets, A28195 (JW5056) and A53700 (JW5221) which were markedly different from all sources and hatchets are more likely to be a hornfels rather than a basalt. While their extreme difference from all the other hatchets makes them and their mineralogical structure interesting and deserving of further investigation, it is not possible with the present dataset to determine whether they came from a local or distant source.

5.2 Patterns of spread of different sources: language groups, source usage and exchange patterns

The second question which this research addressed was whether there was a different distribution pattern of findspots across the three SESA language groups for hatchets made from the same sources. This is of interest because variation in the use of different sources may provide information on social/political structure of, and links between, the three language groups (McBryde 1984b:269; McBryde 1986:84; Robson 2012:19; McBryde & Watchman 1976). Consideration of hunter-gatherer models are now considered in the light of my results.

Sharing and reciprocity are seen as the basis of networking which enabled people to move into another's territory in times of hardship (Baker & Swope 2004:4; Attenbrow 2004:242; Winterhalder 2001:26). This sharing behaviour is seen in SESA in the prolific and extensive spread of desirable stone. The very even and wide spread distribution of the two largest SESA Clusters 8 and 10 suggest that these stones were exchanged easily, that is, the network between language areas was intensive and mobility extended across language boundaries, whether for gatherings (which would have included exchange) or access to resources. The degree of interaction is typical of a low-cost effort needed to maintain a close network between neighbours (FitzHugh et al 2011:92).

While Baker and Swope's Information Network model, Hertell and Tallavaara's model, and Gould and Saggers' Exotic Stone Hypothesis would probably restrict the spread of the most commonly used stone to within one language area, because this requires the least effort, results here suggest a modification to include neighbouring areas belonging to different language groups. Gould and Saggers (1985:132) described an exception to their Exotic Stone Hypothesis which was also a consequence of the quality of local stone.

Findspot patterns of different SESA sources support hierarchical network models (McBryde 1997; Smith 2013:270-271; Berndt and Berndt 1988; Fitzhugh et al 2011: 86; Hamilton et al 2007:2196). At the lowest level, Cluster 2 is relatively tightly clustered, suggesting that these hatchets were not moved far from their source (Figure 25Figure 25); at the next level, an unknown sub-cluster of SESA Cluster 5 was moved over a large area but within a language boundary (Figure 27) at a higher level, SESA Clusters 8 and 10 were moved across language boundaries (Figure 26); and a small amount of far-distant exotic stone from several clusters indicated the highest level of connection. Whallon's two-tiered Model, group B, seems particularly appropriate, because he distinguishes between a Frequent Network connecting adjacent regions, and an Occasional Network with far-removed regions (Whallon 2006:261). The exchange/movement of hatchets in Clusters 8 and 10 between the three language areas fits the closer Frequent Network pattern, and the rarer movement of Mount Isa and Mt Macedon hatchets fits the distant Occasional Network pattern. Exotic stone, not non-utilitarian shell as in the Archaic USA, was used for the Occasional Network, but these hatchets probably had the same symbolic status because of their distance from source (McBryde 1984b:269; McBryde 1987:262; Smith 2013:300).

The intensive sharing of what must be local stone between language groups is in contrast to the exchange of a small number of extremely exotic hatchets. The distance that these exotic hatchets were moved shows that they were not exchanged because they were useful, but were high status, non- utilitarian items. The distance that they travelled also excludes direct procurement as a means of acquisition. They may have been carried by special trading groups for some of the distance, but formal ritualised exchange must have been part of the movement. They indicate an extensive social network (Newlander 2012:316; Tibbett 2002).

Sassaman et al (1988) distinguished between ‘gift-giving’ of utilitarian items within the mobility area of the group, and formalised exchange of sacred or ritualised objects which was restricted to an emerging elite in the late Archaic USA. This concept of a privileged few is supported by evidence of centralised and hierarchical society in SESA (Pate 2006:239) and elsewhere in Australia at the time of colonisation (Smith 2013:300), though there are many differences in the social structures of hunter-gatherers in USA and Australia. Evidence of social hierarchy is also suggested by the possibility of organised and standardised production at Mount Isa (Hiscock 2005; Sassaman et al 1988:90; Winterhoof 2007:35) and SESA finds of only a small number of exotic hatchets, which suggests privileged acquisition.

The main motivation behind hunter-gatherer networking is believed to be a risk management strategy, an information transmission survival mechanism in an area of poor or unpredictable resources, in contrast to well and reliably resourced areas which have tight boundaries and less need of intensive information networks (Mulvaney 2005:311-313; Whallon 2006:264; Fitzhugh et al 2011:89; Gould & Saggers 1985:124). But SESA is comparatively well-resourced in water (average rainfall 707mm.) and food (coastal region), and while it appears to be poor lithically, the large numbers and even and wide spread of same-sourced hatchets shows that there was available source(s) of prolific, good quality stone. However, similar water and food endowed environments in Victoria also maintained socio/political networks (McBryde 1984a). One explanation is that, although not arid, these areas did experience periods of drought and bushfire (these still occur naturally), that is, times of shortage which would benefit from a reliable network.

It is likely that the motivation for networking was complex, evolving with socio/political changes consequent on environmental variation. The existence of risk management measures, increased available marriage (Winterhalder 2001:27-28; Hertell and Tallavaara 2011:32; Walker et al 2011:3-4) and ritual partners (Hill et al 2014:7; Hamilton et al 2007:2201), which in turn reinforced the risk management procedures, and the demands of a privileged few, were all probable motives.

The SESA data also provides supporting evidence of the connecting trade routes described by McCarthy (1939) from northern Queensland to Buandig country. However, the widespread findspots of both Mount Isa and the other exotic source, Mt Macedon, indicate no single distribution point within SESA, nor direct procurement from source, or exchange by one group. Even if the Mount Isa hatchets started via organised single-step long-distance trade, the exotic hatchets probably all arrived at SESA through exchange.

5.3 Typology

An unexpected result was a typological similarity between one SESA hatchet (Figure 16) and hatchets found at Lake Eyre and Coopers Creek, known to have come from Mount Isa (Figure 22Figure 22). There may be no definitive typology for Australian ground-edged hatchets (Dickson 1976:35), but the similarity in shape of this group of hatchets suggests that further investigation into this shape, its spread and sources, could be interesting, in particular, because this hatchet most closely fitted Hiscock's standardised measurements.

5.4 Conclusion

Most of the hunter-gatherer models described above postulate large use of local stone for tools which would not be spread far from source through lower levels of a hierarchical network, and use of special quarries or sources for exchange to maintain higher level networks. However, the data from this research found very few hatchets from known local sources. Instead it found a dominant proportion of highly desirable hatchets in SESA Clusters 8 and 10 that were moved across all of SESA, and into neighbouring language areas. Unfortunately, their sources are unknown, and the width and evenness of the spread of findspots gives no clues to their location.

Despite this finding, the data do support models which emphasise sharing and reciprocity, and both the quality and spread of the dominant proportion suggest direct procurement. The existence of a small number of exotic hatchets supports models of higher level networking, while their spread suggests exchange as the means of procurement within SESA. These results support models which base hierarchical networks on exchange for motives of risk management.

CHAPTER 6

CONCLUSION

I have used a non-destructive geochemical technique (pXRF) to match a collection of archaeological hatchets held in the South Australian Museum with potential geological sources. The resulting dataset was then evaluated in the context of a range of models for hunter-gatherer behaviour in relation to patterns of exchange.

The study identified a pattern of widespread and trans-language group distribution from a limited range of local geological sources, of which only one elemental type was extensively used and probably exchanged across three language areas. It also identified a small number of hatchets which evidently were exchanged over long distances from one origin in the Mount Isa area of northern Australia and another in central Victoria.

These results contrast strongly with current hunter-gatherer models which emphasise hierarchically organised networks of exchange where the greatest frequency of exchange is between local groups within one language area. My results also do not support differentiation between a common stone for local use and special (from selected quarry or quarries) stone for higher level exchange. The widespread and relative abundance of hatchets of one geological type of stone over multiple language regions in my study area suggests ease of procurement, and a scarcity of other useable sources. The implication is that there was just one type of stone, from rich but, because they are not from obvious and known basalt sources in SESA or western Victoria, possibly from physically small sites. Furthermore, these stone sources were not divided into two quarry types, one for tools and the other for exchange items. An alternative or additional explanation is that there was no social need for a separation of local tools and status items, implying a more egalitarian society.

However, while I could identify a compositionally ubiquitous lithic type in SESA, I could not find a match for it with my geological reference types.

The wide distribution of hatchets that share the same compositional profile (from as yet unidentified source(s)) (SESA Clusters 8 and 10) suggests that the geography of SESA was no impediment to communication between Buandig, Ngarrindjeri and Bindjali people. The ubiquity of this compositional artefact class across these language boundaries suggests these hatchets were part of a relatively egalitarian regional system of exchange. This is supported by an absence of any concentrated area of finds, implying that that there was no dominate group controlling access or distribution, unlike the social/political structured access at Mt William in Victoria.

Although the sources of the commonly used stone remain uncertain, my results can be interpreted to suggest means of acquisition. Because SESA Clusters 8 and 10 are so prolific, and because they are from geological sources unlike any of the known SESA basalts, they were probably acquired by direct procurement, not embedded collection, nor exchange. There must have been at least one well-known, easily accessed source, with little cultural restriction, the knowledge and position of which, due to the quick removal of Aboriginal culture of SESA, was not recorded. Determining how far artefacts moved from the unknown source(s) was beyond the geographic scope of the present study.

The small number of exotic hatchets from two different, distant, sources may support both models of acquisition which function to maintain far-distant networks for communities, and also models which include acquisition of rare, far-distant, items to secure high status. However, the even distribution of these exotic hatchets across SESA and the three language areas points to no single group or language group as a dominant, elite group.

Prior to this research project, Mount Isa hatchets are known to have reached as far south as Lake Eyre, and they may have reached the Flinders Ranges. The results of this investigation of SESA hatchets confirm that the distribution of Mount Isa hatchets extended a further 700km south of the Flinders Ranges. The distribution of the three findspots of Mount Isa hatchets gives tentative support for the network described by McCarthy which exchanges artefacts along the South Australian coast from Port Augusta into SESA. The compositional results of one hatchet, A46352, and its typology, support the theory of large scale production of hatchets at Lake Moondara (Mount Isa), because it is the same shape as other known hatchets from that area, and fitting perfectly into the standardised size range described by Hiscock.

In summary, this area of SESA appears to have been well interconnected culturally. The unusual pattern of possibly only one (though possibly two) acceptable, currently unprovenanced, local stone source(s) in SESA must have affected the lithic exchange patterns of within-group, inter-group and extra-group network levels and possibly promoted a relatively egalitarian pattern of exchange between groups in the region.

However, determining the location(s) of these unprovenanced source(s) has been beyond the analytical capacity of pXRF and the geographic scope of this study.

Further work is clearly warranted on this aspect of the study as the identification of the origin of such widely distributed artefacts would enable distribution patterns from source to be more thoroughly determined, and provide further data to evaluate or modify relevant models of hunter-gatherer exchange. As part of this, hatchets of known provenance in other collections should be included. PXRF, for its ease and speed of use, would still be a very good technique to start with, but, with most hatchets having low readings of elements in the range Sr to Nb, other geochemical (and destructive) techniques are likely to provide better discrimination. Examination of the geology of SESA and western Victoria, looking for Cambrian outcrops could be a starting point, including a better elemental comparison of SESA hatchets with stone of the Victorian western greenstone belt than was possible with my data.

