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STUDY OF NEOLITHIC AND BRONZE AGE MONUMENTS IN WESTERN SCOTLAND

A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY AT THE UNIVERSITY OF ADELAIDE

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Abstract

The aim of this work is to contribute to the quantitative analysis and development of testable hypotheses concerning archaeological sites in the landscape.[1] The initial intention was to ensure that valid and reliable outcomes regarding the original use of the freestanding megalithic monuments of western Scotland were possible through its use of appropriate spatial and statistical analyses. Whilst this objective remains, it is no longer the sole objective. Rather, more complex theories regarding the nature of the cosmology of those who built the monuments and the possible cosmological connections between them, other monuments and the environment are considered. Based upon the methodologies and outcomes of the initial investigations, further development of sound hypotheses and robust experimental designs that could be used in conjunction with GIS data and applications was then possible for those more complex considerations.

This project attempts to incorporate systematic project design and quantitative analysis in archaeological investigations.

Keywords: landscape archaeology, archaeoastronomy, cosmology, methodology, GIS, viewshed, orientation, spatial analysis, visibility, directionality, Scotland, megaliths, Bronze Age, Neolithic Age.

[1] Fisher, P., Farrely, C., Maddocks, A. & Ruggles, C. (1997). "Spatial analysis of visible areas from Bronze Age cairns of Mull." *Journal of Archaeological Science*, 24: 581.

STATEMENT OF ORIGINALITY

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, it contains no material previously published or written by another student person, except where due reference is made in the text of the thesis.

I consent to this thesis being made available for photocopying and loan if accepted for the award of the degree.

Signed:

Date: 16/12/03

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SECTION ONE

Background

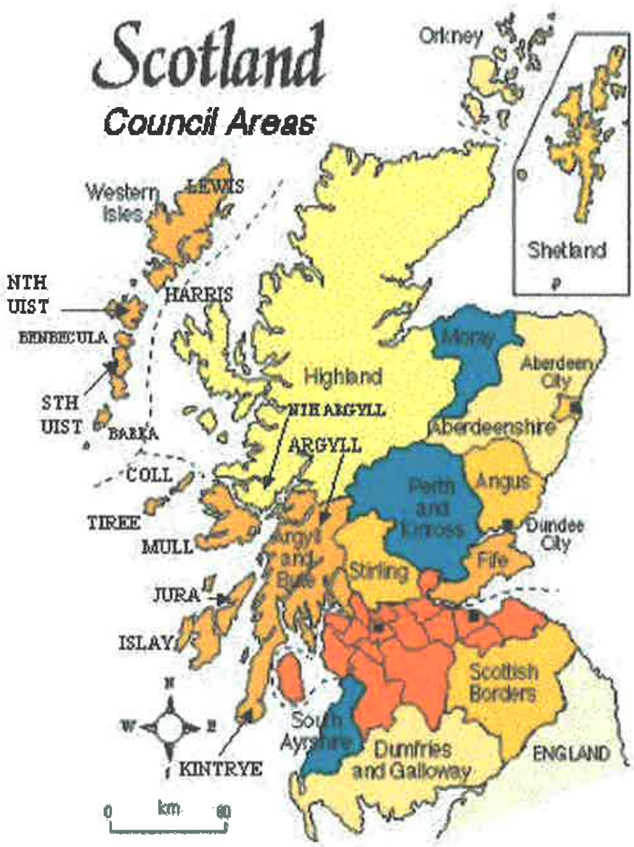

Figure 1: Scotland – Research areas designated by capitals. (Map adapted from http://www.geo.ed.ac.uk/scotgaz/scotland.imagemap)

Chapter 1

Advancing methodological approaches for the study of Neolithic and Bronze Age belief systems

Ultimately, this study investigates the cosmology of the megalith builders of western Scotland (see Figure 1 – map of Scotland). It was decided that an investigation into territory that had previously been studied, geographically and thematically speaking, was the most sensible approach to begin with. However, it was also recognised that new methodologies were required to advance research into prehistoric societies, and archaeoastronomy, in particular. What had appeared as a single *télos* of the study became twin *téloi*: desire for the revelation of reliable conclusions through the development of sound methodological practices.

Notions of improvement and ideas for profitable approaches

In critiques of archaeology and archaeoastronomy there have been pleas to take into account more than one method of analysis. Ruggles points out that:

> studies of … properties of ... different locations within the landscape, taking account of esoteric factors such as visibility and astronomical potential, integrated with excavation and environmental studies, enable us to identify and investigate complex relationships between places in the landscape and ... natural features visible from those places, or motions of celestial bodies visible from them[1]

In addition, he highlights the advantages of focusing upon the middle ground in reference to the study area's size and focus. Too small and you may miss a cultural trend, too big and you miss the sub-cultural differences.[2] Barclay's *Between Orkney and Wessex: the search for the Neolithics of Britain* (2000), as

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1 Ruggles, C., 1999, Astronomy in Prehistoric Britain and Ireland, Yale University Press, London 124.

[2] Ruggles, C., 1999, *Ibid.* Larger studies are usually those that try to incorporate zones, such as Western Europe or perhaps even an entire country. Smaller studies are thought of as those investigating anything from a single monument to, perhaps to a group of monuments like those to be found about Callanish in Lewis.

well as this recent work of Ruggles', concentrate on the notion of multi-faceted, regionally based investigations and emphasise the benefits of such approaches.

This desire to see multi-faceted research pursued can also be found in landscape archaeology. Wheatley and Gillings entitle their concluding paragraphs of "Seeing is not believing: unresolved issues in archaeological visibility analysis" as "The need for enriched approaches to visibility".[3] Basically they call for an elaboration of existing techniques and a working "towards the development of new approaches". Specifically, "seeking to bridge the gap between the quantitative approach of the GIS and more qualitative fields". Their heading and the notion of bridging the gap implies that a single method is no longer considered enough to provide a close understanding of the actualities that we, as researchers, are trying to discover. A list of creative and useful alternatives in relation to GIS that could add depth to the outcomes, and therefore a sense of richness and greater completeness to the conclusions, follow these points and are discussed in Chapter 4 of this thesis.

Bradley's work, *The Significance of Monuments*, revealed that monuments are often neglected in answering the larger questions in prehistory, and that it is these that should be studied for the light they may shed upon these broader topics. Endeavouring to avoid the superficial or the narrow, Bradley advises focusing upon the issues *within* these larger questions and to use unambiguous evidence pertaining to the period studied, namely the "monuments themselves".[4] As for Bradley's work, it is of theoretical, and therefore methodological, relevance to uphold that these monuments "are not by-products of *more* important processes" but may reflect processes that we might not otherwise be able to discover without them: it is worth studying their significance in their own right.[5] Though he was strictly discussing debates on the order of the appearance of monuments and farming, this *directional advice* regarding the study of issues in prehistory is quite applicable to the area of cosmology. For rather than asking the larger and more difficult question of why or how cosmological beliefs evolved we might be able address simpler but still enlightening questions as to the *nature* of the Neolithic and Bronze Age peoples' beliefs.

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[3] Mark Gillings and David Wheatley, "Seeing is not believing: unresolved issues in archaeological visibility analysis" In: B. Slapsak (ed.), *On the good use of GIS in Ancient Landscape Studies*. Ljubljana, in press

[4] Richard Bradley, 1998, *The Significance of Monuments: on the shaping of human experience in Neolithic and Bronze Age Europe*, Routledge, London. 14.

[5] Richard Bradley, 1998, *Ibid.*, Own emphases.

Current project

This project uses environmental information, in the form of local astronomical phenomena, and the location and plan of 115 sites to investigate monuments' positioning, distribution and *setting* in relation to the phenomena.[6] Doing so allows this project to address the questions: "what do we know about the role of the monuments in their own right?" and "why were they built in the first place?"[7] By approaching the study in this manner it might also be possible to fathom: "how did their presence in the landscape influence the experience of people?"[8] In this way this project addresses a lack seen in the larger issues of research archaeology across the British Isles and Europe. The project looks to understand what was important to the builders of the monuments and how is this manifested.

To discover a more holistic picture of the cosmology of western Scotland, the combination of traditional archaeological data of all identifiable Neolithic and Bronze Age monuments in the region along with geographical information were also used. These monuments location in relation to the original study group of freestanding megaliths was assessed. Thus it also became possible to at least consider the question: is it possible that these other Neolithic and Bronze Age monuments, along with the *intervening* geographical places, could be linked to the *same* systems, or might they indicate, represent and/or be part of a differing cosmological belief? Were *any of these* special within themselves?

This study began by reassessing the orientation of freestanding stone monuments and their possible associations with astronomical phenomena, Phase1 and Phase2, respectively, of the project.[9] To investigate the former, information regarding the monuments themselves was acquired from Ruggles 1984 study on *Megalithic Astronomy: a new archaeological and statistical study of 300 western Scottish sites.* For the latter, the environment, in the form of topographical information and details of astronomical phenomena, were used in conjunction with specific monument details. More specifically, the topographical information used was that of horizon shape and distance extracted from digital elevation data. For the astronomical side, the paths taken by the sun and the moon coursing across the skies were used to locate their relative positions upon the horizons. Information regarding the orientation and location of the monuments as well as horizon elevation in the direction of the orientation of the monuments was collated or calculated by Ruggles to create a catalogue of positions at that point on the

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[6] Using the word site here as defined by Ruggles. See Chapter 2, "Codes of practice for data selection", for details.

[7] Colin Richards (1993), "Monumental Choreography: architecture and spatial representation in Late Neolithic Orkney" in Tilley's *Interpretative Archaeology*, 143-180

[8] Richard Bradley, 1998, *Ibid.*

[9] Originally assessed by Ruggles and contributors in 1984.

horizon that the monuments appeared to be indicating. These positions were used in the current study to be compared with the known paths of the sun and the moon to see if it was likely that the points coincided at the horizon. This would reveal evidence for or against interest in astronomical phenomena.

The difference between this work and those that have gone before is that now the entire horizon profile of every 125 unique siting positions can be taken into account to generate random landscape data for comparing with the observed data for a more rigorous and thorough-going analysis of individual regions.[10] Whilst investigating the possible interest of the megalith builders in astronomical phenomena it became evident that a much more complex set of behaviours (deliberate or not) might be revealed. If discovered, these could provide a deeper understanding of the cosmological issues at stake for the builders, and perhaps even those who came before and were to come afterwards. From the beginning, the project was based upon conventional scientific methods with the belief that with proper project design, and the asking of appropriate questions, one can only enhance one's knowledge of the societies one is trying to understand. It is not necessary, then, to fall prey to "missing the humanity …of the times and the places in the past"[11] by applying the experimental approach.

The experimental design for the expanded study, called Phase 3, relied upon the outcomes of the first two phases of the project. Due to their nature, they provided us with valid hypotheses to be tested, and directed the project towards appropriate methodologies to test them with. These later methodologies, as well as those found within the first two phases of this study, are based upon *considerations* current within archaeoastronomy, landscape archaeology and the application of GIS. More specifically, phase three of the study is dependent upon the use or modification of GIS software (GRASS[12] and ARCINFO[13]), primarily those involving viewshed procedures. It was the intention of Phase 3 to further discover the nature of the cosmology of the builders of the freestanding stone monuments of western Scotland. Additional topographic information for the entire land surrounding each monument was considered as well as a stringently acquired list of all Neolithic and Bronze Age monuments (Group 2 sites) located between each original Ruggles site (Group1 sites) and its accompanying horizon. In this way it was hoped to gain some understanding of the reasons for erecting monuments across the landscape. These reasons are considered at two levels: what variables did they consider for the placement of the monuments and why might these variables have been important to these people?

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[10] Though there are 115 sites there are more than 115 monuments or positions for taking orientation measurements. Explanations appear in Chapter 2.

[11] Edmonds, M B, 1999, *Ancestral Geographies of the Neolithic.* Preface.

[12] See http://www.baylor.edu/grass/ for information regarding this free GIS software.

[13] See http://www.esri.com/software/arcinfo/ for details about this GIS software.

Belief systems

Overview

The debates and developments in archaeoastronomy in the last 30 years have somewhat mirrored those of archaeology. Whilst there has been a noticeably continued emphasis upon the methodologies of processual archaeology in some circles, the most recent challenges, as we saw above, have been the desire for studies to take into account pieces of methodologies and theories that might once have been seen to be competing for attention. One of these is the call for studies that can incorporate the cognitive-processual methodological approaches without necessarily favouring the post-processual idea of the focus upon the individual; rather the 'group' can once more be the focus. These interpretations link symbolic concepts, beliefs, human action and material culture. It is assumed that by studying material culture we can come to know the belief systems of a group, or groups, of people. The connection between them is that symbolic concepts are seen as representative constructs of a belief system. This belief system, in turn, guides, or influences, human action and thought and these are seen to be expressed by material culture.

The current project adheres to the possible interpretative and philosophical connection of material culture and belief systems and it is through the study of the former that it hopes to come to know the latter. It takes up the challenge to incorporate a variety of approaches that have arisen within a variety of traditions yet have shown themselves to be compatible and knowledge enriching. This project is not a theoretical one, however, but a methodological one. So whilst Chapter 2 briefly discusses the background of the theoretical debates that prefaced the move for some towards cognitive-archaeology and discusses in particular the relation of material culture to belief systems and from thence to cosmology, it is the aim of this investigation to review and apply methodological approaches from the areas of archaeoastronomy and landscape archaeology, found in Chapters 4 and 5, respectively. The detailed methodologies of project design and application unfold as reading of the project progresses. These are to be found in Chapters 6, 8 and 10.

It is the prime intention of this project to create a sound investigation into the cosmological belief systems of the builders of the freestanding megalithic monuments in western Scotland, as well as the possible connections of these belief systems to those who came before and after. To begin this task Chapter 3 examines in detail how the Mesolithic, Neolithic and Bronze Age landscapes and lifestyles differed from, or were similar to, each other, as well as looking *within* these broader age range definitions. In particular, Chapter 3 also looks at the appearance of monument forms during these periods and examines how Early and Later Neolithic and Bronze Age monuments were incorporated into the landscapes that followed their creation. The outcomes of the project will shed further light on these processes.

Whilst the project takes into account the importance of interpretative approaches for the generation of general hypotheses and ideas, it holds that testable hypotheses must be extracted from these for the production of sound conclusions. Such sound conclusions, having been firmly verified, can be explored in a more interpretive manner, in order to extrapolate helpful and meaningful ideas as to the nature of the Neolithic and Bronze Age culture, as done in the final chapter of this work.

Chapter 2

The Neolithic and Bronze Age in northwest Scotland

Contentious categories

What does it mean to be a person of the Neolithic, and how does this differ from a life lived in the Bronze Age? What was it about the Neolithic, or NEW-stone Age, that made it acceptable to separate it from the previous period, the Mesolithic?

There have been a variety of typologies or definitions for each label but the dominant two can be said to focus upon the technology and economy of the peoples. Both of these could be more correctly described as major innovations in technological 'production'. The Mesolithic was seen as the period witnessing the rise in predominance of microliths, whilst the Neolithic was distinguished "from its predecessors by the appearance of ground and polished tools".[1] The Bronze Age is recognised as the time when people began to produce and/or use bronze and copper.[2]

In some ways, by looking at economy along with technology, a useful thread was added to understanding lifestyle itself, or indeed, lifestyle management. The Mesolithic was traditionally seen to be a time when people gathered and/or hunted wild resources. The Neolithic economy has customarily been seen to be, as Adkins and Adkins so aptly put, "almost by definition ... based on agriculture".[3] The Neolithic has also been seen to differ from the Mesolithic by its knowledge, production and/or use of ceramics.[4] As will become apparent below, it "is very doubtful whether we can meaningfully separate the Neolithic period from the preceding Mesolithic by such criteria",[5] or the Neolithic from the Bronze Age for that matter.

Traditional assertions or contentious evidence

Identifying those who were and were not "farmers" became a goal for archaeologists, for this would enable the determination of which groups of people (Mesolithic or Neolithic) had created the sites

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[1] C. Renfrew and P. Bahn, 1991, *Archaeology. Theories, Methods and Practice*, 543. A. Whittle, 1999, *Europe in the Neolithic: creation of new worlds*, 5.

[2] L. and R. Adkins, 1998, *The Handbook of British Archaeology*.

[3] *Ibid*, 27.

[4] A. Richmond, 1999, *Preferred Economies: the nature of the subsistence base throughout mainland Britain during prehistory*, BAR, British Series **290,** 10.

[5] *Ibid., 5.*

found. Along with this, choosing and/or accepting the right indicators of "farming" behaviour were seen to be necessary. So, what might it tell us if people "farmed"? The theories came pouring in. Clearances were seen as a possibility, for people who grew grain or looked after cattle needed open country. Permanent housing too would be an indicator, as people needed to look after and protect crops, and if they invested in an area via clearance, they must also desire to stay there, for example the occurrence of grain would tell us if people grew it. Though not fully adhered to now, it was thought that agriculture was seen as an evolutionary form of development, and therefore along with linear progression models a sign of progress and improvement for human kind, a sign of civilisation making its way forward. It was also hypothesised that this new sedentary/agricultural lifestyle gave people the opportunity to create monumental structures (megalithic and non-megalithic forms)[6] and invest time in inventing and creating other material objects, like pottery. The Neolithic then became a "Period Package" (similar to the Mesolithic and Bronze Ages), with distinctive assemblages and behaviours with "the adoption of a single package of pottery, stone axes, monumental architecture and farming practices".[7] Other points of this package focused upon social structure and population. In relation to population, Whittle's *Europe in the Neolithic* points out that most population models held that, on becoming farmers, people were "blessed not only with an adaptable and productive subsistence base but with the powers of rapid breeding as well".[8]

Bronze Age "equipage", by the nature of its striking change in assemblage, was certainly a clearer marker by which to divide technological change, and perhaps by association lifestyle change, from those who peopled the Neolithic. The Bronze Age package, along with the introduction of metals, saw changes in monumental structures (preference for stone rows and an increase in stone circles and standing stones), burial practices (cremation, cists and increase in single inhumation) and introduction of pottery styles (Beaker form). These technological and social changes were often seen to come from elsewhere, like those of the Neolithic, rather than being primarily local developments. These products too then, came to be the markers dividing the Neolithic from the Bronze Age.