It would also be of interest to investigate hatchets of shape similar to A46352 to determine if there is a typological distinction which distinguishes a style of mass-produced hatchets from Mount Isa, a style restricted probably in time as well as morphology.

The use of pXRF to quantify elements of a large museum collection enabled production of a dataset previously unavailable because this would have required destruction of at least part of each artefact. PXRF allowed elemental analysis without their removal to a laboratory, and was relatively quick. The information gained from the dataset is valuable and indicates directions of research which would further increase our understanding of hunter-gatherer exchange behaviour. From its success in this study, PXRF should be still be the first step in further analyses of new sources and other provenanced hatchets, though destructive techniques might be necessary to more accurately relate hatchets to sources, especially for rock types impoverished in the elements that pXRF is ideally suited to measure.

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APPENDICES

Appendix A Source samples, with ppm of elements analysed by pXRF and calibrated with Peter Grave's basalt calibration file. Clustering of these sources only gave the 10 clusters in column 1. These are not the SESA Clusters formed from the hatchets and sources comb

source cl	Source	FeKa1	CoKa1	NiKa1	CuKa1	ZnKa1	GaKa1	AsKa1	PbLb1	ThLa1	RbKa1	SrKa1	Y Ka1	ZrKa1	NbKa1
1	DR09255 MtNapier UNE	67707	32.73	96.26	54.39	102.8	19.14	6.56	10.94	0.12	18.72	403.24	17.75	133.6	20.02
1	MtGambier-a UNE	69448	33.00	139.63	73.65	109.7	19.49	2.91	3.71	1.37	27.60	521.21	19.92	173.4	33.88
1	MtGambier-b UNE	71715	33.82	99.66	62.70	105.6	20.06	2.93	4.23	0.80	25.01	476.23	19.96	164.7	28.54
1	XRF049R Condah Swamp UNE	81037	38.29	120.59	84.29	114.2	22.17	3.25	8.37	1.45	20.48	473.27	21.82	152.2	21.87
1	XRF050aC Mt Eccles Q UNE	87677	40.84	148.78	59.37	112.2	21.15	3.87	3.59	1.00	17.90	395.28	20.44	138.1	24.28
1	XRF050aR Mt Eccles Q UNE	86930	40.83	152.97	64.73	116.4	20.70	3.14	3.35	1.21	19.13	406.63	20.56	134.4	23.37
1	XRF050bC Mt Eccles Q UNE	87186	40.83	151.67	65.39	114.3	21.48	3.10	5.26	0.96	19.05	387.30	20.44	133.0	23.09
1	XRF050bR Mt Eccles Q UNE	90548	42.38	158.42	74.37	109.9	19.91	3.66	4.93	1.33	16.94	379.47	18.55	128.8	22.45
1	XRF051C Mt Eccles Q UNE	77530	35.75	84.43	52.82	99.6	22.07	2.52	3.16	-0.19	15.39	356.37	19.34	114.4	11.25
1	XRF051R Mt Eccles Q UNE	74858	33.76	76.53	52.96	102.1	21.15	1.88	3.26	1.28	15.82	382.14	19.81	121.9	10.51
1	XRF052-2013-R Harmans Rd UNE	83482	38.39	131.81	67.31	118.2	21.09	2.63	3.86	1.23	21.77	491.60	22.56	170.4	25.31
1	XRF052C Harmans Rd UNE	79778	36.89	149.68	90.11	105.8	21.94	1.61	4.23	0.56	21.83	446.73	21.21	151.2	19.76
2	XRF042C Mt Muirhead UNE	28462	11.83	67.36	50.15	75.5	15.79	1.34	3.85	-0.27	12.03	527.78	8.17	76.3	6.87
2	XRF042R Mt Muirhead UNE	29440	12.18	71.43	44.38	77.4	16.64	2.35	3.28	0.00	11.42	532.97	7.98	80.5	7.60
3	E060460 Flake MtIsa UNE	76095	36.27	92.86	58.89	118.2	19.34	5.03	6.10	-1.10	31.35	125.22	21.72	66.4	1.31
3	E061292a GeoSpec MtIsa UNE	78245	37.23	55.84	53.74	123.5	19.27	21.94	34.11	1.07	25.22	180.35	22.76	54.7	0.55
3	E061292c Blank MtIsa UNE	70756	33.71	45.48	46.82	115.0	18.27	5.47	9.04	0.13	29.56	100.07	25.52	99.9	4.36
3	E061292e GeoSpec MtIsa UNE	85719	40.90	64.52	58.50	133.8	19.60	33.45	54.40	1.81	31.47	163.57	19.99	56.4	0.54
3	LMQI Area A 45 AP 5 Pile UNE	80583	38.69	67.26	42.44	134.0	17.98	4.47	3.73	-1.15	21.29	137.55	18.80	49.9	0.07
4	E061292b Blank MtIsa UNE	101821	48.69	45.84	82.27	140.9	19.69	8.00	9.45	1.30	49.95	122.90	36.28	154.3	10.16

4	LMQI Area A 45 AP 2 Pile UNE	75787	37.06	63.13	73.16	133.0	19.13	9.19	10.73	-0.16	46.37	138.80	22.86	48.1	0.96
4	LMQI Area A 45 AP 20 Piles UNE	68350	33.72	67.49	49.98	130.6	18.37	6.59	9.00	-1.31	65.44	128.58	23.19	47.7	-0.42
4	LMQI Area A 45 AP 22 Pile UNE	52278	26.10	41.00	44.40	107.9	17.60	6.50	9.55	-0.19	46.25	132.39	21.45	44.8	0.19
4	LMQI Area A 45 APa UNE	62236	30.36	53.45	36.27	117.0	17.74	7.53	7.88	-0.34	50.38	155.39	22.67	45.9	0.77
4	LMQI Area A 45 APb UNE	100731	49.91	114.34	137.96	187.3	18.74	20.37	33.95	1.86	68.21	78.14	28.13	77.0	3.08
5	E038225 Blank MtWilliam UNE	87260	42.24	253.12	41.24	123.0	15.00	5.05	4.61	-3.09	-1.67	45.08	2.88	-24.3	-5.06
5	E042666 Blank MtWilliam UNE	88969	42.90	261.95	46.46	132.4	14.64	7.02	7.60	-2.63	-1.23	39.30	3.16	-29.0	-5.45
5	E049030a Blank MtWilliam UNE	71629	34.31	267.63	42.84	113.5	14.18	8.71	11.06	-2.62	-3.74	58.05	2.99	-28.1	-5.65
5	E049030b Blank MtWilliam UNE	85756	41.74	285.64	46.94	141.2	16.87	50.21	79.26	0.22	-2.28	39.71	4.51	-29.6	-5.53
5	MTWQLOWER UNE	87996	43.29	300.50	22.10	97.3	14.05	2.34	0.57	-3.99	-3.14	41.32	3.36	-28.9	-6.17
5	MTWQTOP UNE	85514	42.25	307.84	34.17	116.3	14.22	2.47	1.26	-3.30	-2.03	32.67	3.04	-29.9	-5.74
5	MTWTOPTEST UNE	83808	41.20	331.77	31.02	101.7	14.63	7.01	0.64	-2.41	17.57	162.65	5.01	-13.4	-5.66
6	DR09257 MtMacedon UNE	37701	17.15	8.82	16.81	82.8	18.31	8.28	13.40	5.52	110.88	189.70	38.34	148.4	3.94
7	DR14548 RamseyRd NE Woodend UNE	37424	16.75	0.58	2.87	97.7	21.47	6.41	7.86	4.83	97.27	179.94	33.87	536.8	63.04
8	DR09265 TrenthamFalls UNE	56568	27.18	38.91	46.92	105.1	19.60	5.95	8.54	2.00	48.75	641.96	23.77	290.0	54.52
8	DR15328 Daylesford UNE	70051	32.99	37.19	53.27	106.0	20.87	3.29	5.95	2.67	34.33	887.78	22.86	267.3	36.77
8	XRF045-2013-C Mt Watch Q UNE	90071	41.93	386.05	104.07	118.5	20.38	4.34	8.02	4.05	45.54	654.16	24.78	292.4	63.65
8	XRF045-2013-R Mt Watch Q UNE	90983	42.08	346.87	113.71	116.6	20.77	4.11	6.75	3.92	44.31	652.31	24.56	290.0	62.59
8	XRF045aC Mt Watch Q UNE	86296	39.92	385.44	98.48	115.4	20.45	3.79	8.02	3.87	43.28	628.83	23.17	280.5	61.32
8	XRF045aR Mt Watch Q UNE	83146	38.56	333.08	113.43	116.0	21.01	4.07	8.06	4.62	37.70	625.19	22.28	270.3	59.14
8	XRF045dC Mt Watch Q UNE	91658	42.75	444.77	105.70	116.8	20.29	3.72	7.56	4.26	35.67	670.10	23.91	301.1	64.37
8	XRF045dR Mt Watch Q UNE	89892	41.56	363.89	143.45	120.6	20.83	3.90	8.12	4.20	32.16	669.68	23.26	292.3	61.63
9	XRF043C The Bluff UNE	86370	40.35	207.59	92.72	112.2	21.65	4.20	7.40	4.45	23.81	861.13	24.97	344.6	71.90
9	XRF043R The Bluff UNE	80998	37.50	125.10	109.49	110.2	23.01	4.43	9.13	5.07	23.87	841.27	25.25	340.8	68.68

9	XRF044C The Bluff RdCut UNE	93193	43.18	247.71	101.18	118.9	22.08	4.79	10.21	5.06	24.52	853.04	26.13	337.9	69.34
9	XRF044R The Bluff RdCut UNE	84662	39.30	171.74	97.80	116.7	21.24	3.95	8.43	4.42	24.18	778.93	25.29	315.1	65.41
10	XRF046C Mt Schank cp UNE	86052	39.88	108.29	75.76	136.5	23.26	4.37	9.98	5.67	62.47	911.88	32.27	393.2	72.88
10	XRF046R Mt Schank cp UNE	83399	38.79	88.22	79.57	134.3	23.57	4.58	10.58	5.92	62.27	930.30	32.63	396.8	74.23
10	XRF047C Mt Schank Q UNE	83956	38.51	108.44	74.01	125.8	22.72	4.74	11.35	6.26	65.58	951.22	34.01	406.1	72.40
10	XRF047R Mt Schank Q UNE	79541	36.97	89.60	83.00	121.6	23.58	4.60	9.92	5.50	61.59	912.74	31.07	380.3	67.65
10	XRF048C Mt McIntyre UNE	83682	38.71	193.67	124.99	113.6	21.17	4.58	8.58	6.83	59.35	936.30	29.49	376.3	78.56