Evidential contentions or evidence of contention

Overview

In Richmond's interesting work on *the nature of the subsistence base throughout mainland Britain during prehistory*, which incorporates his close discussion of indicators for arable farming, as well as

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[6] For instance, causeway camps, chambered tombs, long barrows /cairns, timber circles, henges, stone circles, standing stones.

[7] S. Mithen, 2000, *Hunter-gatherer landscape archaeology: the Southern Hebrides Mesolithic Project.* **Vol 1**, *31*. See also A. Whittle, 1996, *Europe in the Neolithic: the creations of new worlds,* 6.

[8] A. Whittle, 1996, *Ibid.* 6-7

those for permanent settlement, he expands the notions, *the evidence* and the conclusions arising from Hunt's 1987 work, which deduced

> (w)ith the recognition of the sophistication of Mesolithic economic strategies and the evidence for the continued importance of hunter-gatherer activities in subsequent periods, the *distinction between the two economies (Mesolithic and Neolithic) no longer appears as clear cut as it once did.*[9]

By the late 1980's "it was recognised that there were multiple and varied trajectories from the Mesolithic to the Neolithic" and it has since been recognised that there is an *overlap* "in temporal terms of Neolithic and Mesolithic evidence". [10, 11] More importantly, we are now clearly seeing "features which have in the past been viewed as components of the 'Neolithic package' ... being recognised in secure Mesolithic contexts."[12] Further, Richmond's work has shown that the trajectories from Mesolithic to Neolithic ranging "from colonization by incoming farmers, to the seepage of Neolithic material culture into Mesolithic communities (were) only followed at a much later date by economic change".[13] This means that even Zvelebil's idea and Hunt's evidential conclusions - the economy of early Neolithic Britain involved a substantial amount of hunting and gathering - may not be radical enough.[14] It now appears with Richmond's work, that what was once thought to be the innovation and establishment of the Neolithic agriculture and permanent settlement is now seen to be the realm of the Bronze Age. In addition, palynological evidence reveals that it is not until 2600 to 2500 B.C., in western Scotland at least, that synchronous forest clearance occurs at most sites, and not until c. 2000 B.C. to 1800 B.C. that a synchronicity appears in the intensification of existing agricultural behaviour across Scotland.[15]

The evidence

Traditionally the Late Mesolithic has been viewed as a period dependent upon hunting and gathering, however there is now evidence for woodland clearance and the inclusion of pastoral economics within otherwise Mesolithic contexts .[16] Indeed the polished stone axe, long a type fossil of Neolithic

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[9]A. Richmond, 1999, *Op cit.*

D. Hunt, 1987, *Early Farming Communities in Scotland*, BAR **159**, 49.

[10] S. Mithen (ed), 2000, Hunter-gatherer landscape archaeology: the Southern Hebrides Mesolithic Project. Volume **1**, 31.

[11] A. Richmond 1999, *Ibid.*, 9; S. Mithen 2000, *Ibid.*, 31 ff.

[12] A. Richmond 1999, *Ibid.*, 9

[13] S. Mithen (ed), 2000, *Ibid.*, Volume **1**. 31.

[14] M. Zvelebil, 1986, "Mesolithic societies and the transition to farming: problems of time, scale and organisation, in Zvelebil, M. (1989). *Hunters in Transition.*

[15] R. Tipping, 1994, The form and fate of Scotland's woodlands, 29 and 33.

[16] Hunt, 1987, *Op cit.*, 13.

woodland clearance, is now ultimately seen as a Mesolithic development.[17] Pollen evidence suggests that at least some of the early woodland clearances remained open and thus were in use over long periods.[18] This evidence, in the form of pollen counts, identified grasses and herbs in numbers usually associated with open and light-filled areas. The existence of these clearance herbs is seen to support the desire or need for the grazing of animals, whether for the herding of domesticated species or the encouragement of grazing by wild animals. Further, and perhaps more profoundly, it is seen as a possible change in attitude: people are now interacting and participating in environmental control, traditionally assigned to the Neolithic. These clearances are thought to have begun sometime before the deposition of cereals (middle Mesolithic), further confirmation for some that the clearances may have supported animals.[19] Additionally, it has even been suggested that cereal pollen exists in British pre-Neolithic contexts[20]. However, this evidence could be misleading for two main reasons. Some of the evidence was located in the time of pre-elm decline, and the elm decline was used as the marker between the Mesolithic lifestyle of the hunter/gather and the arable farmer of the Neolithic. However, "the elm decline ... has been relegated to a subsidiary position, most commonly thought of as lying within ... the early Neolithic".[21] Further "Smith raised the possibility that some woodland clearances, pre-elm decline and so purported to be Mesolithic, might instead be Neolithic".[22] What all of this tells us, is that clearances occurred both before and after the elm decline, but that some of those purported to be Late Mesolithic, due to the evidence's stratigraphic location, may indeed be Neolithic.

The nature of these Mesolithic woodland clearances though is now in question. It is generally theorised that these woodland clearances of the Mesolithic are now thought to be naturally occurring openings (natural clearing, lightening strikes *et cetera*) within the woodland that have been deliberately maintained for use.

There is further evidence that challenges the traditional view of the "Packages of Ages". Interestingly pottery, once thought to begin within the Neolithic, has since been shown to be used by hunter gatherers within northern Europe, and it is theorised that "perhaps it is only a matter of time before such finds are located in Mesolithic contexts within Britain".[23] Also at the "European level there have been instances of foraging groups with ceramics and the knowledge of livestock domestication."[24]

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[17] Woodman, 1976, 78 in Hunt, 1987, *Op cit.,* 12.

[18] Evans 1971,64; Whittle 1978 ,37; Edwards 1978 in Hunt, 1987, *Op cit.,* 13.

[19] See Mithen, 2000, *Op cit.,* Volume **2,** 623 *ff* for discussion on life style in the Middle Mesolithic versus the Late Mesolithic, as well as the similarities between the former and the Early Neolithic. See Discussion below also. Hunt, 1987, *Op cit.,* 13

[20] Edwards 1998a, 1989, 1993, Edwards and Ralston 1984, Groenman-van Waateringe 1983, in Richmond, 1999, 5.

[21] Tipping, 1994, *Op cit.,* 19.

[22] Smith, 1981 in *Ibid.,*19.

[23] Rowley-Conwy 1983 and Thomas 1999, 7 in Richmond, 1999, *Op cit.,*10. Zvelebil , 1986c in Mithen, *Op. cit.,* Volume **1**, 31.

[24] Richmond, 1999, *Ibid.,* 5

In relation to burials, a practice that was a major feature of Neolithic mortuary ritual at megalithic tombs and other sites was that of the deliberate circulation of bones. It has been known for sometime though, that this practice also occurred in the Mesolithic. There is evidence that particular body parts were deliberately selected to be deposited in particular ways. Outside the British Isles in Germany is the nest of skulls found at Ofnet.[25] Also, the building of megalithic style monuments is also found within European Mesolithic contexts. For instance, the slab-lined cists of Brittany at Téviac, and tiny cairns in southern France.[26] As well there is an individual burial located in a rectangular structure of large slabs, surrounded by large hearths at Roc del Migdia in the Spanish Pyrenees and similar burials known from the Abri Cornille region in France.[27]

As well as these traditions, we find that grave good deposition and the deposition of votive deposits in natural locations and sites, once thought of as Neolithic phenomena, are now seen to operate within the Mesolithic economic context. Bradley argues that grave goods within the Mesolithic can be primarily described as retaining their connection with the natural world and that these objects are natural in origin and are usually unworked.[28] Objects included antlers and animal bone. Interestingly, individual stones were also placed with the body in sites at Vlasac, Serbia.[29] Votive deposition is seen as a Mesolithic development by Bradley with the evidence formed from a number of isolated incidences including a group of decorated bone and shell artefacts buried together in a pit at the Breton settlement site of Beg-er-Vil and the position of the feature was marked by a deposit of antlers![30] Within the British Isles at southwest Ireland, a group of stone-ground axes was also deposited in a pit within a settlement (Ferriter's Cove, Co. Kerry) near to a small group of cattle bones. There are a number of interesting points to make about this example. It is almost an exemplar of this newer paradigm of the Mesolithic-Neolithic overlap: a polished stone tool deliberately deposited within a settlement site near a group of domesticated cattle bones, the latter dated to 4500 B.C.[31], in an economic context that focuses upon fishing and gathering.[32]

Thoughts on the Neolithic/Bronze Age

The general discussion above on the Mesolithic and Neolithic has been used to illustrate that previous applications in distinguishing one "Age" from another were insufficient and that the "Ages"

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[25] Meikeljohn, 1986 in Bradley, 1998, *Op cit.,*27.

[26] Bradley 1998, *Ibid.,* 30.

[27] Bahn 1988, 558 in Richmond, *Op cit.* 1999, 9).

[28] Bradley 1998, *Op cit.,* 25.

[29] Srejovic and Letica, 1978 in Bradley, 1998, *Ibid.,* 28-9.

[30] Kayser and Bernier 1988 in Bradley 1998, *Ibid.,* 27.

[31] G. Cooney, 2000, *Landscapes of the Irish Neolithic*, 13.

[32] *Ibid.,* 13.

themselves should perhaps remain as guiding nomenclatures only, and not words that infuse or imply a clear, insistent package of identifiers.

It will become clear below that the Package of the Neolithic is further undermined, not only by its primary inclusion of what was once thought to be Mesolithic in nature as we saw above, but also a "loss" of association with its former defining quality, that of arable farming; and within most of Scotland itself - permanent settlement. For instance Whittle tells us that ideas regarding "the adaptable and productive subsistence base", and "the powers of rapid breeding" have not found support in the archaeological records, especially for the idea of a 'wave of advance' across Europe, for there are lower than predicted density of sites on the ground for these models.[33]

As mentioned briefly above in the "Overview" the evidence provided by Hunt, Tipping's research overview and Richmond's work tells us that it is in the Bronze Age that we find the strongest and most secure evidence for deforestation on any major scale for the production of cereals rather than just the use. It will be seen that Mithen's and others' work on the Southern Hebrides Mesolithic Project confirms these interpretations as well as claiming support for the paradigm nowadays referred to as the transition model of the Mesolithic to the Neolithic. It will be seen however that unlike the earlier transition paradigms we can no longer consider this transition model to include continuous or widespread dependence upon agriculture, and that if we still wish to define the Neolithic like Hunt, transitional or otherwise, , the Neolithic will include the early and middle Bronze Age.

We now turn to the Ages in western Scotland and view the ever-growing complexity of the picture of the lifestyle of the peoples here.

Shifting sands: the Mesolithic, Neolithic and Bronze Ages in Scotland

All the ideas discussed above can be seen to be reflected in the "Age" models applied to western Scotland and it will be seen below how the traditional models, their identifiers and the supposed supporting evidence for them is now seen as contentious. Further however, it will be seen that even the newer ideas, and supposed evidence, are not as clear as they should be. By beginning once more at the Mesolithic, it will be possible to understand the nature of the Neolithic more clearly, and with the picture of the Neolithic, the Bronze Age will contrast more strongly.

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[33] *Op cit.*, 6-7.

Anthropogenic woodland interferences - complications

Despite Zvelebil's claim that "Mesolithic 'hunter-gatherers' are now understood to have been managing their plant environments in a sophisticated fashion", sound indisputable palynological evidence is not forthcoming.[34] While it is true to say that the elm decline is no longer held to be the palynological divide between the Mesolithic and Neolithic or the symbol of the impact of Neolithic activities, this does not mean that increasing numbers of pollen analyses reveal evidence of activity prior to the elm decline, nor that the effectiveness of Late Mesolithic groups as agents of forest clearance has become clearer as claimed.[35] This is because "much of the (palynological) evidence was not collected specifically with the aim of a thorough pollen analysis in mind but as an adjunct to wider study of man's impact".[36] Despite the fact that it is evident that the Mesolithic and Neolithic overlap, chronologically and contextually from archaeological evidence, and that, according to Edwards (1976), research aimed specifically at identifying the significance and scale of man's activities has revealed trends similar to those on Irish and English sites. Though Hunt adds the last caution on the palynological evidence, Tipping goes further and states that "(t)here are no unambiguous indicators of human woodland modification or disturbance" and that palynological evidence should be able to stand on its own without looking for corroboration from archaeological evidence. [37] Tipping further reports that "the comparative abundance of Mesolithic activity reported from pollen diagrams from Scotland (Edwards and Ralston 1984) can only indicate either astonishingly high population or, more likely, that not unexpectedly we are confounding artificial and autogenic deflections of woodland processes".[38]

Supporting this idea is the evidence for climatic changes - strong enough to cause the alterations seen within the woodland context - which were at some point thought to be evidence of human behaviour.[39] This is particularly so at "woodland margins, (where) fluctuations throughout time in the abundances of tree pollen, and in the woodland remains, are observed in the early-mid Holocene".[40] For instance, on "the Western Isles, Fossitt (1990) recognised a period of severe woodland disturbance at 5900 B.C., broadly synchronous between four sites in Lewis, Harris and the Uists, which … she regarded as climatic, not anthropogenic, in origin."[41] Interestingly too, Colonsay had a sustained decline in

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[34] M. Zvelebil, 1994 in S. Mithen (ed), 2000, *Op cit.*, Volume **1**. 31

[35] Smith 1970, Clarke D.L. 1976, Simmons 1969 in Hunt, 1987, 10.

[36] Hunt, 1987, *Ibid.*, 10.

[37] Tipping, 1994, *Op cit.*, 15.

[38] Tipping, 1994, *Ibid.*, 16.

[39] Tipping, 1994, *Ibid.*, 14

[40] Tipping, 1994, *Ibid.*, 14

[41] Tipping, 1994, *Ibid.*, 14

Birch/hazel woodland from 7900B.C. until 4200 B.C. Independent climatic evidence is established by the Deuterium/hydrogen ratios. These ratios have established a variation in climatic extremes during the Holocene. Whether these reflect changes in precipitation or temperature is not fully established, for they have not been demonstrated by independent means.[42] However, the dates associated with extremes in rainfall are before and at, c.5550 B.C., 4300-3850 B.C. and at 1350 B.C. (though first and third poorly defined).[43] "Before 5500 B.C." may well fit in with Fossitt's findings and the second with that for Colonsay. Also it should be noted that the occurrence of woodland clusters has been established for the periods 6800-5800 B.C., especially for the Western Isles.[44] Thus the independent evidence for clusters and then severe woodland disturbance for the Western Isles seem quite well placed chronologically. Studies by Wilkins, 1984 and Fossitt, 1990 (for Western Isles), Bennett and Sharp, 1993 (for Shetland) and Bridge *et al.*, 1990, (stump evidence across Scotland) show that woodland structure and composition can be modified by non-anthropogenic agencies such as climate change (as above), tree migration and pedogenesis.[45] In an area such as western Scotland, which generally tended to be open woodland, smaller-scale openings could be produced from the death of trees either by minor lightning strikes, severe winds or natural term. These effects could be amplified in positions of altitudinal and latitudinal extremes, but also on cliffs, ravines or stream sides, so that anthropogenic interpretation for so called 'clearance' herbs can be unwise."[46]

Having said all this though, the sites of Machrie Moor on Arran, Lang Loch on the east coast of South Uist, Beinn Eighe in the uplands of the northwest and Cross Lochs of Sutherland have all shown episodes of forest burning dated to secure Mesolithic horizons.[47] This information is used as evidence for controlled burning within western and northern Scotland and thus land management at a time traditionally acknowledged as empty of deliberate land management strategies. However, Tipping rightly cautions his readers regarding the charcoal evidence for reasons of analysis (traditional analysis of microscopic charcoal needs to be interpreted with care due to charcoal's varying sources and origins), and imbedded within this is the general lack of knowing which fires might have been natural and which might have been started or managed by people.[48] Despite these warnings, there are still examples of data used as support for anthropogenic burnings. For instance, at the east coast of South Uist, at Lang Loch, a nearly continuous curve of microscopic charcoal from c. 7000 B.C. is interpreted as possible human presence on the islands.[49] No other palynological evidence is presented in support

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[42] Tipping, 1994, *Ibid.*, 14

[43] Tipping, 1994, *Ibid.*, 13

[44] Wilkins, 1984 and Fossitt, 1990 (for Western Isles) in Tipping, 1994, 13.

[45] Tipping, 1994, *Op cit.*, 13, 15. Also see pages 16 and 17.

[46] Tipping, 1994, *Op. cit.*, 16

[47] Robinson and Dickson 1988, Durno and McVeen 1959, Charman 1992, Bennett *et al.* 1990 in Richmond, 1999, *Op cit.*, 7.

[48] Tipping, 1994, *Op. cit.*, 16

[49] *Ibid.*, 16.

of this. At Callanish, Lewis Bohncke's 1988 work saw Mesolithic disturbance as most likely to account for an abrupt decline in the birch scrub and increases in open ground herbs and microscopic charcoal at the approximate times of 6450 and 5700 B.C..[50] So we have information that supports a gradual move towards control over the environment beginning in the Mesolithic of Scotland, with varying degrees of acknowledgement or acceptance by some.