Appendix B Results of Discriminant Analysis of source samples

Discriminant Analysis

Discriminant Method: Linear
Classification: Cluster

Discriminant Scores

Row	Actual	SqDist(Actual)	Prob(Actual)	-Log(Prob)	Predicted	Prob(Pred)	Others
1	1	4.13049	1.0000	0.000	1	1.0000	
2	6	5.684e-14	1.0000	0.000	6	1.0000	
3	8	8.03880	1.0000	0.000	8	1.0000	
4	7	2.274e-13	1.0000	0.000	7	1.0000	
5	8	28.16514	0.9999	0.000	8	0.9999	
6	5	1.24044	1.0000	0.000	5	1.0000	
7	5	0.27959	1.0000	0.000	5	1.0000	
8	5	0.66825	1.0000	0.000	5	1.0000	
9	5	1.96827	1.0000	0.000	5	1.0000	
10	3	0.81560	1.0000	0.000	3	1.0000	
11	3	9.64412	1.0000	0.000	3	1.0000	
12	4	24.33970	1.0000	0.000	4	1.0000	
13	3	5.37013	1.0000	0.000	3	1.0000	
14	3	1.45173	1.0000	0.000	3	1.0000	
15	4	3.33442	0.9999	0.000	4	0.9999	
16	4	6.71283	1.0000	0.000	4	1.0000	
17	4	5.19362	0.9977	0.002	4	0.9977	
18	3	3.01722	1.0000	0.000	3	1.0000	
19	4	2.83420	1.0000	0.000	4	1.0000	
20	4	8.52885	1.0000	0.000	4	1.0000	
21	1	11.88636	1.0000	0.000	1	1.0000	
22	1	5.17341	1.0000	0.000	1	1.0000	
23	5	0.51723	1.0000	0.000	5	1.0000	
24	5	0.55978	1.0000	0.000	5	1.0000	
25	5	12.51451	1.0000	0.000	5	1.0000	
26	2	0.09350	1.0000	0.000	2	1.0000	
27	2	0.09350	1.0000	0.000	2	1.0000	
28	9	1.60694	1.0000	0.000	9	1.0000	
29	9	1.01134	1.0000	0.000	9	1.0000	
30	9	0.57128	1.0000	0.000	9	1.0000	
31	9	3.47399	0.9998	0.000	9	0.9998	
32	8	2.82631	1.0000	0.000	8	1.0000	
33	8	2.04987	1.0000	0.000	8	1.0000	
34	8	1.78380	1.0000	0.000	8	1.0000	
35	8	1.82724	1.0000	0.000	8	1.0000	
36	8	2.97229	0.9999	0.000	8	0.9999	
37	8	3.36317	0.9997	0.000	8	0.9997	
38	10	0.27422	1.0000	0.000	10	1.0000	
39	10	0.12309	1.0000	0.000	10	1.0000	
40	10	1.34056	1.0000	0.000	10	1.0000	
41	10	1.83082	1.0000	0.000	10	1.0000	
42	10	4.94200	1.0000	0.000	10	1.0000	
43	1	1.90685	1.0000	0.000	1	1.0000	
44	1	1.74740	1.0000	0.000	1	1.0000	
45	1	2.98993	1.0000	0.000	1	1.0000	
46	1	2.63159	1.0000	0.000	1	1.0000	
47	1	1.44208	1.0000	0.000	1	1.0000	
48	1	7.12445	1.0000	0.000	1	1.0000	
49	1	6.65421	1.0000	0.000	1	1.0000	
50	1	2.97051	1.0000	0.000	1	1.0000	
51	1	0.96440	1.0000	0.000	1	1.0000	

Score Summaries

Source	Count	Number Misclassified	Percent Misclassified	Entropy RSquare	-2LogLikelihood
Training	51	0	0.00000	0.99997	0.00613

Appendix C Table of SESA hatchets. Showing the SESA Cluster number, SAM ID, Findspot, Weight in gm, Length, Width, Thickness in cm, and identification number for the ARC project.

Cluster	SAM ID	Find Site	Weight gm	L cm	W cm	Th cm	SAM Box	photo1	photo2	ARC ID
1	A16986	Pt MacDonnell	1009.42	15.5	10.4	3.8	1108	260	261	5035
1	A17175	Nalang	298.33	10.1	7.05	2.9	1128	391	392	5098
1	A28770	Mt Gambier	579.85	10.7	9.2	4	1116	682	683	5152
1	A45627	Narrow Neck Rendlesham	958.44	15.3	9.9	4.5	1124	706	707	5164
2	A17252	Wye	944.48	12.2	9.4	6.2	1113	282	283	5045
2	A17255	Wye	651.13	13.7	8.7	4	1112	284	285	5046
2	A17266	Green Point	670.87	15.7	6.5	4.8	1112	286	287	5047
2	A17275	Wye	211.23	9.2	6.2	2.7	1112	288	289	5048
2	A17245	Mt Gambier	1477.52	15.5	10.4	5.8	1113	626	627	5124
2	A21150	Rendlesham Sandhills	863.36	14.1	7.8	5.5	1114	644	645	5133
2	A28501	Compton	877.93	13.7	8.9	4.45	1115	660	661	5141
2	A28194	Mt Gambier	1446.48	14.7	13.9	4.65	1115	664	665	5143
2	A9860	Mt Gambier district	379.5	9.15	7.1	4.4	1107	801	802	5210
3	A16608	Keilira Stn	226.79	9.4	6.3	2.45	1108	383	384	5094
3	A17173	Nalang	359.36	9.1	6.1	4.3	1128	387	388	5096
3	A46348	Millicent	401.64	11.9	9.05	2.3	1125	785	786	5202
4	A4348	Robe	484.13	10.75	7.15	4.7	1106	571	572	5014
4	A4374	Tarpeena	417.23	10.9	7.9	4.2	1106	579	580	5018
4	A29378	Compton	712.83	12.7	8.9	4.4	1117	593	594	5025
4	A33562	Woakwine Range	335.76	11.6	6.1	3.85	1121	331	332	5068
4	A17202	Pt MacDonnell	454.1	10.9	8.4	3	1110	375	376	5090
4	A46352	Stewarts Range	400.26	9.1	8.6	3.9	1126	397	398	5102
4	A65768	Penola	451.1	10.55	8.05	3.8	1127	409	410	5108
4	A28774	Millicent	235.76	9.2	6.3	3.25	1116	674	675	5148
4	A33542	Millicent	875.92	14.2	10.5	3.7	1120	702	703	5162

4	A33588	Kongorong	327.67	9.45	6.9	3.1	1121	716	717	5169
4	A33589	Kongorong	797.8	13.5	8.3	4.8	1121	722	723	5172
4	A36312	Lucindale	245.81	9.9	6.3	2.75	1122	728	729	5175
4	A45858	Bevilaqua Ford	403.87	11.3	7.7	3.6	1125	795	796	5207
5	A30568	Bevilaqua Ford	663.06	14.4	8.5	3.8	1118	547	548	5005
5	A4375	Tarpeena	180.17	5.9	6.15	3.4	1106	585	586	5021
5	A12161	Naracoorte	561.8	12.2	7.5	3.75	1108	253	254	5032
5	A17251	Wye	391.65	10.8	7.9	3.3	1113	278	279	5043
5	A28955	Kalangadoo	557.11	12.2	8.35	3.75	1116	310	311	5059
5	A33543	Millicent	984.74	14.5	10.8	4.35	1120	319	320	5062
5	A33544	Millicent	456.7	11.6	8.4	3.35	1120	321	322	5063
5	A33569	Beachport	663.71	12.6	10.4	3.9	1121	335	336	5070
5	A35374	Beachport	636.95	13.55	9.7	3.4	1122	343	344	5074
5	A36318	Naracoorte	508.69	13.25	8.1	3.75	1122	347	348	5076
5	A33547	Millicent	831.15	13.1	11.3	4.1	1121	355	356	5080
5	A17194	Mt Gambier	1035.76	16.5	10.7	3.9	1109	359	360	5082
5	A45856	Benara	497.13	11.25	9.1	3.4	1125	414	415	5110
5	A17254	Wye	495.41	11.85	7.95	3.7	1113	630	631	5126
5	A20546	Robe	211.63	6.85	7.7	3.4	1114	640	641	5131
5	A28771	Mt Gambier	838	14.95	8.5	4	1116	680	681	5151
5	A33539	Millicent	967.69	15.4	10.5	4.1	1119	696	697	5159
5	A33553	Beachport	546.18	13.1	7.7	3.85	1120	700	701	5161
5	A33568	South End Beachport	872.25	14.3	9.5	4.6	1121	718	719	5170
5	A37119	Robe	448.37	11.5	7.8	4	1123	741	742	5181
5	A56552	Naracoorte	too heavy	18.1 approx	12.95	4.6	1127	773	774	5196
5	A45859	Beachport	557.03	13.35	8.15	3.15	1125	777	778	5198
5	A9857	Mt Gambier district	502.17	13	8.5	3.3	1107	811	812	5215
5	A55898	Mt Lookout	438.04	11.7	9.4	2.7	2452			5240
5	AUn2	Benara	702.03	12.65	9.1	4.1	3333	867	868	5244

6	A28195	Carpenter Rocks	250.14	10.45	7.2	2.8	1115	304	305	5056
6	A53700	Bordertown	490.08	13.1	7.5	3.3	1129	823	824	5221
7	A21152	Millicent			8.55	7.95	1114	638	639	5130
8	A51252	Mt Gambier	226.77	7.9	6.3	2.6	1118	543	544	5003
8	A30562	Woakwine Station	220.67	7.85	7.7	2.4	1118	553	554	5007
8	A30566	Kongorong	275.32	11.8	5.2	3.3	1118	555	556	5008
8	A4347	Lacepede Bay	421.52	11.8	6.7	3.15	1106	559	560	5009
8	A1079	Lucindale	478.47	11.4	7.3	4.15	1106	561	562	5010
8	A565	Stewarts Range	319.41	10.7	6.7	4.2	1106	567	568	5012
8	A1080	Lucindale	174.36	7.7	6.8	2.5	1106	569	570	5013
8	A970	Lucindale	695.27	13.2	8.5	4.6	1106	573	574	5015
8	A4349	Kingston	408.52	9.75	7	3.9	1106	577	578	5017
8	A9505	Robe	445.94	12.7	5.45	4.05	1106	583	584	5020
8	A7014	Lucindale	321.79	9.4	7.15	2.8	1106	587	588	5022
8	A29380	Millicent	325.85	11.4	6.85	2.8	1117	591	592	5024
8	A29889	Mt Gambier	180.32	7.4	5.3	3.05	1117	595	596	5026
8	A28956	Kalangadoo	331.6	9	6.9	3.7	1117	103-0247	248	5029
8	A29933	Cape Northumberland	161.02	7.85	6	2	1117	249	250	5030
8	A16606	Dairy Range	383.82	10.4	7.4	2.7	1108	257	258	5034
8	A17215	German Creek	362.08	9.5	8.2	3	1111	264	265	5036
8	A17222	Tantanoola	433	9.6	6.9	3.8	1111	268	269	5038
8	A17228	Boola Coola	655.77	11.2	7.6	4.5	1111	270	271	5039
8	A17229	Lk Bonney	380.58	10.5	6.65	3.65	1111	272	273	5040
8	A17246	Glencoe	149.35	7.8	4.5	2.3	1113	276	277	5042
8	A20543	Robe	408-1	9.9	7.8	2.8	1114	290	291	5049
8	A21148	Rendlesham Sandhills	344.58	10.15	6.45	3.3	1114	294	295	5051
8	A21153	Millicent	359.48	9.5	6.5	3.4	1114	298	299	5053
8	A21419	Robe	289.51	8.9	6.35	3.05	1115	300	301	5054
8	A28743	Cape Northumberland	457.55	9.9	7.5	3.3	1115	306	307	5057

8	A28772	Cape Northumberland	331.37	10.4	6.5	3.65	1116	308	309	5058
8	A31265	Naracoorte	517.82	11.15	7.3	3.6	1119	312	313	5060
8	A45626	Mt Burr	476.92	11.7	7.3	3.65	1124	327	328	5066
8	A33561	Woakwine Range	450.78	10.95	7	3.5	1121	329	330	5067
8	A33568	Beachport	872.22	14.25	9.2	4.7	1121	333	334	5069
8	A33586	Kongorong	379.8	9.4	7.7	3.4	1121	337	338	5071
8	A33587	Kongorong	375.55	11	6.3	3.45	1121	339	340	5072
8	A36317	Frances	355.11	10	7.05	3.65	1122	345	346	5075
8	A36921	Lake Leake	418.75	10.2	7.85	3.2	1123	351	352	5078
8	A17192	Mt Gambier	1098.71	17	9.6	4.2	1109	353	354	5079
8	A17195	Mt Gambier	443.12	9.5	7.75	3.4	1109	361	362	5083
8	A17196	Mt Gambier	475.5	9.9	7.5	3.7	1109	363	364	5084
8	A17197	Mt Gambier	434.93	11.3	5.85	4.2	1110	365	366	5085
8	A17170	Bordertown	463.2	11.2	7.5	3.05	1128	385	386	5095
8	A17185	Bordertown	314.24	8.8	7		1128	393	394	5099
8	A17186	Bordertown	450.3	10	6.75	3.8	1128	395	396	5100
8	A46357	Naracoorte	326.67	11.85	7.75	2.2	1126	401	402	5104
8	A46358	Stewarts Range	422.04	12.05	6.5	3.1	1126	403	404	5105
8	A46969	Cape Banks	318.68	7.6	7.15	3.1	1126	405	406	5106
8	A17179	Creecoona	227.92	8	6.6	3.4	1147	416	417	5111
8	A12736	Taratap	307.74	7.8	6.9	2.75	1108	604	605	5114
8	A16514	Brimbago	267.63	9.5	7.15	2.8	1108	606	607	5115
8	A12932	Kingston	347.03	10.1	6.7	3.25	1108	608	609	5116
8	A13105	Kingston	259.78	8.8	6.65	2.85	1108	610	611	5117
8	A15606	Millicent	384.52	6.3	7.25	3.25	1108	614	615	5119
8	A17244	Mt Gambier	299.08	6.45	5.7	3.4	1113	628	629	5125
8	A21146	Taratap		8.45	6.1	2.95	1114	634	635	5128
8	A20547	Robe	372.49	12.8	4.45	3.9	1114	642	643	5132
8	A20544	Robe	404.81	11.45	6.45	3.5	1114	646	647	5134

8	A20545	Robe	521.92	12.55	7.65	3.8	1114	648	649	5135
8	A21154	Taratap	509.03	11.15	8	3.8	1115	652	653	5137
8	A21155	Taratap	402.54	10.95	7.1	3.25	1115	658	659	5140
8	A28740	Mt Gambier	500.54	11.15	7	3.5	1115	662	663	5142
8	A28769	Mt Gambier	172.03	8.5	4.8	2.7	1116	676	677	5149
8	A28744	Millicent	456.87	11.9	8.5	2.95	1116	684	685	5153
8	A32725	Kingston near	408.01	11.95	6.8	3.05	1119	686	687	5154
8	A43114	Taratap	501.58	11.85	7.6	3.3	1124	704	705	5163
8	A43040	Woakwine	321.91	10.15	6.35	3.5	1124	710	711	5166
8	A33590	Kongorong	500.21	13.6	6.15	4	1121	714	715	5168
8	A33563	Woakwine Range	283.77	10.65	6.9	2.7	1121	720	721	5171
8	A35371	Kongorong	402.74	9.4	6.65	3.8	1122	724	725	5173
8	A36315	Lucindale	313.54	5.8	7.4	2.85	1122	734	735	5178
8	A36319	Naracoorte	336.46	9.9	7.5	3.45	1123	736	737	5179
8	A37390	Kongorong	258.34	8.6	6	3	1123	739	740	5180
8	A17213	Millel	216.18	8.5	6.8	2.45	1110	743	744	5182
8	A60345	Kingston	376.07	10.2	7.9	3.4	1128	747	748	5183
8	A16648	Pine Hill	55.93	4.75	3.9	1.75	1128	751	752	5185
8	A16004	Wolseley	197.1	7.7	6.1	3	1128	753	754	5186
8	A46351	Millicent	216.57	8.15	6.95	2.5	1126	759	760	5189
8	A46358	Naracoorte	319.88	9	6.4	3.4	1126	761	762	5190
8	A47506	Beachport	282.24	8.25	7	3.1	1127	763	764	5191
8	A54268	Kingston	355.14	10.5	6.4	3	1127	765	766	5192
8	A53628	Mt Gambier	287.18	9.9	7	2.65	1127	769	770	5194
8	A50527	West Woakwine	236.08	8.15	6.25	3.15	1127	775	776	5197
8	A45882 or 45862	Bevilaqua Ford	248.29	9.3	6.9	2.8	1125	779	780	5199
8	A45863	Bevilaqua Ford	343.71	9.85	6.5	3	1125	781	782	5200
8	A45857	Bevilaqua Ford	132.25	6.5	5.8	2.45	1125	787	788	5203

8	A45861 or 45851	Kalangadoo	326.88	10	6.35	3.2	1125	789	790	5204
8	A47567	Beachport	219.09	9.3	6.35	2.45	1127	793	794	5206
8	A9506	Robe	436.92	10.45	7.2	3.8	1107	799	780	5209
8	A9861	Mt Gambier district	270.2	8.9	6.65	2.85	1107	805	806	5212
8	A37398	Compton	492.96	11.6	9	3	1162	807	808	5213
8	A4352	Kingston	322.1	9.4	6.8	3.4	1129	815	816	5217
8	A36316	Wolseley	425.04	11.2	6.2	3.8	1129	817	818	5218
8	A21493	Bordertown	122.39	6.8	3.9	2.8	1129	819	820	5219
8	A17174	Nalang	356.4	11.1	7.3	2.8	1129	821	822	5220
8	A21422	Bordertown	118.79	8.4	4.5	2.05	1129	825	826	5222
8	A36914	Mundalla	301.86	9.2	7.4	2.95	1129	833	834	5226
8	A29393	Padaways	267.06	8.5	6.5	2.8	1129	835	836	5227
8	A17181	Bordertown	548.13	11.25	7.65	3.9	1129	837	838	5228
8	A17182	Bordertown	379.16	9	5.6	4.5	1128	841	842	5230
8	A30565	Woakwine	168.91	11.15	3.2	3.7	1118	845	846	5232
8	A9859	Mt Gambier district	268.44	9.1	6.45`	3.35	1107	847	848	5233
8	A9858	Mt Gambier district	394.24	8.7	6.9	3.8	1107	849	850	5234
8	A9855	Mt Gambier district	371.98	10.4	6	3.8	1107	851	852	5235
8	A9856	Mt Gambier district	296.16	9.5	6.7	3.8	1107	853	854	5236
8	A9853	Mt Gambier district	625.24	12.3	8.45	4.6	1107	855	856	5237
8	A39674	Rivoli Bay	110.92	6.9	4.75	2.3	2450	859	860	5239
8	AUn1	Mt Gambier	344.21	9.7	6.8	3.4	3333	865	866	5243
9	A31259	Mt Gambier	640.99	12.1	7.8	4.6	1118	541	542	5002
9	A21151	Rendlesham Sandhills	943.9	13.5	10.35	4.6	1114	296	297	5052
9	A36669	Lake St George	659.56	12.05	9.1	4.2	1123	349	350	5077
9	A17210	Glencoe	530.41	10.85	9.65	3.1	1110	377	378	5091
9	A55130	Maria Ck	597.48	13.8	8.1	3.35	1127	407	408	5107
9	A17243	Mt Gambier	429.08	10.6	8.15	3.9	1111	622	625	5123
9	A17273	Mt Gambier	311.42	11.85	7.3	2.7	1112	632	633	5127

9	A21156	Taratap	512.89	12.7	8.4	2.8	1115	656	657	5139
9	A28772	Millicent	245.72	9.4	7.1	2.5	1116	678	679	5150
9	A31263	Mt Gambier district	646.02	13.75	7.5	4.3	1119	692	693	5157
9	A33554	Beachport	375.59	11	7.05	3.5	1120	698	699	5160
9	A41972	Lake Leake	638.6	14	6.4	3.95	1124	712	713	5167
9	A46970	Cape Banks	238.51	8.35	7.2	2.45	1126	757	758	5188
9	A45860	Millicent district	1043.69	14.6	8.8	5	1125	791	792	5205
9	A17180	Creecoona	508.36	11.9	5.9	4.25	1147	797	798	5208
9	A9851	Mt Gambier district	720.54	13.5	9.7	3.6	1107	857	858	5238
10	A31257	Mt Gambier	913.45	16	11.25	3.6	1118	105-0539	540	5001
10	A27152	Penola	1046.44	15.8	9.9	4.3	1118	549	550	5004
10	A30561	Bevilaqua Ford	238.19	8.85	7	2	1118	551	552	5006
10	A4354	Rivoli Bay	399.65	10.7	6.8	4.1	1106	563	564	5011
10	A4350	Kingston	393.29	11.15	7	2.8	1106	575	576	5016
10	A4353	Kingston	279.2	9.7	6.4	3.4	1106	581	582	5019
10	A29381	Millicent	290.83	9.4	5.35	3.8	1117	589	590	5023
10	A29888	Robe	249.17	9.5	6.1	3.05	1117	597	598	5027
10	A29379	Beachport	270.26	8	6.15	3.5	1117	599	601	5028
10	A29382	Millicent	386.29	10.5	7.4	3.3	1117	251	252	5031
10	A16605	Dairy Range	390.44	9.7	6.7	3.9	1108	255	256	5033
10	A17219	Tarpeena	832.5	13.5	8.75	4.6	1111	266	267	5037
10	A17230	Snuggers	764.11	12.8	9.9	4	1111	274	275	5041
10	A17253	Wye	170.54	8.2	6.15	2.2	1113	280	281	5044
10	A21147	Rendlesham Sandhills	261.31	8.5	7.4	2.9	1114	292	293	5050
10	A28192	Robe	669.42	15.5	7.75	3.1	1115	302	303	5055
10	A33541	Millicent	474.74	11.5	8.45	3.15	1120	314	315	5061
10	A33545	Millicent	582.17	13.5	8	3.4	1120	323	324	5064
10	A44222	Mt Gambier	1441.11	17.5	12.8	4.1	1124	325	326	5065
10	A35373	Beachport	781.01	13.8	9.15	4.4	1122	341	342	5073

10	A17193	Mt Gambier	945.26	14.5	9.85	3.7	1109	357	358	5081
10	A17198	Mt Gambier	204.05	9.3	6.6	2.1	1110	367	368	5086
10	A17199	Yahl	316.83	9.4	5.9	3.8	1110	369	370	5087
10	A17200	Pt MacDonnell	993.64	14.65	7.9	5.75	1110	371	372	5088
10	A17201	Pt MacDonnell	607.46	11.6	9.2	4	1110	373	374	5089
10	A17211	Trihi	843.86	13.6	9.5	3.8	1110	379	380	5092
10	A16607	Keilira Stn	478.21	10.8	7.2	3.9	1108	381	382	5093
10	A17184	Bordertown	284.02	9.2	6.8	3.05	1128	389	390	5097
10	A46354	Stewarts Range	485.54	13.3	7.4	3.3	1126	399	400	5103
10	A27153	Penola	332	10.4	5.25	3.7	1118	105-0557	558	5112
10	A28957	Kalangadoo	411.52	11.45	7.15	3	1117	602	603	5113
10	A13104	Kingston	639.63	14.15	7.3	3.5	1108	612	613	5118
10	A12914	Robe	767.1	13.3	9.65	3.5	1108	616	617	5120
10	A13103	Kingston	859.87	14.4	8.9	4.1	1108	618	619	5121
10	A17242	Mt Gambier	293.91	10.7	6.8	2.9	1111	620	621	5122
10	A21149	Rendlesham Sandhills	637.12	13.1	9.05	4.15	1114	636	637	5129
10	A21560	Symon	447.75	12.5	7.7	3.4	1115	650	651	5136
10	A21420	Robe	226.4	8.6	6.2	3.75	1115	654	655	5138
10	A28856	Millicent	600.36	13.7	6.6	3.6	1116	666	667	5144
10	A28952	Kingston	516.62	11.5	8.45	3.5	1116	668	669	5145
10	A28953	Kingston	436.74	11.65	7.1	4	1116	670	671	5146
10	A28846	Hatherleigh	146.64	8.95	5.05	2.6	1116	672	673	5147
10	A31264	Mt Gambier district	417.65	10.85	6.9	3.75	1119	688	689	5155
10	A31261	Mt Gambier district	410.95	10.2	6.8	4.05	1119	690	691	5156
10	A33540	Millicent	418.82	10.8	7.05	3.6	1119	694	695	5158
10	A41971	Lake Leake	196.87	8.5	5.4	2.6	1124	708	709	5165
10	A26314	Lucindale	163.83	7.1	5.5	2.65	1122	726	727	5174
10	A35379	Millicent	700.64	12.1	9	4.7	1122	730	731	5176
10	A36313	Lucindale	425.36	12.55	6.1	2.9	1122	732	733	5177