Things get more complex – archaeological contexts and dates that overlap

However there is other evidence to suggest that those previously identified as exclusively hunter gatherers, and hence Mesolithic, were in fact behaving in ways thought to have appeared in the Neolithic. The evidence comes in the form of Neolithic styles in Mesolithic contexts as well as Neolithic styles with very early dates firmly within or closely overlapping those dates nominally assigned to the Mesolithic. In Kinloch, Rum, for example, bifacially worked leaf point usually associated with the Neolithic was found in a pit associated with charred hazelnut shell fragments which provided the earliest dates from the site of 8590±95 BP [8000-7350 cal B.C.].[51] At Machrie Moor, Arran, charcoal from a pit containing Neolithic pottery has been dated to 5500±70 BP [4500-4140 cal B.C.] and 4820±50 BP [3710-3380 cal B.C.], while that from a dismantled timber circle at Temple Wood, Kilmartin has been dated to 4353-3351 cal B.C..[52] From Lussa Wood, Jura, environmental evidence suggests occupation on a permanent basis as well a site of contiguous stone rings dating from the 7th century B.C.. According to Richmond, Seawright suggests that the due care with which the stones were erected seems to indicate a permanent camp or one that was in regular use and in Oronsay it appears that the extremities of the body were left at the settlement within the shell middens.[53]

The Neolithic

Lifestyle overlap and continuity

What is evident in the Mesolithic of western Scotland, namely traditionally defined Neolithic activities being represented, is also true for the Neolithic. That is traditionally defined Mesolithic activity and reliance on marine sources *et cetera* also reside in the Neolithic of western Scotland. As well at that however, there are data which also emphasise the continuity of the "Neolithic" activities of the Mesolithic such as possible control of woodlands and use of pottery, continuing into and throughout the Neolithic.

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[50] *Ibid.*, 16.

[51] Mithen, 2000, *Ibid.*, Volume **1**, 33

[52] Mithen, 2000, *Ibid.*, Volume **1**, 32.

[53] Seawright 1984, 209 in Richmond, 1999, *Op cit.*,7. Mellars 1987, 9-16 in Bradley, 1998, 27.

At the Ulva Cave in Mull we find evidence for continuity in economy. The midden which has a date of 7660±60 BP [6640-6400 cal B.C.] at its base, is also associated with Neolithic pottery stratified within the upper layers, and charcoal from a pit has been dated 4990±60 BP [3950-3650 cal B.C.] highlighting the continued use of marine resources. Risga, Loch Sunart, Nth Argyll also has pottery stratified in the upper layers of the midden there.[54] At Northton, Harris, there is evidence for marine resources, hunting of wild animals and herding in the Early Neolithic period. Of the six occupation periods identified, two are Neolithic. In the second Neolithic horizon, dated to c.3200 B.C., faunal remains of red deer, sheep and cattle (complete age ranges and even numbers of the latter two) were found, along with evidence for the utilization of marine resources, namely seashells, seabirds, lobster, crab and seal.[55] Importantly, there appears to be an absence of cereal growing in this area.[56] Further south east, too, the Oronsay middens were still accumulating at 5500 BP, and dates include 4770±50 BP [3623-3345 cal B.C.]. Also Cnoc Sligeach, and the Obanian shell midden at Carding Mill Bay were dated to 5060 ±50 [3970-3710 cal B.C.] and 4980±50 BP [3940-3650 cal B.C.].[57] All this tells us that we have a busy economy extending out of the Mesolithic (hunting of wild animals and gathering marine resources) that finds it unnecessary to use or adopt the use of cereals as part of their subsistence economy, moving strongly away from the traditional view of what it is to be a functioning Neolithic system.

Economic change?

The soundest evidence for the use of domesticated animals is in the early Neolithic for western Scotland, where we saw the presence of cattle and sheep bones present at Northon, in Harris. At Eileen Domhnuill, in North Uist there were also found cattle and sheep bones. The evidence of charred hazelnut fragments and crab apple pips from Carinish, Nth Uist, tells us that wild plants continued to be used.[58]

Cereal in clearances

There are Scottish finds of cereal-type_pollen grains in pollen cores which are held to be possible evidence for growing cereal.[59] There are 3 sites identified in Scotland, two of the three are in western Scotland, namely Rhoin Farm, Aros Moss on the Kintyre Peninsula, and Machrie Moor on Arran. For the former, Edwards and McIntosh found three cereal-type grains, with the earliest dated to 3690 B.C..[60] From Machrie Moor, Robinson and Dickson found 5 cereal-type grains.[61] Later research by

[54] Mithen, 2000, *Op cit.*, Volume **1**, 33.

[55] Hunt, 1987, *Op cit.*, 39.

[56] Hunt, 1987, *Op cit.*, 131.

[57] Mithen, 2000, *Ibid.*, Volume **1,** 32.

[58] Mithen, 2000, *Ibid.*, Volume **1,** 33

[59] Tipping, 1994, *Op. cit.*, 19.

[60] Tipping, 1994, *Ibid.*, 19.

Edwards and Berridge, published in 1994, showed cereal-type pollen grains found at Loch a 'Bhogaidh, cores which may date to 5470 BP.[62] There is however a concern with this evidence, for "even (though) the presence rather than the abundance of cereal pollen must represent agricultural activity", due to the nature of survival, identifying cereal-type grains is not the same as identifying cereal pollen.[63] The type found at the first two sites is *Hordeum*, a barley type, which includes wild grass species. Secondly, many of these species occupy a maritime environment[64] like that existing at Rhoin Farm. So from these examples there are no unambiguous identifications.

Cereals at archaeological sites

Interestingly, there *are* distinct examples for *the use* of domesticated cereal in archaeological contexts. At Carinish, in North Uist, 6-row barley and emmer wheat was found. At Ulva Cave, Mull, one pit contained 130 grains of Hulled barley and 30 oat grains. The charcoal from the base of this pit was dated to 4990±60 BP [3951-3649 cal B.C.].

However, it has been argued well by Richmond that cereals at archaeological sites are not evidence for the *growing* of grain. Across the British Isles, the evidence for grain or cereals within the Neolithic has been shown to occur in very specialised contexts, most notably those from enigmatic and perhaps ritualistic sites, including places of burial - for instance the deposit of thousands of spikelets of emmer wheat in a pit outside the Stepleton enclosure Hambledon Hill, near Blandford Forum in Dorset. Also, it has been suggested that finds of saddle querns perhaps like those found at Eileen Domhnuill,[65] could have been used for tasks other than grinding domesticated wheat. Further, we have impressions of cereal grains on pottery which seem to be found in non-domestic contexts. It seems we have the use of cereals in very special conditions and contexts but *not the actual production of the grain.*

New lifestyle - signs of permanent settlement?

Apart from permanent housing found north of the Scottish mainland on Orkney, permanent settlement sites are very rare within the British Isles generally, and have been considered almost non-existent in mainland Scotland. However, what has been interpreted as an early Neolithic farmstead has been discovered at Cowie, near Stirling. The farmstead has related outbuildings, and dated by pottery to c.3000B.C..[66] It consists of "a close grouping of two houses and six small outbuildings - not all of which were standing at the same time". Associated pits contained a variety of domestic rubbish,

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[61] Tipping, 1994, *Op. cit.*, 19.

[62] Mithen, 2000, *Op cit.*, Volume **1**, 34

[63] Tipping, 1994, *Op. cit.*, 19.

[64] Tipping, 1994, *Op. cit.*, 19.

[65] Mithen, 2000, *Ibid.*, Volume **1**, 34

[66] http://www.britarch.ac.uk/ba/ba9/ba9news.html; excavator, John Atkinson of the Glasgow University Archaeological Research Division (GUARD).

including pottery, stone blades, quernstones and charred grain. The stone blades, made of pitchstone, were probably brought from the Isle of Arran, the nearest known pitchstone source, giving possible evidence of trade.[67] The structures "appear to have been constructed out of thin stakes rather than solid posts, with the intervening walls resting on the ground in a shallow trench and ...sophisticated entrances, constructed out of an arrangement of solid posts".[68]

Interestingly, excavations in Balbridie near the River Dee, revealed a large post-built structure, originally roofed and with a number of internal rooms formed by partitions. Charcoal from the remains of the burnt building was dated to the range of 3900-3500 B.C.. Many thousands of emmer wheat, naked barley, bread wheat and grains were identified and dated to within the same range as that found for the charcoal. What might this tell us? Peter Rowley-Conwy feels that archaeologists are too timid in their estimations and interpretations of this structure, especially now that others have been found within the British Isles , including in 2001 another possible Neolithic longhouse structure near Callander in Perthshire. He holds that, with the prevailing view of the Neolithic seen as continuing the nomadic existence of the Mesolithic and perhaps "practising a little agriculture" archaeologists feel forced to fit Balbridie into this model and label it as "an unoccupied store, a ceremonial focus for perhaps several groups of nomads - who presumably visited it now and again to feast on the contents", rather than a site of permanent settlement.[69] To add to this debate, what seem to be houses with hearths and cobbled areas have been identified in Argyll, dating from c. 3699 BC to 3342 BC.[70]

What was it like in western Scotland?

The Neolithic

The overwhelming evidence supports, that although sites such as Balbridie in eastern Scotland may indicate the arrival of new people with a new way of life, a case for this can not be made for western Scotland in general and the southern Hebrides in particular.[71] Also the evidence for a transition from a Mesolithic way of life to that of Neolithic in western Scotland is more substantial than that for eastern Scotland.[72] The following will outline what it *might* have been like in these times within western Scotland. The Neolithic here is defined as the chronological range c.4500 to 2750 B.C..

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[67] *Ibid.*

[68] *Ibid.*

[69] http://www.britarch.ac.uk/ba/ba64/feat3.shtml

[70] Ritchie, G. R.. 1997. The Archaeology of Argyll.

[71] Mithen, 2000, *Op cit.,* Volume **2**, 626.

[72] Mithen, 2000, *Op cit.,* Volume **1**, 32.

The environs

The general picture of the "dryland" woodland of western Scotland, prior to earliest agrarian modifications, can be found in Tipping's map of Scotland c. 3000 B.C..[73] Naturally it is simplistic, but it highlights the more open nature of the woodlands in the area. Having said this Tipping tells us "considerable variation in woodland composition is demonstrated for areas subjected to detailed study, e.g. Skye (Birks and Williams 1983), and by the differences induced through aspect, altitude, soil type and quality and microclimate".[74] According to Tipping, Kerslake detected a greater species-diversity, and marked differences in the proportions of major trees, by studying small-diameter basins in northwest Scotland than pollen studies from large lochs of the same region.[75] Tipping continues to relate an exhaustive study of the outcomes of woodland researches carried out for dating purposes at that time. In the north west of Scotland, for instance, a "forestry" reconstruction placed the boundary of extensive woodland between Skye and Outer Hebrides and across northern Caithness. In addition, pollen analyses from Little Loch Roag, on the extreme west coast of Lewis, indicated, that "no trees colonised this region except sparse stands of birch and perhaps hazel, in support of the bulk wood remains".[76] Added to this, "Wilkins (1984) provided indisputable evidence in the form of radiocarbon-dated stumps (on Lewis and Harris) that pine also grew on blanket peat for a period between 2900 and 1900 B.C., (whilst) Fossitt (1990) has … argued that pine was widespread from 5500 B.C.".[77] As well as this evidence, the work of the following researchers, Birks and Madsen (1979), Bohncke (1988), Bennett (1989) and Fossitt (1990), tells us that areas of thin birch-hazel scrub may have been *restricted* to the thin strip of land on the west coasts of the Western Isles.[78] Further, on this most exposed edge, trees may have been few and far between according to Fossitt's 1990 and Birks' 1991 works.[79] So it seems that the west coast of the Isles may have been fairly open, and due to their exposed nature it is likely that the open scrub form is liable to apply to the majority of the woodlands. Support for this may be seen in the demonstrable lack of pine *forests*, and in Fossitt's 1990 envisaging of only scattered individuals or small stands at any one time.[80] To possibly enrich the patterns of the landscape even further in the Western Isles "Bennett *et al* (1990) tentatively suggest that about half the *sheltered valleys* of Bhein Mhor on South Uist might have been cloaked in trees".[81] Supporting these patterns are detailed palynological investigations employing several sites on one island which have shown the complex mosaic of woodland types that could have develop in sheltered

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[73] Tipping, 1994, *Op cit.*, 11.

[74] Tipping, 1994, *Ibid.*, 11

[75] Kerslake, 1982 in Tipping, 1994, *Ibid.*, 11

[76] Tipping, 1994, *Ibid.*, 11.

[77] Tipping, 1994, *Ibid.*, 11.

[78] Tipping, 1994, *Ibid.*, 11.

[79] Tipping, 1994, *Ibid.*, 11.

[80] I. Armit, 1990, in Tipping, 1994, *Op cit*, 13.

[81] Tipping, 1994, *Op cit*, 13

localities on **Mull**, Oronsay and Colonsay.[82] Finally on a more general note for the woodlands, according to Tipping, it is suggested that their fullest development occurred immediately prior to 3000 B.C., in accordance with earlier reconstructions.[83]

Lifestyle overview

The researchers of the Southern Hebrides Mesolithic Project (SHMP) felt that their project generated a limited amount of new evidence of the Mesolithic-Neolithic transition, but that which did eventuate seems to support the cases previously put forward for overall continuity of tradition as one moves "forward" in time. Despite this general picture produced, the project promotes a more sophisticated and perhaps more detailed picture of what this transition actually indicates. It is claimed that the start of the Neolithic is not a demonstrably new tradition slowly emerging out of that which immediately preceded it, but rather a return to a way of life that occurred or existed in "middle" Mesolithic.[84] So the *appearance* of what is the Neolithic, at least technologically and economically (superficially), is neither a completely new tradition appearing as a sharp distinction from that which went before (as once heralded), nor a time of subtle change within the current way of life towards a completely novel format (a slow transition). Could this be perhaps, a time of readjustment brought about by climatic influence, or more involved still, a time to work the land in the ways of those who had gone before to counter new ideological currents filtering their way through societies of people at the time?[85] So, what *was* happening in the Neolithic in western Scotland? And what might have been happening to these people and why?

Human activity

Overall, the earlier Neolithic in the Western Isles supports a form of vegetation disturbance in that it is similar in character to that which occurs in the Mesolithic. The evidence at Bolsay Farm dated to 5230 BP supports this.[86] In addition an erosional event recorded from Loch Gorm (core CA), dated to 4700 BP "does not appear more substantial than those occurring during the Mesolithic".[87] Also the clearances around Loch a'Bhogaidh, Islay, by 4700±100 BP, are seen as slight and appear relatively wooded, but they did lead to an increase in grasses and plants that enjoyed more light (sorrel and buttercup).[88] Opposite Lewis on the northwest mainland coast, a number of pollen sites within the birch/pine woods suggest low prehistoric human population, in that no or very little human impact can

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[82] Mithen, 2000, *Op cit.,* Volume **1**, 27.

[83] Mithen, 2000, *Ibid.,*Volume **1**, 9

[84] Mithen, 2000, *Ibid.,*Volume **2**, 623.

[85] This is not presupposing that the ideas necessarily had to come from the outside.

[86] Mithen, 2000, *Ibid.,*Volume **2**, 623

[87] Mithen, 2000, *Op cit.,* Volume **2**, 625

[88] *Ibid.,* 623

be recognised.[89] Pollen diagrams from sediments in Loch Clair and Loch Maree provide virtually no anthropogenic activity.[90] This has been purported in the past to be an agricultural regression.[91] However, we have seen from above, and shall see further from below, that there is no evidence for an agricultural (as in cereal growing) revolution for a regression to be considered. The evidence used in the past was that of increased clearances followed by woodland regeneration. Tipping argues that whilst there are obvious areas that reveal some form of woodland regeneration within Scotland, such as at Solway Firth and Machrie Moor, Arran, as elsewhere in the British Isles, it is "equally apparent that neighbouring sites show no such features".[92] Overall, regional synchronicity cannot be deduced from the present data set.[93] Tipping holds that, at the moment it appears safest to assume that these sites reflect local and regionally insignificant fluctuations in land use".[94]

Other forms of occupation can also reflect the amount of human activity in a given area. For instance, the amount of Neolithic activity was considered not less than that found for the Mesolithic at Eilean Domhnuill for 20,000 pottery sherds were found. (Armit 1992 in Mithen, 2000, 36). Further, Mithen's study shows that the Neolithic occupation at Bolsay Farm was even more frequent than the Mesolithic, yet some form of activity had lessened for there was less chipped stone identified with Neolithic occupation of the site.[96] In fact, for western Scotland overall, chipped stone is rare and found in comparatively small numbers. Basically, the quantities of chipped stone at sites shows a distinctive decline, and, according to Mithen, the technological change usually attributed to the Neolithic, is really a shift in emphasis over time.[97] This can be seen at Kinloch, Rum, where the differences found were mainly in the *lack* of microliths and blades in the Neolithic assemblage (as at Bolsay Farm above), however the remains themselves relating to the Mesolithic and Neolithic "were virtually identical in terms of chipped stone technology and their range of features".[98] In the penultimate chapter of the SHMP Mithen makes an interesting suggestion, that the reduction in chipped stone "may not reflect a change in mobility (that is a less mobile community) but simply a change in (culture) that led to the Neolithic people making and discarding far fewer stone artefacts than in the Mesolithic".[99]

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[89] Tipping, 1994, *Op cit.*, 27.

[90] Tipping, 1994, *Ibid.*, 27.

[91] Tipping, 1994, *Ibid.*, 32-34.

[92] *Ibid.*, 32-33.

[93] *Ibid.*, 33.

[94] *Ibid.*, 33.

[95] Mithen, 2000, *Op cit,* Volume **2**, 624.

[96] Mithen, 2000, *Ibid.*, Volume **2**, 624.

[97] Mithen, 2000, *Op cit,* Volume **1**, 33.

[98] Mithen, 2000, *Op cit,* Volume **1**, 33.

[99] [99] Mithen, 2000, *Ibid.*, Volume **2**, 625.

Mobility as a probable indicator of lifestyle

Contrary to the traditional idea of a more settled way of life in the Neolithic is the notion of a semi-nomadic lifestyle that includes hunting, gathering and herding. This now popular notion fits in well with the current model of the Neolithic containing a significant amount of Mesolithic character. The evidence we have seen to date also appears to support this notion. Further possible support for this less than settled way of living comes from the evidence of trade. Mithen states "there appears no reduction in the extent of mobility during the transition to Neolithic and during the Neolithic itself" ... (f)or, raw materials appear as widespread in the Neolithic as in the Mesolithic.[100] Examples Mithen includes are: pitchstone from Arran found within sites in the Hebrides and northeast Scotland and porcellanite axes deriving from Rathlin Island, Antrim, found throughout the Hebrides.[101]

Interestingly, Tipping feels that "it is particularly striking how abundant is the identification of early/mid Neolithic impact throughout Scotland, particularly when later periods are far less obviously consistent in the registration of anthropogenic activities". [102] He states that the identifications commonness "raises questions concerning … the **mobility** of the population in these earlier periods". [103] Suggesting that these groups of people were in fact more mobile than those groups that were to follow.

The economy

The SHMP concluded that the western Scottish lived a hunting, fishing and gathering lifestyle that we would recognise as Mesolithic within mixed Oakland woodland until 6500BP, "after which a substantial disjuncture in settlement pattern occurs".[104] At this point Oronsay is occupied and shell middens begin, whilst the exploitation of Jura, Islay and Colonsay becomes marginal.[105] According to the project outcomes, after 5000 BP significant exploitation begins again, this time by people herding small numbers of sheep and cattle along with substantially previous Mesolithic patterns of behaviour (main difference being the amount of chipped stone debris, see below) within the Inner Hebrides.[106] It seems possible to the current author that now they incorporated herding animals, peoples needed to spread out and moved to new areas that provided more territorial space for grazing, and perhaps greater protection for the cattle and themselves by being on an island. Being on island spaces had the added benefit that the animals could only wander so far. At this juncture too, "…the role of cereals in the economy appears limited … and appear(s) to have been a minor supplement to the continued use

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[100] Armit 1992, in Mithen 2000, *Op cit.*, 34.

[101] *Ibid.*, 34.

[102] Thomas, 1988 in Mithen, *Ibid.*, 32.

[103] Thomas, 1988 in Mithen, *Ibid.*, 32.

[104] *Ibid.*,Volume **2**, 626.

[105] *Ibid.*,Volume **2**, 623.

[106] *Ibid.*,Volume **2**, 623.

of wild plants."[107] On the other hand, Mithen states that the evidence from the Sorn Valley shows that *by 4700 BP* (see Chapter 3.7) tree cover was largely lost, by which time indicators of pasture and crop cultivation were present and "podzolization of soils and the spread of acidic heath were already underway on the valley sides," while at Loch Gorm, Islay, there was peat inundation at 4700±100 BP.[108]

Added interesting complications of the picture of the Neolithic economy are the outcomes of Schulting's work. In 199 Schulting considered human bone samples using ^{13}C and ^{15}N studies. His work found that the samples ranging in date from 4690±40 to 4830±45 BP from the Oronsay middens of Cnoc Coig and Caisteal nan Gillean and the midden of Carding Mill Bay (opposite Mull) reflected an unexpected degree of change in the diet of Neolithic peoples; similarly for samples from a chambered tomb of Crarae, Loch Fynn (Argyll) dated to 4735±40 BP. Whilst the Oronsay samples revealed a very strong "signal" for marine protein equivalent to those found in seal and otter, the others showed a distinct lack of marine protein to the point of exclusion.[109] The Neolithic samples from Carding Mill Bay and Crarae indicated a complete dependence upon terrestrial fare. This seems quite astounding given the evidence of continued use of the middens at Carding Hill Bay. However, Schulting did find an avoidance of seafoods throughout the Irish Sea region from samples taken from coastal caves and monuments.[110] All this further supports the idea that those of the early Neolithic were moving away from the Late Mesolithic lifestyle of marine production and relying more heavily on terrestrial animal meat (whether hunted or domesticated).

Monumental construction

The megaliths of the Clyde and southwest Scotland emerge in the early fourth millennium (Middle Neolithic), as attested by the date for the chambered tomb at Monomore, Arran (3160±110; 3965-3780 cal. B.C.).[111] Their occurrence at this time is further attested by "plain round-bottom vessels typical of the Middle Neolithic found in the segmented chambered tombs at Cairnholy (Kirkcudbright) ... and Bearcharra (Argyll) as well as Monomore."[112] Additional evidence from Port Charlotte, Islay indicates that by 5000 B.P. chambered cairns were being constructed in the inner Hebrides and small herds of domestic animals are likely to have been managed. Further,

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[107] Tipping, 1994, *Op cit.,* 34.

[108] Mithen, 2000, *Op cit.,*Volume **2**, 625.

[109] Mithen, 2000, *Op cit.,*Volume **1**, 35-36

[110] R. Schulting, 2002, "An Irish sea change: practice and perceptions of the sea and land across the Mesolithic-Neolithic transition", paper presented at *The Neolithic of the Irish Sea: materiality and traditions of practice.*, School of Art History and Archaeology, Manchester, 12th-13th April 2002.

[111] *Ibid.,* 310. See de Valera, Ruaidhrí and Ó Nualláin, Seán (1961, 1964, 1972). *Survey of the Megalithic Tombs of Ireland.*

[112] Dates from Piggott and Powell, 1948-49 and Scott 1969 in *Ibid.,* 310.

> (w)hilst these are indicative of substantial social and economic innovation, they nevertheless appear to have been integrated into a settlement-subsistence pattern which had strong similarities to that of the Mesolithic between 8000-6500 BP.[113]

By 3500 B.C. the number of cairns along the north and west coasts, occupations and some settlements as far north as Shetlands, as well as possible pollen evidence of woodland clearance, "bear witness to successful development of an ... economy in increasingly northern and harsher conditions."[114] The actual position of the monuments may be further evidence of the continuity of the Mesolithic within the Neolithic according to Hunt.[115] There are, for example, a large number of Neolithic burial sites along the shores of both sides of the channel, near Northton, Harris, in a region where Mesolithic occupation is known to have been relatively substantial, showing perhaps some support for continuity of area usage.[116]

According to Hunt's research on *Early Farming communities in Scotland* there is a broad distinction between the west and east coast patterns of development which is blurred along the valleys of the Southern Uplands and along the Inner Moray Firth.[117] The west coast communities appear different in several respects from those of the east. This distinction may be reflected in the chambered tomb tradition of the west and north and the continued importance of hunter-gatherer patterns, especially those with local economic emphasis upon marine resources, reflected by the apparent midden use.[118] Further, the distribution pattern of the chambered tombs clearly illustrates the fundamental differences between areas of Scotland (see Table 2.1). The table reveals that western Scotland contains approximately 25 percent of the total, whilst in eastern lowland zones of Scotland, where only a small percentage of the total resides, long barrows appear.[119]

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[113] Mithen, 2000, *Op cit.*,Volume **2**, 625.

[114] Hunt, 1987, *Op cit.*, 78.

[115] Hunt, 1987, *Op cit.*, 37.

[116] Hunt, 1987, *Op cit.*, 37.

[117] Hunt, 1987, *Op cit.*, 78.

[118] *Ibid.*, 30. See also Mackie, 1966, in Hunt. 1984, *Op cit.*, 39.

[119] H. L. Thomas and R.M. Rowlett, 1992, "The archaeological chronology of northwestern Europe in Ehrich, R. W. (ed), *Chronologies in Old World Archaeology*, 339-340.

Region	Number	Percentage of total
Northeast Scotland	137	24.4
North Scotland	132	23.5
Orkney	86	15.3
West (S)	**80**	**14.2**
West (N)	**63**	**11.2**
South-west	29	5.2
Central and South East	21	3.7
Perth-Angus	14	2.5

Table 2.1: Regional distribution of Chambered tombs of Scotland. Western Scotland emboldened. After Hunt, 1987, page 14.

The lack of long barrows along with large, post–holed Balbride-type structures, not yet attested in western Scotland, further differentiate the regions at this time. Importantly, the court cairns of Northern Ireland have wedged shaped mounds similar to those of the Clyde, and Severn-Cotswold tombs further south, and though their internal structures are more complex, the basic structure of the mounds indicates a possible cultural connection to the west in the later Neolithic when most of the court cairns are thought to have been erected.[120]

It seems then, in relation to the current project on Megalithic monuments of western Scotland, that in very broad terms at least the Neolithic monuments of this study can be considered to come from, or be a part of, a similar cultural, occupational and economic tradition. However, Hunt states that the social implications of the distinction between eastern, western and northern Scotland must not be exaggerated for patterns of trade or exchange appear to have integrated the resources of all regions of Scotland. For example, Unstan Ware pottery that was found in the chambered tombs of the north was also found in at Balbridie. Also Hunt's own research reveals consistent factors in the siting of burials and settlements which have been noted for these regions.[121] However it is clear that these regional groups were in existence and were already starting to develop by the beginning of the fourth millennium.[122]

By 3000 B.C. significant developments had began to emerge marked by the appearance of the henge and wood and stone circle traditions. Along with stone rows these developments are seen as an emergence of monuments with a '*public aspect*' .[123] This is in contrast with chambered cairns which have restricted access to the chamber from one side or one end and could only contain a small number

[120] *Ibid.*, 340.

[121] Hunt, 1987,*Op cit.*, 77 *ff.*

[122] H. L. Thomas and R.M. Rowlett, 1992, *Op cit.*, 339.

[123] Hunt, 1987,*Op cit*

of people at any one time. These newer styles, on the other hand, allowed for the involvement of greater numbers at least visually, and thus imply a different social format. The eastern and central regions of Scotland account for 76% of henges, with outliers in north and west, with an overall tendency towards location on important route ways.[124] Whilst a few hengiform monuments have been noted in western Scotland through aerial surveys, Ballymeanoch, Argyll, seems to be the only firmly defined fully-fledged henge there. Hunt suggests that here the usual distinction between henge and stone circles may be misleading in these regions. For here, the distribution of stone circles, like the henges, closely follows that of other contemporary site-types, supporting a relationship between them and the principle concentrations of contemporary populations.[125] We find that, Moray Firth, Aberdeenshire accounts for nearly half (43%) of the stone circle forms, and western Scotland in general, accounting for about 13%.

Standing stones have a wide currency in Scotland in general, and whilst they appear in the Neolithic, and are generally considered chronologically enigmatic, their appearance seems to have increased dramatically in the Bronze Age. The regions with the demonstrably higher numbers in order of greatest to least are the west coast (south), with about 34%, central and southern Scotland, second and third, with the northeast region of Aberdeenshire coming last, containing only 9% (see Table 2.2).[126] The Cup marked stones, another enigmatic group chronologically, are also thought to begin with the Neolithic traditions and continue throughout the Bronze Age. Overall, Hunt counts 700 marked stones, *not including* marks on other monuments such as cairns.

Work much more recent than that of Hunt's has examined these site types for more detailed local distribution patterns, such as Bradley's work on cup and ring-marked stones in Argyll.[127] However, numbers gained from Hunt's compilation can be said to be a fair guide of the regional distributions, along with the appropriate warning that his sample is obviously conditioned by the extent of fieldwork at the time (as stated by Hunt himself). For example Dr. Margaret Stewart's work in the Upper Tay Valley provides us with concentrations of numbers there.[128]

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[124] Hunt, 1987,*Op cit.*, 124. As Hunt points out, the disproportionate amounts of aerial surveying must be recognised.

[125] Hunt, 1987,*Op cit.*, 24.

[126] Hunt, 1987,*Op cit.* Constructed from information throughout the work.

[127] Bradley, R. 1997, *Rock art and the prehistory of Atlantic Europe: signing the land.* See Chapter 5.

[128] M. Stewart, 1958, Start Tay in the second millennium BC – a field survey. *Proceedings of the Society of Antiquaries of Scotland,* **92**, 71-84.

Region	Henges	Stone Circles	Standing Stones	Cup and ring stones
Orkney	2	0	39	2
Northern Scotland	2	17	32	12
Western (North)	**0**	**22**	**34**	**20**
Western (South)	**1**	**20**	**159**	**227**
Northeast	10	136	56	71
Perthshire/ Angus	9	59	150	194
Central	8	30	132	95
Southwest	3	35	44	113
Totals	35	319	646	734

Table 3.2: The regional distribution of monuments in Scotland, after Hunt, 1987. For descriptions of which geographical areas are allocated to which regional headings in this table see Hunt, 1987, Op cit., 4. Areas that contain this projects study area are in bold.

Though there may indeed have been a different social format evolving with the development of these open design monuments, the number of people and the specific social format is likely to have been different for each monument type, and, even individual monuments may have had specialised functions. Also, the later Neolithic monuments, along with Bronze Age sites, have a broadly similar but more extensive pattern of "land exploitation" than that of chambered tombs.[129] Further, sites like Temple Wood (near Kilmartin) are seen to be located centrally to important clusters of sites. Hunt suggests that such concentrations with a general spread throughout the region, may be indicative of the emergence by the early third millennium of centres of more than local importance[130]. This contrasts with sites in other regions, such as those on the Caithness lowlands, which are more broadly related to contemporary resources and were clustering is not so marked.[131]

Having placed so much emphasis upon these new traditions it is worth noting that the chambered tomb tradition or at least internment extended well into the 3rd millennium, and was broadly contemporary with activity on the Grooved Ware sites.[132]

Very specific examples and developments

Templewood, from the circle tradition, includes a setting of large timber uprights which were replaced by another of stones and is dated to before 3000 BC (3075 bc ±190; GU 1296).[133] It is especially

[129] Hunt, 1987,*Op cit.*, 119.

[130] Hunt, 1987,*Op cit.*, 123.

[131] Hunt, 1987,*Ibid.*, 123.

[132] Hunt, 1987,*Ibid.*, 120.

interesting that this site may never have been completed, given that it was dismantled in prehistoric times and then covered by a layer of cobbling. It becomes even more intriguing as there is a possibility that it might be contemporary with the standing stones in its vicinity, like Nether Largie.[134] However, at some point the focus of activity later moved to the South-West Circle until the Bronze Age (also see below). It has been suggested that the long sequence of construction and reconstruction of this circle, helps provide a context for the several other monuments in the Mid Argyll and Cowal as well as "making it likely that the stones of Nether Largie may in some way be linked to the function of the site".[135] With its many geographically concentrated and contemporaneous sites, the area from Lochgilphead and Kilmartin may be a societal focal point that was deliberately set up. This region, distinctive by its numbers of sites in close association, may well, like those of Machrie Moor on Arran and Callanish on Lewis, represent or be part of a unified concept.[136] The RCAHMS in Volume 6 suggests that the area from Lochgilphead and Kilmartin may be the result of planning over a long period of time, though "more recent work undertaken on the development of monumental landscapes suggests that they develop in a rather *ad hoc* way – monuments as on-going projects - without a fixed plan guiding the constructional episodes".[137] Examples of monuments within Scotland that tend to be assigned to this form of development include Cairnpapple Hill (henge with internal cove/rings), recumbent stone circles including Berrybrae, Balfarg (henge), and Balbirnie (stone circle) in the east of Scotland and Templewood in the west.

The Bronze Age - c.2750 to c.700 BC. BC.

The environs

Despite the number of pollen analyses available from this region, detailed studies of anthropogenic impact in the Later Neolithic and Bronze Age are very restricted. This is in part due to the broader difficulties of recognising such effects in an area where closed forest may have been the exception rather than the rule in its vegetation history. As described in the environs section of the Neolithic above, woodland was scarce throughout much of the north and west. This was likely due to the extreme exposure, low summer temperatures, short growing season, frequent storms and a high incidence of salt laden spray.[138] The more detailed pictures of the environs in the Early Bronze Age are also similar to those found in the Later Neolithic, with the following changes taking place. Pine advanced to Lewis, eastern Skye and Rum after c 2850-2450 BC, growing on blanket peat. Yet, less

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[133] Royal Commission on the Ancient and and Historical Monuments of Scotland, 1988, Argyll: an inventory of the monuments, **Volume 6**, Mid Argyll and Cowal, Prehistoric and Early Historic Monuments, 10. No 22.

[134] *Ibid.*, 10. No. 222.

[135] *Op cit.*, 10.

[136] *Ibid.*, 10.