10	A17183	Bordertown	396.17	10.7	6.3	3.7	1128	749	750	5184
10	A16003	Wolseley	166.34	7.7	5.9	2.3	1128	755	756	5187
10	A52893	Mt Gambier	187.12	7.1	5.25	3.15	1127	767	768	5193
10	A56149	Lucindale	576.97	12	8.45	3.6	1127	771	772	5195
10	A46347	Millicent	596.98	12.7	8.95	3.2	1125	783	784	5201
10	A9862	Mt Gambier district	186.23	6.5	6.8	2.85	1107	803	804	5211
10	A9854	Mt Gambier district	408.84	11.15	7	3.45	1107	809	810	5214
10	A9852	Mt Gambier district	536.46	12.25	9.55	2.8	1107	813	814	5216
10	A17221	Bordertown	296.11	8.5	6.05	3.5	1129	827	828	5223
10	A21494	Wirrega	588.78	12.6	7.6	3.9	1129	829	830	5224
10	A53686	Bordertown	479.31	11.1	7.7	4	1129	831	832	5225
10	A17171	Bordertown	182.27	6.8	5.4	3.2	1128	839	840	5229
10	A17172	Bordertown	279.9	9	6.4	3.25	1128	843	844	5231
10	A4376	Tarpeena	114.89	6.7	5.3	2.3	47	861	862	5241
10	A30521	Cape Buffon	211.15	7.75	6.9	2.9	2444	863	864	5242

Appendix D PXRF data of SAM hatchets

Cl	SAM ID	MnKa1	FeKa1	CoKa1	NiKa1	CuKa1	ZnKa1	GaKa1	AsKa1	PbLb1	ThLa1	RbKa1	SrKa1	Y Ka1	ZrKa1	NbKa1
1	A16986	3073.00	407826	182.77	69.99	156.27	109.73	22.31	75.97	29.81	5.76	16.37	246.18	24.15	81.33	16.03
1	A17175	769.09	46704	20.57	18.59	64.07	119.33	19.14	7.12	10.81	1.31	14.08	482.37	14.26	130.78	0.09
1	A28770	912.88	56020	25.06	43.44	77.43	342.19	19.85	10.88	17.92	2.18	31.66	514.27	16.01	137.96	0.00
1	A45627	830.69	51592	23.50	30.51	85.83	160.09	21.08	8.54	13.45	0.41	19.03	441.42	14.82	140.04	0.00
2	A17252	1649.32	156904	74.54	71.98	129.64	174.87	23.92	27.15	33.23	3.98	31.31	371.75	29.95	170.51	25.87
2	A17255	1499.10	105590	49.69	166.02	96.29	136.26	22.33	15.47	22.87	2.75	35.83	564.42	22.27	185.57	40.55
2	A17266	1113.11	93676	44.98	93.96	108.86	164.62	22.25	16.49	25.49	2.95	24.54	472.71	23.07	161.56	29.12
2	A17275	1395.62	89465	42.05	189.68	108.71	140.96	21.69	7.67	13.52	2.03	32.70	633.26	21.93	212.51	38.11
2	A17245	2175.89	103100	47.50	149.68	73.70	170.31	21.66	48.14	26.20	2.35	21.71	478.57	25.29	169.78	28.53
2	A21150	1342.91	79391	37.28	155.02	93.19	208.99	22.91	19.71	34.34	3.05	26.65	664.38	21.75	196.67	30.60
2	A28501	1307.81	83751	38.87	143.66	79.43	161.07	22.89	6.53	12.25	1.71	28.61	670.98	22.60	208.40	35.39
2	A28194	1610.54	99768	46.69	153.44	127.15	134.19	21.44	7.92	12.03	1.22	29.33	401.26	22.19	181.79	37.48
2	A9860	1690.48	106151	50.54	220.33	116.39	399.34	22.00	18.24	28.65	2.72	23.53	543.93	22.64	190.07	33.03
3	A16608	1847.27	89819	41.63	27.25	54.76	165.61	22.04	7.87	15.37	3.78	101.67	358.79	56.21	229.67	8.03
3	A17173	468.24	31400	13.45	28.01	53.55	127.49	19.49	15.02	28.57	5.39	96.91	252.71	26.14	154.27	6.74
3	A46348	397.43	39488	17.16	13.03	20.25	85.48	17.34	11.87	8.44	5.94	99.80	72.15	34.88	199.83	7.42
4	A4348	1327.76	83504	38.68	41.85	55.69	120.88	20.53	10.31	15.25	0.20	20.63	287.30	30.87	158.18	2.98
4	A4374	1264.24	67286	30.42	15.37	47.80	108.78	21.81	30.28	38.04	3.23	63.49	334.34	37.41	255.41	4.75
4	A29378	1437.89	86525	39.96	45.91	70.70	1208.33	31.68	258.78	321.45	14.08	29.06	288.38	38.27	159.78	1.89
4	A33562	1191.75	67560	31.33	28.11	124.44	256.89	25.36	45.91	82.67	4.55	43.34	323.46	28.45	183.18	3.33
4	A17202	1659.61	89830	42.05	35.38	143.68	164.43	21.60	16.59	26.23	1.01	25.91	321.13	28.11	168.88	1.95
4	A46352	1789.78	105451	49.60	78.90	139.06	282.57	21.99	19.03	31.04	2.50	53.77	142.78	32.02	95.03	4.07
4	A65768	1361.16	83675	39.09	35.96	130.63	160.12	20.93	6.83	9.84	1.00	15.42	265.51	29.08	158.40	2.90
4	A28774	1186.63	71702	33.56	45.28	125.24	165.87	40.44	381.05	664.36	29.36	27.95	323.07	38.89	152.69	0.84
4	A33542	1074.92	65090	29.81	98.62	96.16	176.55	20.92	25.94	44.80	4.14	34.55	353.76	31.64	99.97	1.03

4	A33588	1370.90	76303	35.19	23.62	95.99	571.54	23.95	37.80	64.82	2.48	40.30	338.20	35.08	234.22	3.10
4	A33589	1341.77	82606	38.20	33.82	116.68	163.74	20.62	9.49	11.40	0.66	16.44	305.99	30.52	161.65	1.61
4	A36312	1240.56	78981	36.94	28.41	99.62	145.80	20.04	9.70	13.56	0.43	22.03	255.54	26.84	153.81	2.28
4	A45858	1154.67	66528	30.93	33.64	100.01	135.68	20.47	11.56	15.64	0.78	16.53	291.99	28.58	145.42	1.46
5	A30568	978.85	55895	25.50	50.06	25.99	88.96	18.44	6.07	10.47	2.40	24.52	331.67	18.11	97.33	0.51
5	A4375	1362.56	79228	37.97	96.31	100.40	747.43	22.56	16.58	25.49	0.51	51.97	146.76	23.56	46.66	0.45
5	A12161	956.43	60004	26.76	71.87	53.70	161.78	21.37	66.98	111.31	5.27	33.60	375.73	24.04	100.19	0.72
5	A17251	990.83	56873	25.60	44.08	78.26	155.57	19.01	14.74	24.87	2.72	37.10	302.93	20.24	94.05	0.00
5	A28955	798.63	48645	21.84	45.07	83.63	115.08	28.32	163.71	281.69	15.72	33.53	430.58	25.61	134.91	0.46
5	A33543	824.08	49289	21.77	35.84	100.50	146.87	19.67	15.46	29.28	4.65	39.20	444.08	21.23	139.52	0.70
5	A33544	732.76	46296	20.58	50.12	61.81	130.72	19.69	11.47	21.55	1.55	28.76	287.08	18.22	112.76	1.43
5	A33569	818.40	48087	21.34	47.47	72.59	120.87	20.54	10.53	17.31	1.92	33.96	341.44	19.04	113.97	0.46
5	A35374	1034.19	62835	28.54	87.89	111.04	127.58	19.46	8.61	14.34	1.35	32.57	305.33	17.30	90.99	0.16
5	A36318	1255.00	68470	31.65	126.68	154.19	192.62	21.47	37.40	59.61	1.47	48.51	164.53	25.92	29.17	0.00
5	A33547	961.37	58595	26.24	79.49	92.87	119.31	20.77	11.42	14.55	1.77	38.23	332.06	20.08	125.40	1.56
5	A17194	1140.11	65392	29.91	96.22	98.47	159.43	19.37	14.12	22.85	2.06	31.23	315.03	17.62	102.42	0.11
5	A45856	873.13	51893	23.38	58.33	74.58	103.43	18.15	4.29	7.85	1.91	23.54	352.34	15.48	87.35	0.00
5	A17254	994.06	56432	25.56	87.31	61.87	115.67	18.26	9.84	15.27	1.90	44.51	284.64	21.77	97.07	0.25
5	A20546	872.34	50949	22.78	48.40	70.56	103.15	19.09	5.48	9.84	4.37	58.94	343.92	23.77	128.24	0.86
5	A28771	1193.93	107211	50.54	71.28	101.98	201.10	21.32	40.40	45.86	4.09	30.21	379.83	19.37	98.83	0.20
5	A33539	1096.20	65817	30.45	103.11	73.58	144.72	19.44	15.72	27.04	3.51	34.74	319.06	18.02	104.28	0.23
5	A33553	892.71	53315	24.51	54.30	77.76	111.45	18.84	6.97	10.73	1.09	31.01	284.48	18.98	85.71	0.00
5	A33568	1036.75	60731	27.67	86.67	82.18	172.31	20.73	22.37	38.08	4.02	36.11	417.93	21.41	128.79	0.63
5	A37119	808.72	48252	21.85	47.02	87.60	152.67	18.59	14.58	22.46	2.69	31.98	387.63	17.98	118.40	0.22
5	A56552	807.77	48876	22.65	36.31	144.14	141.09	25.69	146.03	263.61	13.43	34.99	309.07	21.30	90.71	0.63
5	A45859	868.29	53820	24.16	47.91	86.89	112.95	18.57	5.97	7.45	2.04	28.61	358.38	18.28	96.10	0.62
5	A9857	1131.92	65337	29.75	99.35	93.90	143.36	19.53	10.55	16.69	3.85	36.42	348.12	20.59	109.48	0.40
5	A55898	1075.69	55983	25.39	84.19	94.06	106.79	19.27	4.13	6.59	1.46	46.27	330.72	20.31	94.56	0.27
5	AUn2	915.81	55619	25.11	68.05	88.30	157.27	19.53	7.08	12.41	2.95	47.54	348.93	20.70	109.74	0.30