[137] *Ibid.*, 11. Mark Gillings, 2002, personal communication. See also J. Barrett, 1994, *Fragments from Antiquity.*

[138] Hunt, 1987, *Op cit.*, 121.

than 1000 years later, c. 2000 BC – 1800BC, a dramatic collapse in its extent occurred throughout Scotland[139]. Climatic influences have been favoured for this decline rather than anthropogenic activity, and "in particular a substantial increase in precipitation over the British Isles"[140]. Interestingly, Blackford *et al* 1992, suggested a link between this pine decline and an eruption of Helka, either through the fallout of tephra or volcanically induced climatic deterioration.[141] Around the area of Lewis and Harris, where prior to c. 2450 BC small local stands of oak, elm and alder existed, while ash and possibly rowan and poplar appear.[142]

Lifestyle overview

Human activity

Walker and Lowe, 1986 and Andrews *et al.* (1987) feel that the earliest detectable human-induced disturbance occurred after 2000 BC. Tipping holds this to be likely on individual islands, like Colonsay, but he feels that such a view can be challenged at most dated sites.[143] Basically, the picture is one of "uneven clearance forays in the woodlands, both in time and scale" suggesting that overall *"no regionally synchronous pattern of clearance is recognisable"*[144]. The evidence comes from a number of studies attended to by Tipping, supported by the SHMP's outcomes as well as Richmond's research. The only distinct pattern, if that is the correct description, to come out of this area is that at 2600 –2500 BC, the majority of sites "show some anthropogenic activity. This is so even at sites which failed to attract attention of agricultural communities at other times, such as Loch Ashik on eastern Skye."[145] So we see that on Western Islay, though some clearance occurred beforehand, *the first major impact was delayed until* c 2500 BC.[146] At Loch a'Bhogaidh, Islay, there is a major clearance at 3600 BP.[147] Opposite Jura, at Loch Cill an Aonghais, much the same pattern occurs as in western Islay with the first major clearance at c 2600 BC, though it is only the first in a number of short-lived incursions, with the landscape remaining substantially wooded beyond 600 AD.[148] Instances of "uneven clearance forays in the woodlands" include eastern Skye where the only clearly discernible prehistoric impacts initial date to 3250 and 2250 BC.[149] However at Loch Cleat, also in Skye at Trotternish, sustained clearance beginning c 2200 BC occurs, creating a treeless landscape by

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[139] Tipping, 1994, *Op cit.*, 27.

[140] Tipping, 1994, *Ibid.*, 27.

[141] Tipping, 1994, *Ibid.*, 27.

[142] Bennett *et al.*, 1990, and Fossitt, 1990, in Tipping, 1994, *Ibid.*, 27.

[143]

[144] Tipping, 1994, *Ibid.*, 28. Italics added.

[145] Tipping, 1994, *Ibid.*, 28.

[146] Tipping, 1994, *Ibid.*, 28.

[147] Mithen, 2000, **Volume 2**, 625.

[148] Tipping, 1994, *Ibid.*, 28.

[149] Tipping, 1994, *Ibid.*, 28.

600 BC.[150] The east coast of Rum shows similar impacts that are thought to be 'agricultural' from c 2950 BC, which led to an increased land usage after 2000 BC without apparent regeneration.[151] Mallaig, Lochan Doilead, shows possible disturbance at c. 3650 BC but no further impact for a further 1000 years. Thereafter at Lochan Doilead, between 2600 BC and 1600 BC small-scale intakes only are recorded, with sustained influence coming only after this until perhaps 500 BC. At Machrie Moor, Arran, there seem to be intense bursts of agricultural activity (arable and pastoral) separated by phases of woodland regeneration and agricultural decline. Clearance stops at c 2350 BC, resumes to a limited extent after c 1950, (P28) intensifies btw 1550- 800 BC. The reduced farming seen after this may due to blanket peat spread and climatic deterioration. P29

It was traditionally held that during the Early Bronze Age the woodland began to regenerate and some time in the middle of this Age forest clearance began anew. However, with the evidence above of the Neolithic period not being the grand defining moment of farming and forest destruction, the idea of widespread abandonment of clearings and forest regeneration can not be strongly sustained. What might be sustained however, is Tipping's interesting proposal that "the presumed synchronicity of the previous 'regeneration' of woodland phase was greatly emphasised by the degree of synchronicity at its end".[152] This latter synchronicity appeared in the form of 'renewed' clearance in the period c 2000-1800 BC, which could rather be looked at as the *intensification* of existing agricultural behaviour.[153] Further it has been previously concluded that sustained grazing pressures, along with " natural reductions in tree populations through soils deterioration, climate change and the spread of blanket peat, … grazing densities needn't be high, just constant" to influence the constant decline of tree populations.[154] Such ongoing events wear away the fabric of a woodland, and so these, along with abrupt anthropogenic events, like the possible felling or burning of trees which are recorded by sudden drops in arboreal pollen, indicate quite a high level of activity.
Such considerations, and the evidence that follows, increases the likelihood that the early Bronze Age was a period of real agricultural expansion.[155]

Economy

As explained above there is no evidence for large scale vegetation clearance of the nature one would expect in cereal based economies until the Bronze Age coinciding with the spread of Beaker pottery through western Scotland, and with the appearance of settlements of substantial architecture and

[150] Tipping, 1994, *Ibid.*, 27-28.

[151] Tipping, 1994, *Ibid.*, 28.

[152] Tipping, 1994, *Ibid.*, 33.

[153] Tipping, 1994, *Ibid.*, 33.

[154] Tipping, 1994, *Ibid.*, 36.

[155] Tipping, 1994, *Ibid.*, 33.

extensive field systems.[156] For example "by 3500 BP ... communities with field systems and round houses had become established on (Colonsay and Islay)" with the majority of woodland being cleared and a settled lifestyle being established, though very interestingly, hunting, fishing and gathering are likely to have continued in some form. Specifically, strong evidence for clearing comes from soil destabilisation from woodland loss at Bolsay Farm on Islay and soil erosion at Colonsay.[157] Charred grains of emmer wheat from Staosnaig, Colonsay suggest that crop grain was being used.[158] On Islay, round houses are found at Ardnave, with a date of 3687±60 BP [2273-1889 cal BC] and at An Sithean, field systems suggest substantial cultivation.[159] At Rossinish, Benbecula, old land surface with ard marks sealed beneath the primary midden preserved is considered direct evidence of agricultural activities (dates from middens are 2385 ± 112 BC, 2481 ± 112).[160] Permanent house structures, which are likely to date from the second millenium were found at Kilpatrick, and Tusmore, Arran, Ardnave on Islay, Sorisdale, Coll and Cul a'bhaile on Jura.[161]

As the Bronze Age ends, further climatic deterioration occurs. Despite this, Tipping concludes that the widespread dereliction of marginal land (as postulated by Burgess in 1985) is in doubt.[162] With this climatic degeneration occurring during the times of Bronze and Iron Ages it may well have become increasingly difficult to rely upon the usual natural resources that Mithen and others have argued were still a significant part of the economy until then. Perhaps these natural resources were under threat. This being the case, various forms of agricultural production may well have been taken up more rigorously to aid the subsistence levels, rather than the other way around. Basically their environment was under stress so the Bronze Age, and later Iron Age peoples, had to gain some control over their resources. It is interesting to note that during the Bronze Age the majority of sites have both arable and pastoral elements and that there are no clearance events characterised by cereal pollen only, supporting that mixed farming was an ubiquitous event.[163] This may also support the idea that even on the most fertile lands the conditions were such that a single form of controlled resource was not enough to support the populations, although Tipping argues that at the subsistence level agriculture would probably require the maintenance of both.[164] As well as this it may even just mean that people preferred variety, as they always had done up to that point, even when completely relying upon natural

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[156] Mithen, 2000, **Volume 1,** 35.

[157] Mithen, 2000, **Volume 2,** 625.

[158] In keeping with Richmond's theory that appearance of agriculturally derived grain is not evidence for the growing of grain, but rather the use or even, perhaps, the production of secondary foodstuffs, the current author, does not support the conclusion of crop agriculture taking place at Staosnaig.

[159] Ritchie and Welfare, 1983, and Barber and Brown, 1984, in Mithen, 2000, *Ibid.,* 35.

[160] Hunt, 1987, *Op cit.,* 134.

[161] Hunt, 1987, *Op cit.,* 137.

[162] 1994, *Op cit.,* 33.

[163] Tipping, 1994, *Op cit.,* 36.

[164] Tipping, 1994, *Op cit.,* 36.

resources. But here comes the circular argument. Did the Mesolithic and prior populations preferentially choose to have a variety of natural resources or were the demands such that it was necessary to do so to survive? So the argument as to variety being a preference or a necessity in the Bronze Age has not yet been established.

Monumental construction

The Bronze Age is noted for the continuing and intensifying traditions of standing stones, carved stones, and cremations, the likely introduction of cist burials, and a variety of cairn styles. In western Scotland, 40% of the burial sites are accounted for by poor quality land, a larger than comparable figure for Southern Scotland and almost 4 times that of Eastern Scotland.[165] This likely reflects the harsher topographical constraints and the degree of land quality reversion in these times. When the distribution patterns are detailed however, a strong bias towards better quality area is still marked for the area.[166]

Like the Neolithic before it, the Bronze Age reused sites by modifying their structure, and with this Age came the initiation of closing formally open-plan monuments. Basically those sites which began as an open enclosure, or sequence of open enclosures, were increasingly taken over for the construction of burial cairns".[167] With these modifications, many of the Neolithic monuments frequently appear to have served as loci of activity into the orthodox Bronze Age. The South-West Circle at Templewood, for example, had innumerable additions from the early to the late Bronze Age. Beginning perhaps with the uprights of the circle, their role as free-standing monoliths were altered by the "addition of smaller orthostats designed to fill the spaces between them" forming a closed ring.[168] The monument is then used for burials, within and without the circle, first stone cists and later cremation burials. The ring of uprights formed an internal revetment of a bank of stones that enclosed the stone circle and covered the outer west and northwest kerb cairns. The final action appears to have been burying the entire perimeter wall with rubble, extending across large parts of the interior, but possibly with the original stone circle protruding above this.[169] Effectively we now have open monuments with a possible internal public forum reverting to closed, unapproachable spaces. What has happened to the notions of open space, public forum and circularity? Did they disappear? The current research project on Megalithic monuments in western Scotland will show that these notions, rather than disappear, actually expanded, encompassing not just the area designated to symbolise

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[165] Hunt, 1987, *Op cit.*, Table 30.

[166] Hunt, 1987, *Op cit.*, see pages 138 and following.

[167] Bradley, 1998, *Op cit.*, Figure 45, 141. See Chapter 9 of Bradley for general discussion of topic.

[168] *Ibid.*, 10. No. 222, 142. Bradley states that the "first major alteration to this monument involved the building of a low stone wall joining the base of the original uprights" with the additional slabs placed between the original uprights after this.

[169] Bradley, 1998, *Ibid.*, 136

previous cosmic notions but came to include the largest circular property that one could envisage/experience, that of the horizon.

Final say on the Ages

It is generally believed that in the British Isles, the traditionally viewed "Mesolithic culture persisted much later than on the Continent because the beginning of the (traditionally viewed) Neolithic cannot be placed much before a (conventional) mature Neolithic appeared in France and the southern Low Countries".[170] It is clear from the calibrated radio-carbon dates listed within Thomas' and Rowlett's 1992 paper for the British Isles, as well as those provided in this work, that the Mesolithic survived well into the fifth millennium in England and perhaps even later in Scotland and central and south Ireland.[171]

We find too, that the Early Neolithic is a marked contrast to the marine-dominated diet of the final Mesolithic. Overall the Neolithic of western Scotland can be summarised by the following words of the SHMP project:

> The Neolithic appears to arise from the adoption of new economic, social and ideological ideas, perhaps spreading from immigrants elsewhere in Scotland, by an indigenous Mesolithic people who created a mixed economy including foraging, herding and a limited amount of plant cultivation. As such, the Neolithic does not appear to constitute an economic or social watershed in the southern Hebrides. If one of these dates exist, then the date of *c.* 3500 BP is a far better candidate.[172]

For western Scotland it is the Early Bronze Age, then, that is identified with more intensive forms of farming, whether, that means pastoral or cereal or a mixture of both.

It has been shown, overall, that we cannot clearly define what it is to be a person of the any of three ages by simply applying the terms Mesolithic, Neolithic, or Bronze Age in the ways they were used in the past. The application of the original definitions, in regards to the use of specific technology only, were purer and clearer forms of usage, but, nevertheless, tell us little about the peoples. They were not designed to do so, but with time they were used as if they did. This was done by employing economy, pottery production along with tool technology, as useful threads to the understanding of prehistoric lifestyle or lifestyle management. As has become apparent, it is very doubtful whether we can meaningfully separate the Mesolithic from the Neolithic period, or the latter from the Bronze, by such structured considerations. In this work, these Age labels are used as rough chronological guides only,

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[170] H. L. Thomas and R.M. Rowlett, 1992, *Op cit.*, 333-334. The author has inserted the bracketed words for they fit the reality of the conclusions of the quoted work and thereby indicate one of the conclusions of this work, that cultural behaviours overlap the Ages previously attempted to contain them.

[171] *Ibid.*, 334. See Tables 1 and 2 on pages 292 and 293 for listings of finds and dates.

[172] *Op cit.*, **Volume 2**, 625. These conclusions are supported by Richmond's research into the nature of subsistence across Britain generally and Hunt's and Richmond's works across Scotland, more particularly.

or more specifically, point to one very general time that preceded or came after another. For the Neolithic period read c. 4500 BC to c. 2750 BC, and for the Bronze Age read c. 2750 BC to c. 700 BC.

Chapter 3

Theoretical considerations

How theory affects methodology

Introduction

Whilst not going intc any great detail into the actual research done by processualists or post-processualists specifically, this chapter investigates fairly thoroughly the basic theoretical concepts that these two trends either adopted or fought over. The aim here is to understand, or see, how philosophical theory can affect the development and use of particular methodologies. In addition, it shows that forms of metaphysics were incorrectly put aside by the Logical Positivists only to be highlighted once more by the earlier trend of the post-processualists. Having said this, the term Logical Positivist does *not* directly accord with that of processualist, but is often used, as is the word positivist, and can make for some confusing debates.

Moving on from these the chapter looks at the ways material culture, beliefs and cosmology can be related and how the study of the first item makes it possible to come to know something of the latter two.

The chapter then returns to some notions addressed in previous chapter, that of the use of Age labels. It briefly addresses, further, theoretical flaws not discussed previously, especially how these Ages were often used to indicate changes in the lives of the prehistoric peoples. Chapter 2 expressed the belief that such Age labels should usually be cast aside except to indicate the simplest point, that of chronology preferentially. It is here further suggested that the study of changes in the lives of the prehistoric people may be attended well by the study of material culture and a possible concomitant change in the minds of people. To do this, Chapter 3 investigates a previous study that used monuments in an attempt to understand why people's behaviour changed. This study, by Richard Bradley, postulated a theory that linked behavioural change to a change in ideas, specifically the ways in which prehistoric people's constructed or saw their world. This study can be found his *The Significance of Monuments*.[1] It is used here as a demonstration of the possibilities of reasoned interpretation and, very interestingly, a philosophy that has in fact developed out of the traditions of Analysis and formal Logic, if not a reference to scientific or mathematical discourse.

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[1] Bradley, R. (1998). *The Significance of Monuments*.

Overall the aim of this chapter is to review the methodological implications of theory to demonstrate the origins of the methodologies of this study.

Two main trends: processualism and post-processualism

Philosophical fundamentals

Much of the Newer archaeological theories process of the 1980's onwards have "contested the New Archaeology's, philosophical basis, substantive interests and explanatory capabilities".[2] As many archaeologists rightly point out, the reactionary movement was not confined to their own field,[3] Often named processual (or even settlement-subsistence archaeology) the philosophies and methodologies of the 1970's are seen as a response to traditional archaeology, "which was primarily descriptive and concerned with defining culture-history"[4]. Culture-history can be defined as a narrative approach that focused upon circumstance (events) to an almost exclusive degree. It is also said to have relied on Inductive Reasoning.[5]

By attempting to formalise the intellectual process through adopting the scientific theory of knowledge and its concomitant methodological practices (verification), processualists claimed they were more assured than could be culture-historians of the validity of their knowledge as well as that of the conclusions they could draw from this knowledge.[6] It is often held that processualism is based upon positivism when in fact it is based upon logical positivism (the former commonly used as a short hand for the latter at least since the 1970s). Positivism is the view that all true knowledge is scientific, in the sense of describing the co-existence and succession of observable phenomena.[7] Named by

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[2]David Whitley, 1999, *Reader in Archaeological Theory: post-processual and cognitive archaeology*, 1.

[3] Including Ian Hodder, 2002, *Archaeological Theory Today*, Chapter1; Whitley, 1999, *Ibid.*, 1.

[4] Whitley, 1999, *Ibid.*, 3

[5] Renfrew, C. and Bahn, P. (1995). *Archaeology: theory, methods and practice*, 540. Inductive reason is ****. If this really is the case, however, it is odd that one is dividing the culture-historians from the processualists on this account, for the processualists, in a brotherhood stance for scientific method and an attendance to the theoretical school of Logical Positivist (see below) would have embraced inductive reasoning on the grounds of the power of generalisation.

[6] Whitley states that this form of scientific methodology was current in the 1950's and less so in the 1960's. However, hard sciences today still base their scientific *methodology* or *experimental analyses* upon it. Which is not to say that scientists do not look for ways of knowing things differently at a theoretical and methodological level. In addition, scientists adhere very much to the idea of observation being a key to Truth or True knowledge (see discussion on positivism). However, methodologically speaking only, this observation can sometimes take the form of indirect evidence at least for the point of possible discovery, whereby the observation of one event indicates to scientists the likely existence of another. For example: at the simplest level, the images displayed on oscilloscopes, attached to gamma-ray detectors or radio telescopes, are readable signals, which may be defined as indirect evidence. More complexly: the existence of gravitational waves, though never observed directly, are supported by the fact (observation) that certain astrophysical objects are seen to emit less energy than is theoretically predicted in astrophysics, with the observed difference being equal to that energy that is predicted to be emitted by gravitational wave radiation Einstein's theory of relativity.

[7] A. Bullock and O. Stallybrass, 1977, *The Fontana Dictionary of Modern Thought*, 488.

Auguste Comte in the 19th century, it was simply the avoidance of all speculation and, similar to the philosophies of the Epicureans of the Greek Hellenistic world, and the Roman thinkers that followed, such as Lucretius, it was based on the surety that all truth can be known through sensory data alone.[8] Logical positivism, however, developed in the 1920s, and is based upon the following:

a. Philosophy consists purely of Analysis,
b. conducted with the assistance of formal Logic
c. with a view to the logical reconstruction of mathematical and scientific discourse.

(a) Where Analysis in the 20th century, as originally conceived by Bertrand Russell and G. E. Moore, allows for the "discovery of verbal forms of expression for complex ideas and Propositions which make explicit the complexity that is hidden by the more abbreviated character of the usual verbal formulation"[9]. The process of Analysis allowed for the creation of "defining terms that were more elementary and unproblematic than the terms being defined".[10]. For instance the term "cause" can be defined as "invariable unconditional antecedent", as done so by J.S. Mill. It is related to the Empiricism of Locke, Hume and Mill, which sought to show how "complex Ideas (e.g. material object, cause, person) with which the mind thinks about the world are composed of simple ideas acquired through the senses".[11]

(b) Though Logic is seen as the study of Inference, it concerns the "rules of valid inference" by which the premises of the inference (eg. this is red) entails its conclusion (this is coloured) and may be distinguished from those whose premises are not. Basically for each of the entailments there is a corresponding rule of valid inference (from this is red, infer, this is coloured). Importantly, Logic is formal and systematic, where application of the former requires the use of an indefinite number of abstract inferences, each one being particular.

(ci) It is easy to see the connection with philosophical Analysis and point (c) above. For, by making concepts explicit and refining them in a sense to simpler ideas, we have moved to that form of Analysis based upon mathematics and its attendant discourse, in particular to that of calculus. Initially calculus was formulated using intuitive notions, but later it was realised that precise definitions are

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[8] The Epicureans, though, would add that "right thinking" along with sensory data would lead us to truth. As to what "right thinking" was - it meant avoiding all untrue and improper thoughts. Improper thoughts included all those not based upon rational forms of thinking. The above can be summarised by the following statement of Lucretius: "darkness of mind must be dispelled by insight to nature, and a scheme of systematic contemplation." *De rerun Natural*, Book II, lines 56-61. Similarly, the rationalists of the 17th century like Spinoza. To define these further is to go beyond the scope of this chapter.

[9] A. Bullock and O. Stallybrass, 1977, *Op cit.* 20

[10] A. Bullock and O. Stallybrass, 1977, *Op cit.*, 20

[11] A. Bullock and O. Stallybrass, 1977, *Op cit.*, 21

required to guide the correct handling of limiting processes within calculus.[12] This is done in the following manner. By finding a case(s) for which our intuitive ideas do not hold we highlight the shortcomings of using intuitive thinking. We can then use this case to *refine* our initial, intuitive idea into a more rigorous statement. For, by altering our initial, intuitive idea to encompass this new case more correct expressions of definitions and theorems can be produced for the process under examination. The steps of Analysis, though, do not stop here they are continuous. We then find another case that does not hold for our new statement, and refine our new statement further, and so forth. In the eyes of the Analysts, by this iterative process we can arrive at a truly rigorous statement. Through the use of the counter cases, they refined intuition to the point where correct formulations of definitions and theorems can be found and rigorous proofs given.[13, 14] It can be seen, that up to a point, the methodology is a metaphor of infinitesimal calculus itself.

(cii) To Logic is attributed the making of definitions more rigorous in a way parallel to that used in formal mathematics, like the system of Logic developed by Gottlob Frege. This means that definitions used in Logic can be manipulated in a fashion similar to symbols used in algebra. Frege's work is based upon predicates, which essentially describe a subject; it is a quality. It is interesting to see then, that what the Logical Positivists proposed in the 1920s, "the logical reconstruction of mathematical and scientific discourse" had already begun with logician and mathematician Frege.

(ciii) Modern Logic is based upon the logic of predicates, or Predicate Calculus, which is the formalisation of the use of predicates within a rigorous mathematical framework, or Quantification Theory. For Predicate Calculus, Quantification Theory (QF) is understood to mean that a quantifiable formula does not necessarily mean quite the same thing in ordinary language. A QF is an exact, defining statement allowing the manipulation of the order of predicates according to a systematic formula. The QF removes the ambiguity present in ordinary language. Thus the connections to mathematical discourse, in particular to algebra, are clear for the use of predicates in Logic. So too, the use of rigorous, simplified definitions can be seen to be a reconstruction of a part of the discourse for scientific method.

(civ) Modern Logic is also based upon the logic of compound propositions or Propositional Calculus or Truth-Function. A Truth-Function is a compound proposition "whose Truth or Falsity is unequivocally determined by the truth or falsity of its components for all possible cases".[15] Therefore if one component is false then the Truth-Function is false. This form of reasoning is referred to as extensional and holds that all compound propositions are reducible to truth-functions of their ultimate

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[12] A. Bullock and O. Stallybrass, 1977, *Op cit* 20

[13] A. Bullock and O. Stallybrass, 1977, *Op cit* 20

[14] Christian Killow, Department of Physics and Astronomy, University of Glasgow, gave assistance in the form of private communication on the workings of calculus and the understanding of points found in A. Bullock and O. Stallybrass, 1977.

[15] A. Bullock and O. Stallybrass, 1977, *Op cit.* 648.

components. It is here that Modern Logic has strongly influenced traditional 20th century scientific discourse and method with the latter's use of reduction. For science uses the notions arising from "to be reducible to truth-functions of their ultimate components", to test for an example of the particular (component) so that they might generalise to the whole (compound proposition). Hence scientific conclusions are often drawn from Generalisations.

It should be noted that (ci), (cii), (ciii) and (civ) have influenced the notion and development of hypothesis construction and testing in scientific procedure, or at least developed alongside of LP.[16] Loosely an hypothesis is a supposition made as starting point for an investigation. How that supposition is created and used is nowadays formulated via the hypothetico-deductive (HD) method, and a more apt definition becomes a "supposition made as a basis for reasoning, without the assumption of its truth"[17], for it is the truth of the matter that you are testing. (cii) and (ciii) are particularly linked to the creation of simplified, unambiguous statements, the components of which can be manipulated easily to create hypotheses and alternative hypotheses to be tested. These components may be words (themselves abstract representations), mathematical symbols etc. (ci)'s link to the H-D method and the scientific method generally is two fold: its use of the discovery of cases that *do not hold* for our ideas or statements and its iterative procedure. Very simply put, this is because the HD methods argue that hypotheses must be tested through a sustained search for negative instances. The iterative procedure is used in a similar way to that of Analysis, once a hypothesis (that states a certain condition) has been tested, the theory is modified accordingly and another test devised to test the truth or falsity of that, and so on. The end of (civ) explains how science is connected to the "Truth Function" of Logic. Somewhat bizarrely, theories are held to be unprovable until proved false not until they are indeed verified (verification) in the H-D. This is not to be confused with the idea of being able to disprove an hypothesis. Very interestingly, H-D is further connected to Analysis for it allows the used of intuitive thought as a first step, where the "(e)nlargement of our provisional knowledge begins with the conversion of the hunches or other imaginative insights into hypotheses".

A final few words on the stands taken by the school of Logical-Positivists now follows. Their doctrine included the assertion of the meaningless of metaphysics, which "it held to consist of all propositions that are neither verifiable by empirical observation nor demonstrable as Analytic".[18] Metaphysics is the investigation of "what really exists" by rational argument as opposed to direct or mystical intuition. However there are two forms of metaphysics. One is transcendent, for it holds that what really exists lies beyond the reach of ordinary experience whilst that of the immanent form, takes reality to consist "exclusively of the objects of experience".[19] The author is certain that it is the

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[16] Karl Popper's book, *The Logic of Scientific Discovery* was published in 1934.

[17] H.W. Fowler and F.G. Fowler (eds), 1964, *The Concise Oxford Dictionary*, 1344.

[18] A. Bullock and O. Stallybrass, 1977, *Op cit.* 356.

[19] A. Bullock and O. Stallybrass, 1977, *Op cit.* 356

transcendent form that the Logical Positivists (LPs) object to on the grounds of lack of empirical verification, whereas it is possible that conclusions drawn from rational argument based upon exclusively of the objects of experience might be empirically verified. It may be true that the use of the immanent form of metaphysics does not guarantee Analytical logic by the metaphysician, but is it true to say that all its propositions cannot be demonstrable as Analytic? Even if both objections were true, it seems odd that the LPs would so fully object on these counts, for *formal concepts* of Logic themselves, which one might think the LP would be in favour of, include *a priori* concepts. These *a priori* concepts either allow that the mind is constitutionally endowed with concepts or ideas which it has not derived from experience or that there is knowledge which does not depend for its justification on experience. Further than this, the latter do not have to be Analytic in character. There appears then, some inconsistency in the application of formal Logic by the LPs. Finally, there is a form of metaphysics that clearly supports some aspect of scientific method. The latter is dependent upon objects of experience, as are those for immanent metaphysics. Admittedly how these objects of experience are defined may well include items that cannot be directly observed (like thoughts or gravitational waves) but by definition it clearly has to include objects that are. From this we can possibly see the connection to "support by indirect evidence" as well as direct.

It is on these latter grounds alone that we can say that post-processualism does not need to hold a theoretical stance against LP but rather, perhaps, the *methods* pulled out of LP by various processualists. For not only is imagination and reasoned hunches allowed as part of the intellectual process, but forms of intuition via the grace of the Analytic method are expected. In addition, through immanent metaphysics lies the possible axiom behind both direct and indirect evidence. It is possible too, that *a priori* concepts would appeal to some post-processualists. Remembering that these *a priori* concepts either allow that the mind is constitutionally endowed with concepts or ideas that it has not derived from experience or that there is knowledge that does not depend for its justification on experience. Here formal Logic, through *a priorism* accepts emergent properties. For not only is it accepted that there is a mind, but there is the possibility that either the mind can creates its own ideas and concepts. So, as ideas can develop within people without them having been cause by the outside world, there is a stance to made for post-processualists who feel that may processualists looked only to those events that occurred outside of the body and influenced the behaviour of the person. Apart from behaviourists themselves, other forms included the functionalists who focused upon economy, technology and the climate and so forth .It seems that even for the evolutionary-minded, that some ideas or concepts may indeed be innate could be find theoretical grounding in *a priorism.*

Processualism and post-processualism

So we have, quite interestingly come across strong Analytic and Logical positions that actually support many theoretical and methodological points brought up by processualists as well as post-processualists. It appears that the divide should not be so great after all, even at the most fundamental levels. Also it is inappropriate or misplaced that processualists are called Logical-Empiricists and then criticised for a highly narrow view and application of the scientific method and so forth. For Logical-Empiricism (LE), though this movement arose in North America after the collapse of the school of LP, does not actually contain the fundamental difficulties that the post-processualists find so distasteful. LE was a doctrinal shift from LP "most notably a remission of the anti-metaphysical fervour of the original LP and a less polemical concentration on the task of articulating or reconstructing in a logically explicit and rigorous form of concepts and theories of discourse, above all mathematics and natural science".[20]

As we know the group that not only came after the processualists, but also often opposed much about them, are labelled post-processualists. Hodder states that

> Much of the critique of processual archaeology was about theory rather than method, and the main emphasis was on opening archaeology to a broader range of theoretical positions, particularly those in the historical and social sciences.[21]

Though this often appears to be the reading of the evidence it seems too that in the discussions of post-processual archaeology, theory and method sometimes become entangled, and that methodology was indeed central to some of the opponents of processualism. Often, too, the post-processualists who "formed" as a response to processualists, often define themselves in terms in opposition to processualism: for instance, processualism doesn't do A but as post-processualists, we do A. Peebles paper does this, albeit in a fairly sophisticated manner.[22] One of Peebles' major aims of was "to show that neither positivism (read LP) nor behaviourism is necessary to the practice of archaeology as a science".[23] The position adopted in paper was that

> *... history, representations, mind and mental events have been eliminated from the archaeological research , not because they lack theoretical interest or have no analytical utility, but because they did not fit into a very restrictive definition of just what comprised a properly "scientific" archaeology. Their exclusion was in large part of the quest to distance archaeology from archaeology from history and embed it firmly in the scientific as opposed to the symbolic part of anthropology.*[24]

Prior to this he has stated that he believes that it is worthwhile to ask why archaeologist have abandoned the notions of history and historical methods as worthwhile pursuits as well as "why

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[20] A. Bullock and O. Stallybrass, 1977, *Op cit.* 356

[21] Ian Hodder, 2002, *Op cit.*, 1.

[22] Christopher Peebles, 1992, "Rooting out latent behaviourism in prehistory". In Jean-Claude Gardin and Christopher Peebles (eds) *Representations in Archaeology*, 357-384.

[23] Christopher Peebles, 1992, *Ibid.*, 357.

[24] Christopher Peebles, 1992, *Ibid.*, 357-358.

mental events – human intention, cognition, and representation-play little or no role in much of contemporary archaeology?"[25]

In these ways Peebles is telling us what he is, by emphasising and pointing out what he obviously is not. He is not a researcher who spurns such topics. Two responses need to be made at this point, whilst it can be supported that history, representations, mind and mental events have *often* been eliminated from the archaeological research in the 1960s, 1970s and even in the 1980s, they were not completely eliminated but *were* highly opposed and often not addressed in research. Secondly, as has been shown above, even a strict definition of *scientific method*, though not for one option of LP, would have allowed for the inclusion of these things. It could have been only the appearance of a lack of scientific rigor, not the actuality of it, that pushed people away from these areas of research, and perhaps too, the philosophical stance perhaps of transcendent metaphysics. It is likely that some researchers looked to the main school of LP without trying to investigate metaphysics itself or even formal Logic for that matter and its use of *a priorism*. In fact, surely, like "there is more than one brand of post-processual archaeology"[26], there is more than one version rigorous scientific method and more than one form of processualism.

It is proper to add, though, that in implying that "history, representations, mind and mental events did not lack theoretical interest or have no analytical utility", Peebles has been supported by the investigations above. It is likely too, that in the view that many processualists may have been following the LP, he is then likely to be correct in stating that "because they (the representations etc.) did not fit into *a very restrictive definition* of just what comprised a properly "scientific" archaeology (my emphasis)" they were shunned.[27]

Having seen above how much of both Analysis and formal Logic can fit the aims of both processualism and post-processualism, a brief consideration is given to the relation between material culture and belief systems and thence to prehistoric cosmology. In finishing this chapter, how beliefs may be said to arise and manifest themselves in material culture will be viewed with a thought to the significance of monuments.

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[25] Christopher Peebles, 1992, *Op cit.*, 357

[26] D.S. Whitley, 1992, Prehistory and Post-positivist Science. In Michael B. Schiffer, *Archaeological Method and Theory*, 58.

[27] Christopher Peebles, 1992, *Op cit.* see his arguments on processualism's weaknesses or limits as well as its positive application to archaeology itself, page 360

The relation between material culture and belief systems

The relation between material culture and belief systems is often viewed through the eyes of cognitive archaeology (CA) and cognitive-processual archaeology (CPA) and is often encamped in the post-processual movement for its avid interest in the mind as well as its interpretive stance.[28] This is somewhat based on the earlier social sciences' interest in the cognitive formulation to explain "culture as a system of values and beliefs, or in a word, a worldview".[29] Hodder, just quoted, lists a number of ways that the various researchers in his book have chosen to explain relationships or connections that exist humans and material culture. Also in this list are the connections between mind or rather thought, and material culture, and in particular thought as a worldview. In listing the number of theoretical stances, it does in fact demonstrate that material entities and human beings connect on a number of levels. In fact Hodder states that material culture has a role to play in "what it means to be human and that Humans and things are dependent upon each another".[30] For instance as La Motta and Schiffer, argued, behaviour includes people and objects for behaviour includes action upon something, and when that thing is acted upon, a reaction will result, which affects further action. Leonard in Chapter 3 argues fascinatingly from a geneticist's viewpoint and goes so far as to say that material culture is part of the human phenotype and reflects characteristics that are manifest in the individual. Mithen's work on cognitive evolution shows how religious thought might become dependent upon material objects. This form of dependence may evolve by an action that helps make religious entities memorable, transmitted, and shared, enough even so that religious institutions can be formed. Leach argues that we convert religious ideas into material objects to give them relative permanence so that they can be subjected to operations that are beyond the capacity of the mind.[31] The first half of this argument is runs parallel to that of Donald's (1991) external symbolic storage idea found in Renfrew in Chapter 5. This list of how material culture is linked to the mind shows us that belief systems (like religion and cosmologies) are connected to the objects around them. In fact, the external storage notion is very appealing. To use Hodder's words then, it is being argued, that regardless of some of the theoretical differences, the thing that brings these divergent researchers together is that "an understanding (that) human behaviour, agency and culture needs to include a close study of the ways in which human beings depend on the material world". Methods then, are required to be developed.

In Hodder's words, at the analytical level; a separation is usually made between the objective physical materiality and the meaning assigned to it. Material culture itself is universal, yet "its use, form, substance and symbolic meaning are (seen to be) culturally relative".[32] The division of meaning from

[28] D.S. Whitley, 1992, *Op cit.*, 59.

[29] D.S. Whitley, 1992, *Ibid.*, 60.

[30] Ian Hodder, 2002, *Op cit.*, 9.

[31] Leach, 1976, *Culture and communication*, 173. In Ian Hodder, 2002, *Op cit.*, 110.