6	A28195	700.04	55388	25.14	43.14	34.85	128.68	22.60	14.99	31.52	10.22	263.76	68.44	58.62	95.16	12.56
6	A53700	505.42	43444	19.17	56.66	56.04	167.16	20.78	14.00	22.89	12.15	241.83	103.20	52.55	92.51	11.60
7	A21152	1497.72	99651	46.30	254.03	121.69	146.30	20.61	12.73	21.22	4.88	16.99	444.19	28.97	280.65	59.62
8	A51252	1813.91	92744	43.67	274.37	32.16	133.12	15.68	13.20	20.09	0.00	0.00	37.28	3.34	0.00	0.00
8	A30562	2117.17	115505	54.77	369.67	45.73	113.11	15.70	3.03	2.23	0.00	0.00	44.10	3.27	0.00	0.00
8	A30566	1312.14	72202	33.28	76.95	41.39	92.14	16.70	2.64	3.52	0.00	0.00	70.93	6.85	0.00	0.00
8	A4347	1775.36	101790	48.56	378.58	42.87	135.20	18.04	39.10	56.65	0.96	1.35	66.56	5.09	0.00	0.00
8	A1079	1858.15	99136	46.94	358.44	44.77	130.45	17.71	9.90	13.18	0.00	2.81	99.13	5.12	0.00	0.00
8	A565	2544.08	105250	49.56	347.13	40.89	134.03	16.88	25.10	39.90	0.57	0.00	71.31	4.47	0.00	0.00
8	A1080	2449.92	114366	54.58	466.46	44.17	125.53	17.01	9.95	15.34	0.00	1.62	108.87	3.66	0.00	0.00
8	A970	1307.58	97003	45.66	192.25	45.99	118.16	16.63	13.71	19.02	0.00	0.30	33.23	5.41	0.00	0.00
8	A4349	1993.89	92512	43.72	363.84	46.52	132.83	16.56	13.19	19.43	0.00	0.00	32.08	3.56	0.00	0.00
8	A9505	1937.83	95459	44.99	365.35	34.82	106.28	15.56	9.28	10.39	0.00	0.00	43.86	3.05	0.00	0.00
8	A7014	1791.55	94453	44.74	388.10	47.13	229.57	15.50	10.36	14.06	0.00	0.00	76.71	2.85	0.00	0.00
8	A29380	1621.83	90831	42.31	161.22	66.20	110.89	17.88	7.14	5.35	0.00	0.00	113.92	9.12	0.00	0.00
8	A29889	1823.72	110717	52.26	315.24	130.66	167.75	16.98	20.86	30.07	0.00	0.00	86.68	3.79	0.00	0.00
8	A28956	2088.26	115766	54.80	356.39	65.68	132.56	17.07	22.44	37.35	0.21	0.36	72.92	4.80	0.00	0.00
8	A29933	1881.90	97191	46.54	421.95	72.31	184.26	15.85	4.57	4.21	0.00	0.00	47.30	3.44	0.00	0.00
8	A16606	2023.87	125687	60.30	344.92	63.69	225.37	16.64	10.27	12.60	0.00	3.58	36.60	5.77	0.00	0.00
8	A17215	1681.51	92942	43.88	240.53	71.50	143.31	17.34	20.41	30.50	0.39	0.17	46.74	4.61	0.00	0.00
8	A17222	2123.15	101835	48.86	486.98	70.55	134.78	16.85	10.13	13.04	0.00	0.00	76.12	3.17	0.00	0.00
8	A17228	2101.71	108947	51.81	355.28	72.66	144.60	15.64	10.24	16.16	0.03	0.00	96.94	3.35	0.00	0.00
8	A17229	1948.78	107520	50.71	253.82	66.50	174.05	19.83	72.61	117.57	3.22	0.48	71.76	6.42	0.00	0.00
8	A17246	1883.42	107583	51.30	549.17	69.72	140.97	16.28	8.45	11.88	0.00	0.00	39.43	3.09	0.00	0.00
8	A20543	789.59	39836	17.77	155.81	36.62	157.56	17.16	5.55	5.66	0.00	0.00	64.55	3.52	0.00	0.00
8	A21148	1867.78	116791	56.03	314.72	61.20	143.05	15.53	4.14	3.95	0.00	0.00	57.88	4.78	0.00	0.00
8	A21153	1631.03	83009	38.72	339.65	57.63	115.31	15.69	5.33	7.04	0.00	0.00	121.44	4.25	0.00	0.00
8	A21419	2314.77	105280	49.91	313.48	113.57	144.24	16.60	20.89	27.89	0.07	0.00	43.03	4.79	0.00	0.00
8	A28743	2263.45	115218	54.31	303.57	96.15	149.71	17.96	25.76	38.24	0.56	1.77	54.44	4.52	0.00	0.00

8	A28772	1278.54	59187	27.24	56.66	84.50	108.42	17.90	5.90	10.65	0.00	1.89	184.30	7.90	13.17	0.00
8	A31265	2237.71	99656	47.63	261.55	100.87	176.97	17.42	23.86	36.50	0.52	0.00	85.97	4.81	0.00	0.00
8	A45626	1942.25	114087	54.84	336.63	118.38	165.89	16.47	6.16	9.17	0.00	0.00	47.28	5.15	0.00	0.00
8	A33561	1242.59	65446	29.92	337.64	99.78	129.47	16.91	6.95	8.71	0.00	1.12	131.50	7.50	19.69	0.00
8	A33568	2404.86	161736	77.65	364.90	136.22	152.09	17.36	7.85	8.98	0.08	0.00	91.68	3.80	0.00	0.00
8	A33586	1954.51	111152	52.93	388.52	108.88	138.92	15.50	5.52	6.01	0.00	6.19	64.45	4.48	0.00	0.00
8	A33587	2208.44	108429	51.49	408.56	86.80	149.82	16.08	9.99	15.98	0.00	0.00	43.21	3.86	0.00	0.00
8	A36317	1874.37	98600	46.67	375.63	117.62	151.48	16.05	9.11	12.91	0.00	0.16	40.49	3.88	0.00	0.00
8	A36921	2093.91	119488	57.67	348.03	141.55	395.17	19.14	43.12	66.56	1.68	0.00	50.58	5.17	0.00	0.00
8	A17192	889.15	45328	20.29	97.28	89.98	222.67	18.24	13.01	16.62	0.00	2.51	70.48	4.45	0.00	0.00
8	A17195	2133.18	117082	54.73	285.25	126.99	189.40	18.08	16.52	24.77	0.00	1.17	63.56	5.12	0.00	0.00
8	A17196	2373.79	156112	74.02	339.14	143.09	194.28	17.18	13.78	21.97	0.00	0.00	31.62	4.50	0.00	0.00
8	A17197	1931.79	120139	56.57	348.80	103.82	155.49	17.35	9.79	15.22	0.00	0.00	43.36	3.89	0.00	0.00
8	A17170	1527.31	80951	37.83	278.80	96.07	196.98	17.17	12.58	17.78	0.00	0.00	68.93	4.11	0.00	0.00
8	A17185	1910.49	110082	51.82	217.32	125.25	214.55	17.62	9.06	14.06	0.00	0.00	59.56	3.92	0.00	0.00
8	A17186	1996.29	110349	51.91	277.50	115.33	156.52	16.50	6.33	8.19	0.26	0.00	59.57	3.47	0.00	0.00
8	A46357	1707.03	103809	49.33	323.30	108.04	220.43	17.96	32.14	49.67	0.54	6.14	40.10	5.59	0.00	0.00
8	A46358	1982.71	96166	45.17	336.62	113.30	257.90	16.15	19.15	17.32	0.00	0.00	47.41	3.48	0.00	0.00
8	A46969	1807.08	85051	39.66	380.27	107.23	162.94	16.28	12.48	16.00	0.00	0.10	176.86	3.99	0.00	0.00
8	A17179	1838.46	100307	47.79	260.01	129.53	321.67	17.53	12.37	16.27	0.00	0.00	83.90	4.15	0.00	0.00
8	A12736	2225.55	115470	54.86	407.10	102.62	194.33	17.76	24.86	31.25	0.36	0.00	84.50	3.85	0.00	0.00
8	A16514	1727.10	83428	39.59	407.13	55.06	118.86	16.11	5.94	6.38	0.00	0.00	48.14	3.18	0.00	0.00
8	A12932	2020.62	110853	53.99	374.46	94.26	2962.90	21.73	8.05	10.47	0.00	1.87	73.53	3.80	0.00	0.00
8	A13105	1781.75	98432	47.28	352.66	77.57	380.55	18.46	53.44	92.15	1.73	0.00	85.90	5.13	0.00	0.00
8	A15606	2067.52	107984	51.11	396.39	68.43	155.59	16.73	24.93	36.38	0.22	0.00	55.11	4.14	0.00	0.00
8	A17244	2113.33	110469	52.07	321.85	61.06	175.35	17.36	24.69	44.55	0.00	0.00	65.70	4.32	0.00	0.00
8	A21146	2136.70	111081	51.01	383.51	83.38	377.60	18.04	13.79	22.53	0.00	1.60	149.39	5.53	0.11	0.00
8	A20547	1899.48	108744	51.86	377.45	57.84	120.91	15.18	4.19	3.33	0.00	0.14	40.41	3.12	0.00	0.00
8	A20544	2017.02	105168	50.16	378.93	85.27	152.66	15.28	7.48	9.06	0.00	0.00	70.12	3.12	0.00	0.00