[32] Ian Hodder, 2002, *Op cit.*, 7.

object allows archaeologists to sort artefacts into different categories and begin to evaluate their significance in a society. This analytical separateness is seen as helpful in understanding

i) how meaning is assigned and

ii) how relations within society shift

iii) the latter causing changes in the meanings of the objects.[33]

It is hoped that the current study will contribute to the knowledge somewhat in this area. Specifically this study adopts the application of scientific methodology and very rigorous hypothesis testing (which is like CPA) to discover the possible meaning of particular objects, monuments, (Interpretative methodology), specifically to try to discover what the world view might be of past societies of the prehistoric Scotland. The study upholds that if we are unwilling to use the only physical clues of our past for fear of misinterpreting them, then discoveries may be near impossible to make. Conversely, if we extrapolate from which we find now along with that which we know now, we stand a good chance of building a false picture of the past. If we accept that the latter way will give us a result (as opposed to none at all) then we have at least a starting point. From this point we can modify our theories, as we understand our finds better. With careful use of the small amounts of data available to us we can gauge how close (or far away) from the truth our conclusions are. As long as we accept the limitations of our methods then we are no worse off than when we started. With a well-considered approach we should be more knowledgeable of our past.

Changing Tack – Interpretation - different ways of seeing and understanding

Within with the traditional models of development for the Ages that we discussed in Chapter 2, the sense of change that occurs from Mesolithic to Neolithic, from Neolithic to Bronze Age, and within these Ages also, is one of chaos to order: for example an increase in forms of control over one group of people by another within the same.[34] This chaos to order model, is seen too, in the idea of human control over the environment through farming. We are seeing then, that the traditional models of the "Ages" indeed hold further weaknesses, for they adhere somewhat to a flawed philosophical and rather idyllic concept of change that was in favour during the Enlightenment.

There are approaches still being developed to overcome the problem of identifying peoples' ways of life and, perhaps, casting aside the packaging approach. Whilst still using the labels for particular Ages, they attempt to understand how people, singularly and as a group, constructed their world, for this might enable the production of a clearer picture of peoples in the past, enabling the understanding

[33] Ian Hodder, 2002, *Op cit.*, 7.

[34] R. Bradley, 1984, *The Social Foundations of Prehistoric Britain: themes and variations in the archaeology of power.*

of how or why they did, what they did. From our discussion above, it can be seen that Cognitive archaeology could assist in this direction.

The advent of change is sometimes seen as a distinguishing and meaningful factor in the assessment of the mechanisms of behaviour. Once such an advent occurs, and the likely mechanism discovered, it is possible to see if such a mechanism was also responsible for other alterations in the same or different places. In the topics discussed in Chapter 2, for instance, it may well be probable that the mechanism that triggered the use of pastoral techniques also triggered that of agricultural. For instance, it may have been a slow development in climate that culminated in the Bronze Age negative climatic change that affected the way people chose to use the land. Or it may have been a change in outlook or understanding about the relationships people thought they had with their surroundings, or how they "saw" or understood themselves in relation to them. Regarding behavioural triggers, Bradley argued for the latter in 1992. He proposed that rather than Neolithic monuments being a result of economic surplus provided by farming, it was a change in belief system, ways of seeing the world and themselves, which could be attributed to their appearance. Following on from this, Bradley felt it was possible that "the use of monumental architecture … created the conditions in which farming became acceptable".[35] With the evidence presented in Chapter 2 it is now clear that monument building was far more prolific and widespread than cereal farming ever was in the Neolithic period, thus Bradley's idea that monuments were unlikely the result of economic surplus has support. Whether it was a change in belief system, and which belief(s) in particular, is still conjectural. However, the remaining parts of Bradley's theory are still very compelling.

Specifically, Bradley suggests that it may have been *unthinkable*, at one point, for people *to change the natural world by building monuments* (due to firmly established beliefs discussed by Bradley)[36] and, hence the actual building of the monuments can be used as an indicator of a change in what was now seen as possible. The presence of the monuments, in turn, changed both the physical locality of the environment and then the peoples' experience of it.

In much the same way, Thomas' *Rethinking the Neolithic:* "argued that the distinguishing feature of the Neolithic was a new understanding of the world: 'The idea of a way of life which separates humanity from nature may have been more important than the material reality. The appropriation of nature may have been conceptual as much as it was physical (1991, 181).'"[37] For the "Mesolithic people (may not have) considered themselves separate from the natural world. Did not make a sharp

[35] This idea was first presented in a 1992 lecture to the Society of Antiquaries of Scotland, and later appearing as the first chapter to Altering the Earth(1993), as stated by Bradley in his preface of *Significance of Monuments: on the shaping of human experience in Neolithic and Bronze Age Europe, 1998.*

[36] R. Bradley, 1998, *Op cit.*, 14.

[37] J. Thomas, 1991, *Rethinking the Neolithic*, 181 in R. Bradley, 1998, *Op cit.*, 21.

distinction btw themselves and the animals they hunted.[38] In this discussion Bradley seems to be asking "Did the Neolithic people separate themselves from their surroundings intellectually; did they think of themselves as separate entities, living on top of or in their environment, were they self aware?".

From these questions we might ask: did those of the Neolithic think they *were* changing the Natural World when they constructed the monuments? Further, did they differentiate bewteen the natural and the artefactual (what they could make - that is, the possibility of making)? Was what they made (or was the act of making) seen as 'unnatural or interfering' or was it seen as participating in the natural order of creation? The first question has at least two main levels of interpretation: what do we mean by change the Natural world? Do we mean that we have altered the Natural world itself? That is, is our additions part of that natural order of things? Or is what we create separate from Nature? Did those of the Neolithic think so? Certainly there have been philosophers of the 20th Century who support the view that as we are a natural entity or an entity of nature then everything we create must necessarily be natural. All part of the evolutionary deal. But if the Neolithic people thought they were considered to be part of Nature, what was the necessary connecting thought?

We can see from this plethora of questions that it is unlikely that we shall ever know the exact answers to these questions. Thus the actual mechanisms that set in motion the behaviours we can observe could remain a mystery. However, studying the behaviour of peoples can help us narrow the list of possibilities, and with each new piece of evidence in any form, the previous theories and conclusions can become clearer or tighter, or even be dismissed.

The intention of this work is primarily methodological, as indicated in Chapter 1, and the extension of this is the adoption and incorporation of the implications of Cognitive Archaeology's method. In this way it is envisaged to come to know something of the intentions of the individuals or groups, who lived in prehistoric Scotland, through studying their material culture.

[38] R. Bradley, 1998, *Op cit.*, 14.

SECTION TWO

METHODOLOGICAL REVIEW OF SELECTED ARCHAEOLOGICAL FIELDS

In essence the three fields archaeoastronomy, landscape archaeology and geographical information systems (GIS) to be applied in this research are intricately woven. Each of them can be used to enrich our understanding of cosmological representation in the material culture of prehistoric societies. Each can provide particular data formats, methods and theoretical bases. Naturally, many of these provisions overlap heavily, and it is rather the differing emphasis upon, or a novel angle of, the same or similar concept that allows for fresh methodological approaches, and therefore new knowledge, to be revealed.

Chapter 4

Archaeoastronomy and the experimental method

The question of reliable and valid research in the British Isles

We are looking at archaeoastronomy first because, in essence, some researchers in this field developed and applied the experimental method more quickly and more thoroughly to their investigations, than the other fields considered in this work.

Mechanics of Interpretation

In complete agreement with Heggie[1] the astronomical theory of megalithic sites is really a group of theories. Even a single monument may be interpreted in several different ways astronomically: celestial objects may be various and the supposed purpose of megalithic astronomy ranges from calendar keeping to eclipse prediction. What keeps us from placing more, or less, importance on one form of orientation consideration than another? How do we decide, on coming to a site, what we should consider as the intended orientation of that site? For some complex sites, such as Stonehenge, this can be impossible to answer fully. The following presents the major issues that were current in British archaeoastronomy from the late 1970's onwards, focusing particularly upon the issues of reliable and valid research. From there, the discussion moves on to research methods developed for, or applied to, the study of the archaeoastronomical potential of the megalithic monuments in western Scotland.

Thom's Orientation Work:

Alexander Thom was an engineer who used his skills in that area to come to an understanding of the megalithic monuments in the British Isles. Added to his research on metrology, Thom also investigated the *possible indications* of stone alignments of the sites and their possible associations with astronomical phenomena. He went into the field and measured the orientations of the sites

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[1] 1981, *Megalithic Science*, 85.

himself. It is well held that he was "thc **first** to back up his conclusions with statistical evidence".[2] He believed he had found support for low precision calendrical, lunar and stellar alignments[3] and high precision lunar alignments.[4] He then did further work on lunar alignments of extreme precision with his son A. S. Thom, investigating issues of perturbation in the first instance, and then small variable corrections of the declinations, such as variable parallax[5] and concerns of refraction[6], in the second. However, what of the state of his research and his claims of providing informative, accurate results?

Ruggles and Thom - the cry for statistical rigour

Overview

A variety of people from other disciplines added *their* interdisciplinary expertise to further assess the likelihood of highly precise indications in megalithic alignments. Rather than looking at another form of evidence, these people decided to reassess forms of evidence already "brought to bear" by thoroughly investigating Thom's methodology and results. One of these was Clive Ruggles[7]. Thom, Ruggles concluded, could be challenged on any of the following four grounds: archaeological status of sites, astronomical theoretical considerations, method of data selection and statistical analysis.[8, 9] Having looked closely at all four grounds he concluded that evidence was "overwhelmingly against lunar indications of very high precision".[10]

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[2] C.L.N. Ruggles, 1988, "The stone alignments of Argyll and Mull: a perspective on the statistical approach in archaeoastronomy", Ruggles, C. (ed) *Records in Stone*, 232.

[3] A. Thom, 1967, *Megalithic Sites in Britain.*

[4] A. Thom, 1971, *Megalithic Lunar Observatories,.*

[5] The three papers are as follows:

a) A. Thom and A. S. Thom, 1978, *Megalithic Remains in Britain and Brittany.*

b) A. Thom and A. S Thom, 1980, A new study of all megalithic lunar lincs, *Archaeoastronomy* **2**, S78-89.

c) A. S. Thom, 1981, Megalithic lunar observatories: an assessment of 42 lunar alignments, *Astronomy and Society in Britain During the period 4000-1500 BC*, eds. C.L.N. Ruggles and A.W.R. Whittle, 14-61. *BAR* **88.**

[6] *Ibid.*, (ref 5c), see Appendix 1.5, 60.

[7] Then astrophysicist and computer programmer.

[8] As shown in his articles:

a) 1981, A critical examination of the megalithic lunar observatories, *Astronomy and Society in Britain During the period 4000-1500 BC*, eds. C.L.N. Ruggles and A.W.R. Whittle, 153-209. *BAR (Oxford)*, **88**;

b) 1982a, Megalithic astronomical sightlines: current reassessment and future directions, *Archaeoastronomy in the Old World*, ed. D.C. Heggie, 83-105;

c) 1982b, A reassessment of the high precision megalithic lunar sightlines, 1: Backsights, indicators and the archaeological status of the sightlines, *Archaeoastronomy,* **4**, S21-40;

d) 1983, "A reassessment of the high precision megalithic lunar sightlines, 2: Foresights and the problem of selection", *Archaeoastronomy*, **5**, S1-36.

[9] The summary of his critique of Thom's research is set out very clearly in Ruggles' "Recent developments in megalithic astronomy", in A.F. Aveni (ed.), *World Archaeoastronomy*, 17.

[10] *Ibid.*, 17

Data selection and its statistical import

In *Megalithic astronomical sightlines: current reassessment and future directions* Ruggles discusses the three main aims of his work in archaeoastronomy at that time. [11] Namely, to

1) reassess Thom's site data,
2) suggest improvements in the methodology of site work having concluded step one, and
3) carry out new site work.

It is point 1 that we will be concentrating upon in the first instance. Ruggles divided his assessment of the Thoms' work into four levels of orientation accuracy, which was dependent upon the time the work was done. The earliest work was associated with a lower level of accuracy and the latest with a higher.[12] Professor Thom claimed, in his earliest works on lower-precision calendrical, lunar and stellar alignments, that evidence for deliberate astronomical indications to an accuracy of 30′ of arc was found.

Levels 1 and 2 - 30' of arc[13]

This is the primary level at which Thom first worked and published. It includes data from his 1955 and 1967 publications. At this level of the study there do not seem to be any major problems with the choice of sites or orientation data *per se*. As Ruggles points out, there appears to be no prime procedural concerns in Thom's method of site selection for the 1967 publication that would have an influence upon the statistical analyses he performs. [14] Secondly, it appears that in both 1955 and 1967 he included "all the available data".[15] Although this quote was originally restricted to the 1955 data, when he divulged the results of his hunt for the origins of Thom's 1967 data, the conclusion was essentially the same. Further to this, for the 1955 data, there was no bias found in Thom's determination of *what* constituted an *indication*. Any such bias could have influenced the testing of his astronomical hypothesis, that is, it could have statistically influenced the rejection or acceptance of the null hypothesis, where the null hypothesis states that the observed outcome is due to chance factors. There were, instead, rigid selection criteria for what constituted an indication at any given site; indications, therefore, were not preferentially selected in favour of an astronomical hypothesis, or otherwise. Though this strict methodology was not adhered to in the indication selection for his 1967 study, there were not too many instances where obvious unknown or known factors directed the indication choice, for instance, in choosing an intersite indication at a site rather than the intrasite one at the same site.[16]

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[11] 1982a, *Ibid.*, 84.

[12] See footnotes 2 to 4 above.

[13] Each discussion that follows these headings focuses upon issues found at these levels.

[14] 1982b, *Ibid.*, 93.

[15] *Opcit.*, 93.

[16] *Opcit.*, 94.

Ruggles concludes, however, that such instances of selection influence are less problematic than a further issue that arose from this same study: the merging of two distinct hypotheses into one. This merging of hypotheses was brought about by the inclusion of more than one indication type within a single theory.[17] Unlike the 1955 study which only included those orientations that were indicated by structures on the ground, the 1967 study included orientations that were indicated by a combination of a) structures on the ground, and b) features on the horizon that were considered to be indicated foresights by the structures on the ground. According to Ruggles the hypotheses that fit these scenarios are 'Type 1' - it is the structures on the ground that provide the astronomical indication and 'Type 2' - it is "the natural horizon foresights (which) provide the astronomical sightline, and all the structure on the ground has to do is to point out - preferably uniquely - which foresight is to be used".[18]

Apart from this concern, there is the further problem of how to deal with the sites and the information they represent in an analysis of the 'Type 2' Hypothesis. For example, in which direction is the structure indicating, and how do you define the manner in which you chose to make this decision (e.g. - Stone shape, outlier etc.). Secondly, if you feel you have a direction, how explicitly is it pointing to the horizon itself (is it "pointing" a bit downwards, or perhaps towards another structure then the horizon)? Thirdly, if it is pointing to the horizon, is there a broad band of viewing from the backsight along this horizon, or is the kind of indication you have arrow-like, clearly indicating a distinct feature or position on the horizon? Finally, this last example also shows us how difficult it would be to make a decision, if you do not have any predetermined criteria, whether a site forms an indication of the 'Type 1' hypothesis or 'Type 2', without introducing bias in the very first instance. Ruggles, himself, points out the problems this last example can cause in biasing data selection, and its effect upon researcher outcomes. The concern here, is that there is a chance that an investigator could be made to make inappropriate choices, or rather, to make choices in an inappropriate way, when in the field. For instance, if there are no notches in any given indicated stretch of horizon, we might conclude that, if the sightline was significant at all, it could only have been of the on the ground type (Type1 hypothesis).[19] If, on the other hand, we find "one or more notches within our horizon range", it is possible that "we might choose to conclude that the sightline, if significant at all, is of the indicated horizon foresight type (Type 2 hypothesis)".[20] Having said these things regarding decision making in should be noted that in Thom's early work there is no corroborating evidence to support decisions being made in this way. However, such arbitrary decisions in the field *are* possible if you do not set down your selection criteria before you collect your data.

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[17] *Opcit.*, 94.

[18] Ruggles claims that about 20% fall into category 2, *Opcit.*, 94.

[19] *Ibid.*, 95.

[20] *Ibid.*, 95.

It would be appropriate to mention here that there is a further problem with Thom's analysis. Not only are there two different forms of data being used within a single database, *the method of selecting* which indication is which is itself unclear: we do not know how he determines whether a site is an "on the ground" type or not. Such indefiniteness can incur a further loss of data clarity or purity and thus possibly confound any outcomes arising from statistical analysis. It is important to clarify these issues, as indication type may be an important variable when testing the larger hypothesis of the astronomical relevance of sites. [21]

Level 2 - upper and lower limbs - 10' of arc[22]

Despite his above warnings however, Ruggles held that the *real* danger in Thom's 1967 study lay in a second form of inappropriate data choice. This second form occurred when Thom had to decide whether an alignment's sightline could be categorised as an indicated horizon foresight type or not. In this case Thom is said to have been influenced not only by the existence of a feature on the horizon, but also by the declination that the horizon feature turned out to be.[23] Thom included in his analysis, then, those indications that gave a declination associated with astronomical phenomena from within his original site database. This kind of selection procedure is clearly biased, and, of course, appears even more so, when any other background reasoning of Thom's is not included.

The *real* danger in the present author's eyes, though, is not that the outcomes will be biased in the direction of that favoured by the researcher, but that the outcomes themselves will be *completely* invalid. There is a hierarchical order of validity. In this particular case, bias in the direction of that favoured by the researcher is a less fundamental error than that of an initially impure database. Ruggles is quite correct to point out the important selection issues discussed above, upon which researchers must build their investigations. However, by placing two distinct forms of indication data into one data base, and when the indication type is the fundamental basis of your research, you risk the possibility of "clouding" the data. This ultimately means that the data you have will *already* hold the status of "dubious" and, as a result, any outcomes that you have will be unjustifiable. So, regardless of any other previous or later selection biases that occur when analysing or reducing your

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[21] This kind of information is especially relevant then, for studies that wish compare the possible orientation differences between the two data types or to prevent the confounding of data types when a study is to be done on one type only.