8	A20545	1280.68	66373	30.92	105.58	40.09	109.60	15.49	2.96	3.84	0.00	0.00	103.27	4.12	0.00	0.00
8	A21154	1912.54	86169	40.95	205.23	71.59	125.04	16.24	9.73	12.77	0.00	0.00	109.40	3.90	0.00	0.00
8	A21155	2153.38	112296	53.55	298.97	91.17	232.59	18.76	53.09	86.18	2.88	0.92	49.67	6.16	0.00	0.00
8	A28740	1021.99	51708	23.56	122.24	62.66	120.62	17.50	13.89	20.26	0.00	0.00	50.00	5.06	0.00	0.00
8	A28769	1391.23	72753	33.73	122.26	88.37	536.77	18.75	9.02	11.23	0.00	0.00	58.85	8.42	0.00	0.00
8	A28744	1961.18	112205	53.27	375.81	91.41	397.22	18.04	7.86	10.03	0.30	4.80	42.04	5.36	0.00	0.00
8	A32725	1789.49	108590	51.80	387.23	83.95	133.27	16.29	9.80	12.43	0.25	0.00	46.53	5.56	0.00	0.00
8	A43114	2458.82	136151	64.80	390.39	135.36	364.84	17.22	12.84	11.74	0.07	1.94	40.74	4.45	0.00	0.00
8	A43040	1353.95	69943	31.98	128.92	99.11	117.97	18.00	3.47	4.83	0.00	0.00	73.25	7.82	0.00	0.00
8	A33590	2052.60	103812	49.38	222.51	121.08	164.76	17.96	29.14	44.65	1.13	0.07	48.65	7.43	0.00	0.00
8	A33563	1508.12	80391	37.41	127.79	122.88	163.40	18.39	11.79	16.07	0.00	0.00	128.05	7.38	0.00	0.00
8	A35371	672.44	37673	16.50	125.64	54.25	96.29	16.62	5.76	6.56	0.00	0.00	65.23	3.56	0.00	0.00
8	A36315	1705.98	86710	40.87	358.11	83.26	166.19	17.28	24.93	38.71	0.32	0.00	69.20	4.45	0.00	0.00
8	A36319	216.87	18597	7.11	0.02	19.04	63.30	13.92	1.03	0.48	0.00	0.00	145.60	2.82	0.00	0.00
8	A37390	2041.78	112800	53.71	367.62	146.05	406.79	17.31	10.76	14.96	0.00	1.75	55.24	3.83	0.00	0.00
8	A17213	2105.04	116330	55.43	408.22	112.05	163.82	17.28	16.00	24.25	0.00	0.72	53.85	4.28	0.00	0.00
8	A60345	2042.58	96981	46.20	444.23	136.18	141.77	15.72	5.10	6.33	0.00	0.00	54.06	3.01	0.00	0.00
8	A16648	2364.57	123336	58.67	449.03	129.31	141.16	16.11	4.98	7.17	0.13	4.69	109.25	4.15	0.00	0.00
8	A16004	1733.88	102680	48.70	458.33	89.52	131.20	15.51	7.62	9.19	0.00	0.00	39.90	3.04	0.00	0.00
8	A46351	1685.35	89626	42.33	234.35	102.16	201.50	22.53	128.01	209.51	7.46	0.00	50.84	8.99	0.00	0.00
8	A46358	1941.89	108138	51.22	381.47	111.89	320.95	20.95	110.64	174.82	5.19	0.92	61.94	6.28	0.00	0.00
8	A47506	1663.75	86897	41.71	386.46	111.57	176.73	17.17	34.12	55.68	0.12	0.00	43.57	4.04	0.00	0.00
8	A54268	1909.27	114449	54.86	351.57	124.23	180.73	16.87	23.84	36.84	0.03	0.00	55.57	5.08	0.00	0.00
8	A53628	2052.16	120789	57.66	254.44	112.09	173.64	17.10	14.72	13.58	0.00	3.18	41.36	4.10	0.00	0.00
8	A50527	1734.09	105064	50.69	479.76	88.16	110.59	15.87	3.15	4.32	0.00	0.00	36.26	3.74	0.00	0.00
8	A45882 or 45862	1879.79	101175	48.54	232.92	92.15	138.65	16.12	8.84	12.62	0.00	0.00	54.28	3.81	0.00	0.00
8	A45863	1779.55	101046	48.09	215.88	114.14	192.94	17.60	28.05	29.96	0.00	3.58	136.41	9.28	16.16	0.00
8	A45857	1803.73	83300	40.12	261.79	106.54	123.52	15.14	13.26	5.70	0.00	0.00	79.95	3.46	0.00	0.00

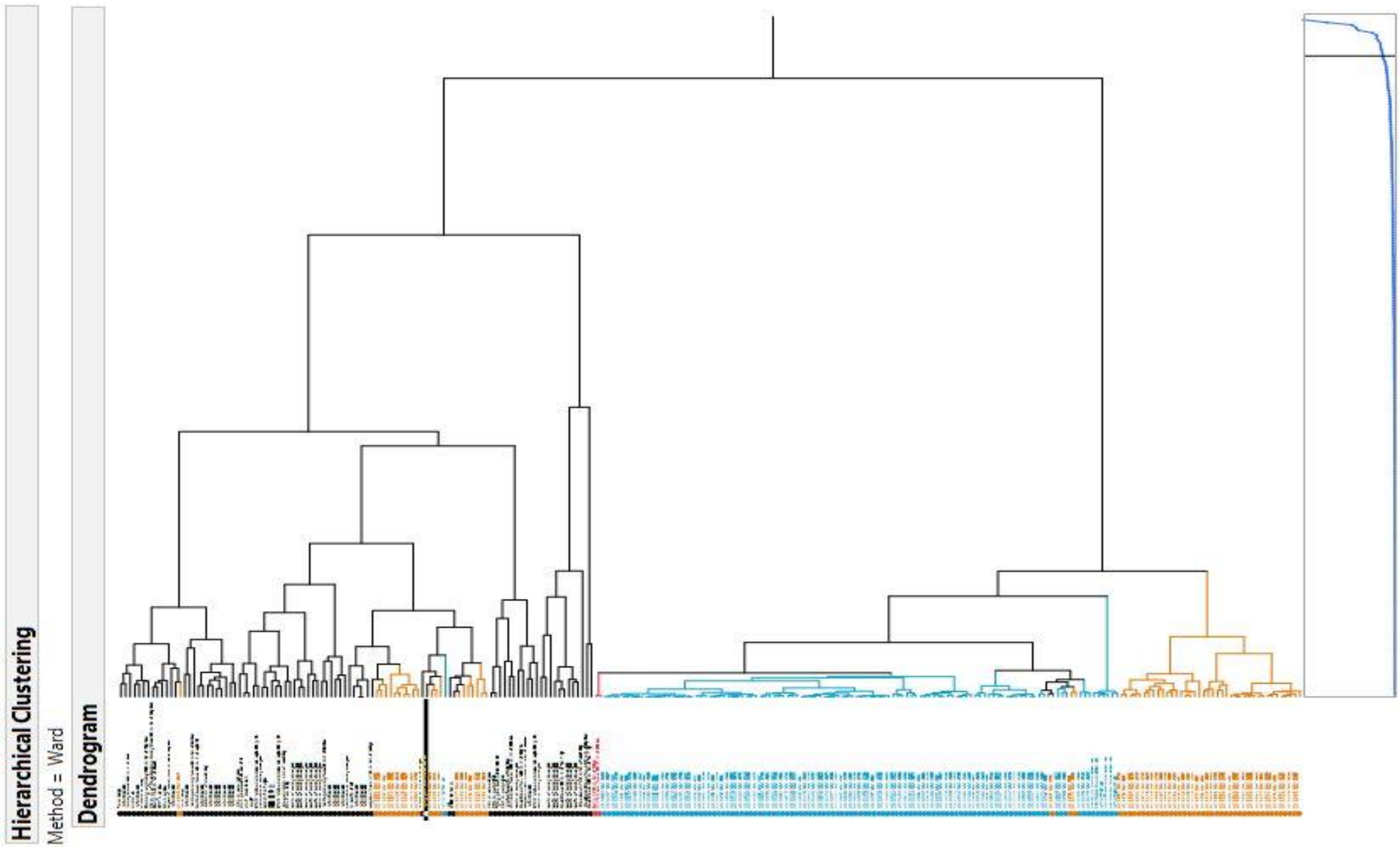
8	A45861 or 45851	1890.50	99845	47.19	393.79	87.86	161.99	16.31	14.42	18.67	0.00	1.47	48.51	4.43	0.00	0.00
8	A47567	1778.25	98753	46.97	394.78	101.41	158.20	15.84	11.25	14.15	0.00	0.47	45.92	3.69	0.00	0.00
8	A9506	2170.63	117962	56.83	304.55	122.84	376.96	16.87	8.65	13.55	0.03	0.26	44.29	4.46	0.00	0.00
8	A9861	2691.39	124808	59.79	311.78	122.21	1357.82	19.37	24.21	35.95	0.63	0.66	41.43	4.78	0.00	0.00
8	A37398	1853.78	95668	45.75	250.07	119.25	206.67	22.29	121.19	213.25	7.76	0.00	57.64	8.61	0.00	0.00
8	A4352	1793.13	85540	40.79	290.70	96.12	210.11	23.93	153.83	260.32	9.40	0.07	63.08	7.70	0.00	0.00
8	A36316	2182.05	115749	55.61	218.46	134.17	191.85	18.12	27.93	35.44	0.28	3.55	91.00	5.92	0.00	0.00
8	A21493	2196.35	103615	49.66	369.64	91.85	120.72	16.73	4.32	5.10	0.00	0.00	55.25	3.50	0.00	0.00
8	A17174	1968.63	116817	55.85	442.25	91.09	240.40	16.37	7.10	7.13	0.00	3.04	62.29	3.88	0.00	0.00
8	A21422	1600.54	86449	41.57	418.24	88.91	151.10	15.04	7.21	7.83	0.00	0.00	41.32	3.79	0.00	0.00
8	A36914	1885.03	103296	48.85	298.69	144.36	358.26	17.20	22.44	33.98	0.13	1.03	65.71	3.88	0.00	0.00
8	A29393	2589.18	103743	49.06	350.65	108.24	131.70	15.32	6.02	9.02	0.00	0.18	64.94	3.63	0.00	0.00
8	A17181	1959.62	109290	52.64	335.07	85.16	159.56	16.65	8.96	9.69	0.00	0.03	62.20	3.83	0.00	0.00
8	A17182	2162.94	111743	52.85	404.92	105.17	393.04	17.61	13.37	21.68	0.00	0.00	33.05	3.23	0.00	0.00
8	A30565	1269.88	67601	31.13	120.90	72.68	105.95	18.01	2.11	1.67	0.00	0.00	64.98	6.76	0.00	0.00
8	A9859	1216.97	73803	33.63	209.81	97.17	112.07	16.09	4.96	5.13	0.00	0.00	86.99	8.61	0.00	0.00
8	A9858	2434.37	136961	65.57	358.21	136.23	152.85	19.08	43.53	66.74	2.23	0.00	38.01	5.59	0.00	0.00
8	A9855	1931.88	106265	51.30	394.97	80.02	125.94	15.78	11.36	13.98	0.00	0.04	46.86	3.58	0.00	0.00
8	A9856	1570.65	87269	40.99	301.82	103.87	200.60	16.57	15.37	22.69	0.00	0.00	46.48	3.72	0.00	0.00
8	A9853	703.51	38220	16.91	105.72	73.65	119.55	17.87	35.16	33.38	0.55	0.00	54.39	4.05	0.00	0.00
8	A39674	1626.91	90085	42.03	141.72	116.43	129.12	18.20	4.38	3.45	0.00	0.00	60.96	7.53	0.00	0.00
8	AUn1	1551.12	90478	42.42	201.53	111.17	131.01	16.32	3.37	3.56	0.00	0.00	72.06	4.27	0.00	0.00
9	A31259	1701.66	76799	35.52	41.06	83.43	178.92	21.40	26.76	43.83	0.64	3.88	234.45	27.77	82.58	0.00
9	A21151	1681.82	96904	45.37	64.04	100.75	152.24	21.24	7.21	10.74	0.15	0.00	134.12	30.42	57.07	2.90
9	A36669	1326.55	74227	34.31	66.90	138.22	177.93	20.67	14.75	23.35	0.14	2.22	145.11	25.32	59.48	0.70
9	A17210	1819.26	110064	50.81	99.61	129.84	168.47	18.84	10.85	14.14	0.00	0.39	103.06	31.02	58.99	1.40
9	A55130	1508.71	91890	41.83	86.56	166.06	428.15	22.63	53.72	86.60	2.41	4.18	141.28	26.28	43.04	0.00
9	A17243	1297.80	75758	35.11	105.85	106.69	134.07	21.08	10.23	14.41	0.00	25.03	120.18	23.96	23.97	0.00
9	A17273	1732.05	99530	46.16	69.34	128.18	370.69	22.01	13.23	21.81	1.63	10.70	156.57	26.39	67.88	1.05

9	A21156	1539.01	85603	39.81	94.06	96.73	170.13	19.95	11.63	16.85	0.00	0.71	93.35	29.61	53.67	0.01
9	A28772	1464.12	82037	38.46	71.10	117.55	166.05	20.35	10.59	18.02	0.07	21.45	191.87	27.62	54.44	0.00
9	A31263	2314.94	155173	72.40	91.12	112.06	141.58	21.02	11.16	16.26	0.43	4.57	97.63	27.55	86.00	2.81
9	A33554	1845.38	110884	52.56	105.75	138.64	217.51	21.03	30.52	51.76	0.41	1.41	114.88	31.76	59.17	1.51
9	A41972	1119.59	64014	29.76	106.38	121.38	294.77	22.53	46.80	73.21	2.64	15.03	171.45	25.09	40.85	0.00
9	A46970	1382.13	81452	38.24	65.11	131.44	193.41	20.26	7.44	11.47	0.00	0.00	263.52	24.40	77.60	0.95
9	A45860	1345.88	74830	34.56	236.77	129.36	260.36	20.88	37.17	60.81	0.69	16.70	128.24	22.81	20.80	0.00
9	A17180	1345.01	72734	33.89	119.81	113.79	512.59	29.04	199.46	323.76	13.23	0.67	82.10	28.54	0.00	0.00
9	A9851	1456.41	79548	36.46	88.90	139.61	129.26	21.23	42.12	66.60	1.92	29.61	118.82	22.37	22.69	0.00
10	A31257	1012.46	55061	25.04	53.78	31.36	266.22	23.66	81.91	138.01	5.98	24.31	290.06	20.77	78.47	0.00
10	A27152	1241.88	69766	31.95	68.02	76.39	421.80	20.87	20.82	24.71	0.00	0.58	105.42	18.39	19.93	0.00
10	A30561	15527.05	128602	55.59	181.98	54.75	145.43	16.75	10.09	10.64	0.22	5.92	85.76	13.97	12.80	0.09
10	A4354	1117.86	87825	40.79	36.50	54.07	119.18	19.63	23.51	34.71	0.00	0.00	62.50	11.12	0.00	0.00
10	A4350	20105.92	148023	62.64	84.93	81.30	159.33	19.49	21.13	32.04	1.02	0.22	197.95	18.34	19.00	0.00
10	A4353	1052.12	65916	30.40	65.36	31.93	94.71	20.78	28.60	44.17	1.71	24.26	264.47	14.10	46.51	0.00
10	A29381	2514.07	124942	59.74	251.11	70.99	187.20	31.41	295.05	514.47	20.16	0.66	142.58	13.32	0.00	0.00
10	A29888	1690.80	97990	45.48	118.64	83.08	126.52	18.49	5.64	7.67	0.00	0.00	53.37	13.61	0.00	0.00
10	A29379	7863.10	95354	42.83	94.00	45.22	157.91	18.24	25.43	31.35	0.02	9.93	119.54	14.88	2.24	0.00
10	A29382	844.31	57609	26.15	46.80	21.54	370.01	20.83	40.02	64.72	3.37	6.70	353.31	12.26	83.81	0.00
10	A16605	1431.02	78637	36.30	77.14	58.43	133.60	19.53	21.54	33.75	0.87	4.44	274.95	13.10	24.31	0.00
10	A17219	1539.69	86297	40.61	92.36	115.76	152.91	17.67	14.75	21.28	0.19	0.00	92.23	11.01	0.00	0.00
10	A17230	1331.15	74308	34.04	94.00	128.36	247.32	21.07	17.70	27.20	0.00	3.29	111.88	19.57	14.48	0.00
10	A17253	763.39	48498	21.75	58.77	62.97	102.45	18.15	4.45	6.42	1.49	13.11	305.34	15.28	77.00	0.00
10	A21147	955.76	56278	25.34	58.68	65.32	368.23	19.67	5.29	9.01	0.37	17.18	372.04	11.72	57.31	0.00
10	A28192	1566.80	89434	42.01	105.85	106.35	170.13	18.73	13.89	20.86	0.00	0.00	57.95	12.12	0.00	0.00
10	A33541	1639.54	92813	43.76	105.63	130.47	147.93	18.16	12.31	20.58	0.00	0.00	56.87	10.73	0.00	0.00
10	A33545	2033.65	120274	56.75	129.16	133.25	164.39	19.40	25.22	44.96	0.55	0.00	43.79	12.51	0.00	0.00
10	A44222	829.85	50253	22.51	62.61	81.38	175.02	19.39	37.68	62.81	3.14	22.43	261.45	18.25	67.02	0.00
10	A35373	741.19	44314	19.56	47.79	68.75	102.67	18.61	6.16	10.50	0.93	17.13	286.41	15.25	100.40	0.32

10	A17193	691.54	41554	18.48	43.79	80.10	116.05	25.18	123.01	207.53	9.20	16.86	268.68	20.45	98.89	0.00
10	A17198	10102.13	105746	46.98	99.46	174.20	179.02	18.51	17.70	28.50	0.11	11.64	77.23	19.48	23.51	0.16
10	A17199	9799.32	119192	53.01	79.84	105.20	189.72	18.60	29.41	36.67	0.71	13.97	68.32	16.53	10.22	0.00
10	A17200	2498.74	135950	65.26	279.07	154.49	370.08	33.95	320.61	541.35	22.24	3.25	173.30	20.58	31.88	0.00
10	A17201	1238.50	70704	32.78	56.23	132.79	140.24	20.56	9.47	13.81	0.12	2.77	109.04	22.50	36.20	0.00
10	A17211	1481.03	82348	38.64	107.70	150.82	187.37	18.48	17.11	25.82	0.24	0.18	59.47	12.17	0.00	0.00
10	A16607	1647.30	88790	42.16	188.32	119.54	124.05	17.87	4.56	4.09	0.00	0.00	100.16	18.35	5.18	0.00
10	A17184	1788.31	101982	48.00	106.33	142.62	162.01	19.98	6.75	7.59	0.00	0.00	57.81	15.64	0.00	0.00
10	A46354	1057.75	59387	27.06	33.60	87.61	113.27	17.70	4.06	4.73	0.56	30.83	178.73	11.07	19.95	0.00
10	A27153	1686.87	86206	39.75	415.20	28.89	161.06	16.94	15.00	22.53	0.14	2.42	370.85	6.19	24.35	0.00
10	A28957	1615.49	90690	42.32	132.46	69.98	117.70	19.15	13.35	11.96	0.00	0.00	167.42	17.06	24.29	0.00
10	A13104	1291.69	72798	34.03	131.31	74.53	136.38	21.07	19.46	30.08	0.51	0.55	159.35	19.53	12.72	0.00
10	A12914	1362.81	72444	32.83	54.10	73.91	290.89	18.99	10.86	14.10	0.00	0.90	162.48	17.63	23.55	0.00
10	A13103	1640.80	93077	43.11	99.21	74.65	139.00	17.39	13.25	12.29	0.00	0.00	52.21	11.08	0.00	0.00
10	A17242	5794.23	84001	37.71	112.21	50.31	140.42	17.25	12.39	15.79	0.06	10.34	40.79	14.88	9.81	1.50
10	A21149	950.45	55833	25.32	55.38	51.41	157.01	19.06	5.93	11.32	0.59	14.73	284.09	15.19	77.51	0.09
10	A21560	1667.39	93235	43.46	122.29	103.86	124.69	17.81	5.80	6.80	0.00	0.00	73.93	16.92	0.00	0.00
10	A21420	1447.79	81245	38.21	94.00	131.17	146.05	19.15	41.64	62.32	1.34	0.00	68.51	15.41	0.00	0.00
10	A28856	2146.87	115252	54.59	250.41	116.88	221.60	22.97	113.98	177.35	5.65	0.40	136.97	11.11	12.45	0.00
10	A28952	1350.20	77517	36.46	94.44	108.27	156.85	22.09	55.64	95.71	2.10	0.18	116.03	21.61	27.13	0.00
10	A28953	891.45	52803	24.22	54.65	92.16	125.28	19.53	13.90	19.99	1.53	15.87	253.86	15.94	78.44	0.00
10	A28846	900.95	53175	24.17	53.80	53.44	91.52	15.97	3.22	4.36	0.00	7.46	182.96	10.12	33.88	0.00
10	A31264	1790.30	102155	47.90	116.65	103.93	406.07	25.36	134.90	214.33	7.83	0.00	60.81	15.58	0.00	0.00
10	A31261	1276.11	71722	33.11	28.73	80.13	190.06	22.43	71.02	113.57	1.45	4.16	140.63	18.48	4.60	0.00
10	A33540	1272.30	71123	33.40	67.16	63.20	174.29	18.25	17.82	23.24	0.00	21.12	169.25	11.18	22.43	0.00
10	A41971	1632.39	89209	41.85	164.81	170.25	325.57	31.73	228.40	372.85	14.59	0.03	105.96	24.03	15.81	0.00
10	A26314	1810.75	105311	50.00	132.35	133.68	150.11	19.13	6.94	7.91	0.00	0.00	49.35	12.70	0.00	0.00
10	A35379	1269.17	74112	34.38	105.49	107.82	145.84	20.16	11.64	18.01	0.00	3.69	129.49	21.50	23.15	0.00
10	A36313	2030.74	113965	53.75	145.35	123.21	150.59	19.84	8.79	11.29	0.14	0.68	58.91	13.76	0.00	0.00

10	A17183	1845.33	99422	46.70	334.66	113.66	151.53	16.41	15.96	16.39	0.00	1.85	280.55	4.35	4.60	0.00
10	A16003	1220.01	69446	31.89	79.96	119.57	135.46	20.05	5.58	10.32	0.00	6.99	135.99	21.44	30.18	0.00
10	A52893	1007.25	57178	26.08	186.90	117.38	144.58	20.01	49.92	74.52	3.03	11.73	232.86	13.97	39.54	0.00
10	A56149	1793.63	89473	41.88	308.33	128.96	280.90	17.87	44.91	39.30	1.43	0.59	257.25	4.90	5.28	0.00
10	A46347	718.33	46168	20.75	54.55	63.86	96.68	18.04	4.25	5.54	0.32	16.43	254.20	14.58	83.73	0.16
10	A9862	1340.53	75499	34.57	74.51	100.23	128.70	21.26	70.40	99.74	2.79	11.11	324.52	13.36	27.21	0.00
10	A9854	1284.02	70567	32.83	113.65	110.36	145.29	20.21	18.00	25.84	0.37	3.86	213.73	21.20	50.01	0.18
10	A9852	1299.43	75787	34.78	91.58	103.23	147.09	20.01	35.36	44.56	0.67	0.70	121.91	18.30	19.38	0.00
10	A17221	1467.64	82371	39.36	110.17	154.69	3728.32	30.42	106.20	170.50	6.04	1.77	90.35	14.94	0.69	0.00
10	A21494	1387.49	75935	35.25	164.05	127.66	135.21	17.73	10.28	12.57	0.00	0.17	109.45	17.48	7.51	0.00
10	A53686	1583.25	96527	45.25	137.82	109.54	193.94	18.63	5.67	7.23	0.00	0.00	48.62	10.40	0.00	0.00
10	A17171	1401.14	73310	34.34	143.51	88.47	123.51	18.66	6.13	9.53	0.46	16.51	186.42	10.35	23.14	0.00
10	A17172	1561.66	88147	41.43	199.71	134.68	160.62	19.46	9.50	14.11	0.00	0.45	105.57	19.52	0.99	0.00
10	A4376	1604.14	95070	45.35	126.04	121.37	994.45	27.26	146.87	240.21	9.11	1.49	53.92	15.02	0.00	0.00
10	A30521	5927.12	76651	34.30	98.32	73.74	161.58	16.88	8.73	11.29	0.00	9.11	81.56	12.05	1.02	0.00

Appendix E Hierarchical Cluster diagram of SESA Clusters 8 (blue) and 10 (orange) and Victorian Geological Survey material (black). There is a small overlap of sources with hatchets, but these results are suggestive and should not be accepted as proved.


Hierarchical Clustering
Method = Ward
Dendrogram