[22] Though this new sub-section continues the previous argument of inappropriate data selection, this section focuses on points found within Thom's work where he was claiming accuracy to within 10' of arc.

[23] 1981, section 4.3; and re-reported in 1982a.

A declination can be viewed as the numeric value given to a celestial body's path in the sky. It is the measure of angular distance of a body from the celestial equator. The earth's equator can be considered to be on the same plane as the celestial equator, and so any measurements that are positive can be considered to be north of the equator and those that are negative, are considered as southerly. Strictly speaking the declination value is a co-ordinate.

data, the effect of merging hypotheses can be to invalidate your statistical results and any conclusions arising from them.[24]

Indicated horizon types - differentiating data (an aside)

At this point, it is worth looking at the wording of the second hypothesis (Type 2) as stated by Ruggles. It seems to imply that, if we disregard bias, the natural horizon *features* will provide the astronomical sightline, and all the structure "on the ground" has to do is to indicate, or point out, which feature is to be used as a foresight.[25] This interpretation of the hypothesis, however, does not link into Ruggles' later discussions on selective bias where he points out the problems connected to deciding which kind of indication it is that you have (i.e. either the "on the ground" type only, or the "combination form"). For instance, he later states that if there are no notches in any given indicated stretch of horizon, there is a danger we might conclude that if the sightline was significant at all, it could only have been of the "on the ground" type, and if there were any distinct features within the horizon range or nearby there is a danger that we might conclude that is of the indicated foresight type. This logic of this argument implies that it is possible, regardless of whether it is probable, to have indicated foresights without distinct horizon features, and/or that it is possible to have an on the ground type of indication which might be completely independent any of the horizon features that might exist. This has some repercussions in deciding how to word and test your hypotheses, and how to differentiate between them. This in turn illustrates how important it is to be aware of the implications of your hypotheses and what it is that you are testing for. In order to prevent unclear testing or outcomes it is always best, in the first instance especially, to have hypotheses that are testing for the existence or absence of one condition only.

One other minor point worth mentioning in this search for statistical rigour is, though Ruggles has clearly pointed out that these hypotheses must be tested separately, his following comment may be misleading to those new to the field of statistical ideas and the implementation thereof. He states that "there is nothing to stop us using the same data base" for testing both hypotheses separately. Though this is true, the information that is left out is that you cannot decide *a priori* to test for one effect on a data base, and, finding a negative result for that set of analyses, proceed to test another related hypothesis on the same set of data without statistical penalties. The penalties involved are heavier if it is the actual outcomes of the test that suggest another hypothesis to you and you then chose to test this on the same data base. The penalties usually involved require you to accept the critical value obtained by the test you used, at a much lower level of probability.

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[24] The use of merged hypotheses can only ever be undertaken if previous research that shows that such a merger will not effect the outcome, or will only effect it in ways that are irrelevant to the current research being undertaken.

[25] 1982a, 94.

Level 3 - 3' of arc and recording of 9' arc perturbation in the moon's motion

Overview of A. Thom's and A.S. Thom's 1971 work

In 1971, part of Thom's study was to focus upon hypothesis 2 discussed above, namely that distant horizon features, such as sides of hills and notches, provided natural foresights, and that the "on the ground" structures were used by the constructors to identify the backsight and to indicate which foresight was to be employed. In this assessment then, it seems that Thom did not make the erroneous decision to combine those data types that should be tested by two *separate* hypotheses. He was investigating the possibility of statistical evidence for highly accurate lunar observations. The assumption that lies behind this investigation is that, by using a distant foresight, an orientation upon an astronomical body may be aligned with far greater accuracy than an orientation laid out "on the ground" only[26]. If we only use data from the former group, instead of combining the two, the expected outcome of this investigation should reveal orientations that are of far greater accuracy than those found at his level 2 study. Thom felt justified in going this step further as he believed he had proof of preferential observation from the second level of investigation for the upper and lower limbs of lunar and solstitial declinations to about 10' of arc. At level 3, Thom held that he discovered evidence for the recording of perturbation in the moon's motion and, therefore, lunar observations to an accuracy of 3 minutes of arc. Such outcomes, however, are not supported by Ruggles' reanalysis.

A summary of Ruggles' critique of the Thoms' lunar analyses[27]

The main areas of concern here for Ruggles, as with levels 1 and 2, are the decisions behind the collection of raw data in the field and what is then done with these data. Of the 40 orientation lines that are used by the Thoms, Ruggles claims that only 13 actually indicate horizon features. Of the remaining 27, 21 are not indicated at all[28], 5 cannot be seen due to the intervening local ground and 1 is non-existent. As Ruggles points out, there is a further concern with the subset n=21 orientations. These data appear to have been gathered by surveying "unindicated notches (etc.) in astronomically 'interesting' directions." Apart from the evidence that Ruggles brings forth to explain the possible mechanics of this *modus operandi*,[29] it is easy to glean from the published works of the Thoms,

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[26] In fact, Thom himself was able to make declination measurements himself within 2 minutes of arc by using horizon features as a foresight, rather than being limited to the average direction a monument might be facing using "on the ground" orientation analysis.

[27] Footnote 5 a, b and c deal with the Thoms' work in this area.

[28] 1982a, section 4.4.2 and 4.6, 196. However, his 1982b paper states that "*19* of the 40 claimed 1111foresights are not in fact indicated on the ground at all".

[29] 1982a, 88.

statements that further support these ideas.[30] Of the 13 sightlines that actually indicate horizon features, only 3 were found to represent uniquely indicated foresights.[31]

Ruggles' attempts, in 1981, to remove the selective bias of subjective data choices, by including all notches and dips in the horizon that could have been "equally well indicated by the structures 'on the ground'", and the reanalysing thereof, failed to discover any evidence for the observations of the moons' perturbations.[32] Thus at this level too, Ruggles has been unable to support any of the Thoms' claims.

These finds further highlight the ways in which investigators can directly effect all levels of data compilation and the final results.

Level 4 - variable corrections - 1' of arc[33]

In 1978, 1980 and 1981 A. Thom and A. S. Thom continued to produce works in the area of extremely accurate lunar orientations. The 1981 paper is the largest and most thorough of the three in its descriptions of intent and methodology. This time they chose to omit all unindicated sightlines from their assessment, and each sightline is considered individually.[34] They take into account such small variable corrections as refraction and variable parallax in their calculations of declination, and therefore survey the indications to within 1 minute of arc for the azimuths and 20 seconds for altitude.[35] Here the Thoms claim to have support for orientation levels required by people for eclipse prediction. However, the selection effects that are discussed above, continue to dominate their work. Basically, an orientation, having already been measured and found to be astronomically significant in its calculated declination, [36] then undergoes further procedures that absolutely ensure, *prior to statistical analysis*, that it is not only representative of a lunar perturbation, but of one kind in particular.[37] It is not surprising, then, that they find results supporting the hypothesis that there are,

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[30] See examples from Thom, 1978, 15, and Thom, and Thom, 1981, 24.

[31] In his 1982a paper, Ruggles states the number 15 instead of 13, which, of course, counter balances his use of 19 instead of 21 in the same paper. Further to this, he reports in fig. 1(c), 1982a, that he did the final analysis on 13 of the 15. It is possible, but not clear, that these other two may have been left out because they were not of the dips and notches type and all the remaining "indicated options" may have been of the same type.

[32] 1981; all of section 4.4.4 delineates the steps of the analysis. His summary of the conclusions can be found on page 196. Ruggles specified only notches and dips, he chose to omit other horizon types, such as sides of hill slopes, knobs etc., due to their lack of distinctiveness and 'discernability'.

[33] 1981; see page 19 where A.S. Thom explains that by "using a suitably distant foresight (Megalithic Man) obtained an accuracy of one arc minute in declination", and so forth.

[34] 1981; see section 1.4.

[35] 1981; see page 24 for description of earlier study and page 29 for current study. An azimuth is an orientation reading in degrees, measured from due north. Here, azimuths refer to the orientation readings indicated by the monuments themselves, e.g. axis of a stone row.

[36] 1981, 19. To quote "if we stand at a marked backsight and make careful measurements of the profile of part of the horizon which turns out to contain a significant declination we can assume that we are at a real observing point." This illustrates the first step in the "back to front" procedure of data selection, with the emphasis upon select.

[37] 1981, 24.

indeed, very accurate lunar alignments to be found in megalithic sights. All of these procedures effectively weight the data in the direction opposite to that of the null hypothesis. Moreover, there has been a combined circular and almost circuitous path in the calculations involving the parallax values. It is to these we now turn.

Thoms' astronomical calculations

Before the Thoms' work can be discussed further, it is important to understand some terms used in hypothesis testing, namely expected and observed values or models. Information about a single variable is created by using all information about that variable from the entire population (or what is known about the entire population). This is called the *expected* value or model. The *observed* value or model is information about that same variable seen to operate within very specific circumstances of , or a *subset* found *within*, the entire population. This observed value, therefore, represents a *sample only* of the entire population. In order to discern if an observed value was likely to come from a particular population (expected), they are compared. If they are seen to be significantly different, it is considered unlikely for the observed, or sample, to be representative of the expected model or population.

Calculating the observed with the observed

The Thoms acknowledged the need to recalculate the previously "observed" and expected declination values (δ_o and δ_e), including the appropriate corrections suggested by Morrison.[38, 39] To do so, they chose to take into account the times of day they found the value for refraction and use mean parallax. In their determination of the value of time (t), needed to calculate parallax, however, the Thoms' chose to speculate and use the approximate time of when the monuments were built. Due to the paucity of dating in the archaeological record they were driven to an inappropriate solution. They chose to reckon time (t), and therefore ε (obliquity of the ecliptic), by letting the age of the site (and therefore t) equal that of the initial observed orientation (δ_{o1}). Added to this, the δ_{o1} itself was based on the assumption that the site *was* indeed used to observe eclipses. They then extracted or determined *this observed* ε (ε_{o1}) from the δ_{o1} equation and placed it into a parallax formula to re-calculate a new and final declination (δ_{o2}). So what we have, effectively, is the figuring of probable past observed values determined by initial observed values, themselves based on astronomical assumptions. To see the circularity more effectively, observe the following numbered points:

1) Want to calculate δ_o and δ_e;

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[38] "Observed" is in quote marks because all declinations are, strictly speaking, calculated values; though of the first order.

[39] L. V. Morrison , 1980, "On the analysis of megalithic lunar sightlines in Scotland", *Archaeoastronomy*, **2**, S65-77.

2) Need to calculate refraction; to do so, need to calculate parallax;

3) To calculate parallax need ε; problem, ε varies with (*t*);

4) Reckon *t* by equating with age of site (AS);

5) Let AS equal the time that site was used (i.e. built) for orienting towards an eclipse;

6) Find date of an eclipse that would have been in line with this orientation in the range of times it was known that these monuments to be built (tE)

7) Place *t*E into formula to calculate ε_{o1}.

8) Put this observed ε (ε_{o1}) into the parallax formula and re-calculate a new declination (δ_{o2}).

It is obvious that, strictly speaking, the answer of point 8 (δ_{o2}), leads us back to point 1 (δ_o), where (δ_{o2}) becomes (δ_o). Here then, the Thoms are calculating the observed data to be used in the statistical calculations with information from the observed.

As we are really looking at statistical rigour, one might ask, why is the circular argument being pointed out here. The reason is, that the reduction, for statistical analysis,[40] of any raw datum should not be done by combining the datum with, or making it reliant upon, other data that it itself has been extracted from. Here, the data used to calculate δ_{o2} includes the variable, ε_{o1}, extracted from the calculation of δ_{o1}, which itself includes the raw data of azimuthal readings etcetera. Further to this, the Thoms the *use this same ε_{o1} to calculate δ_e*. This means that the observed (δ_{o2}) and expected (δ_e) *calculated* data are both dependent upon the *same set* of *different* observed calculated data (δ_{o1}), themselves based on inappropriate assumptions of time (*t*). The problem is not necessarily that δ_e has some dependence upon δ_o, rather, it is its *form* of dependence. This operational knowledge of such dependence is valuable. Consequently, the explanation of how the calculation of these final observed and expected values became interdependent is described below.

Calculating the observed and the expected value from the observed

To find any *expected* or observed lunar declination (δ_o and δ_e) you need, in order of effect:

- azimuth;
- latitude;
- altitude;
- ε, decrements in relation to moonset or moonrise;
- inclination of the moon in relation to ε, (if calculation required in relation to standstills -lack of coincidence of the nodes with the equinoxes must be acquired);

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[40] Reduction meaning a form of appropriate modification for analysis, e.g. measured azimuths (orientations), altitudes and latitudes of indications are *calculated* to find the "observed" declination.

- to calculate ε, you need to know about the following variables:
  - the extent and direction the declination or path of the moon is effected by *perturbations* (minor deviations in the moon's motion);
  - note that perturbations themselves are dependent upon the longitudes of the Sun (L_s) and the moon (L_m) measured along their orbits from the orbits of the node (b);

and, finally,

- semi-diameter of the moon (*s*), which itself is dependent upon parallax (p),where (p) is dependent upon the value ε.

Clearly many of these variables are connected and are reliant upon a correct calculation of ε.

Having calculated δ_{o1} in this way, the Thoms now calculate *a mean* value for ε, the original of which they had *extrapolated* from the observed data (δ_{o1}), based on the associated variable, time(t_1). They then use this mean, extrapolated variable, ε_{m1}, to obtain the observed declination (δ_{o2}); finally, these same t_1 and ε_{m1} are placed into an equation, becoming t_2 and ε_{m2}, to calculate the expected data.

Now the fact that $t\delta_o$ and $t\delta_e$ are similar is not an issue in itself, for it is necessary to assume that the expected and the observed data occur in the same time frame. What is problematic, is the dubious status of *t*, given its invalid origins, and the cumulative effect it will have on each variable and each stage of the calculation that is dependent upon it. This leads us to conclude that that any outcome dependent on *t* is also dubious. So not only is t dubious, so too $\varepsilon\delta_o$ and $\varepsilon\delta_e$, and ultimately δ_o and δ_e.

Overall, this shows us how intimately the initial assumptions of a site's purpose (in this case it was presumed from the outset that the sites comprised very precise lunar indications) and the resultant value, δ_o, are connected to δ_e, in the Thoms' study. At no time is there an independent way to calculate the obliquity, ε, in their work.

Such handling of the data can only confound one's results, and using a statistical test at all becomes irrelevant. It is surely likely why, on top of the selection procedures described earlier, the calculated "β values (observed) cluster round (Q) the expected values" in Thom's figure 1.8,[41] and that the residuals (R=β-Q) are so low, prompting the Thoms, therefore, to claim support for even more precise lunar indications. The results, however, merely mimic the dependence of the expected values on the observed data and the assumed (values).

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[41] 1981, 36 and see fig. 1.8, 27.

Cumulative minor inaccuracies

From the above, it can be seen that if any errors are made along the way, such as inappropriate assumptions for the variable t, the cumulative effect arising from this is an impact on the *final variable value,* such as δ_o. Such cumulative effects are of greater import when researching or querying indications of very high precision, where accuracy of minute measurements are required. The effect on more general indications such as major standstills of the moon will, of course, be less.

Further Comments on Thoms' attempts at the iterative approach:

What the Thoms have tried, is an iterative approach to their research. Whilst such an approach in itself is valid, an appropriate use of this approach is necessary for it to lead to reliable information and/or results. The iterative approach entails successive approximations of the expected data you want until you can reach a satisfactory result that is useable in your following analysis; for example, moving from an initial declination to get a rough value for ε. Use of this method is generally acceptable if you are investigating limited forms of accuracy. If not, it is better to get the known date of a similar site and extrapolate from this if you are going to extrapolate at all. Of course there are not many of these, but it would be a good start to start with a known date group similar sites in similar areas, and use the value for ε obtained from a single known site and start from there. Otherwise your testing for second and third order effects (like perturbation, parallax, refraction), will not be valid.

We have been discussing the more theoretical implications of the Thoms' methodology upon their 1978/1981 research outcomes. We now turn to a more experimental or applied analysis of the Thoms' work by reviewing Ruggles' reassessments, seeing precisely how the Thoms' methodology and assumptions affected their results. In *A reassessment of the high precision megalithic lunar sightlines, 1 and 2,* Ruggles attempts a reassessment of all aspects of the high precision lunar alignments of the Thoms', analysed in their 1978, 1980, 1981 papers.[42] He points out that it is important to be able to separate data effects from researcher-imposed ones. We saw earlier, for instance, the importance of determining the exact hypothesis we wish to test and its impact on the clarity of our data ("on the ground" indications versus horizon foresights). In these papers Ruggles focuses upon the issues pertaining to calculated and raw data.

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[42] 1982b and 1983.

Further steps towards statistical integrity

Calculated data

Ruggles firstly investigated the raw site data, altitude measurements, and the effects that refraction corrections may have upon the final calculated values for altitude and declination in the Thoms' work and more generally. To do this, as well as to create a reliable database, Ruggles resurveyed as many sites as possible, weather permitting.[43], so that he had his own reliable raw data base. He also calculated his altitudes without refraction corrections in order to compare his dataset with that of the Thoms, which had the added corrections. He then extracted a subgroup of comparable data from each of the main databases[44] to observe the differences, if any. Having obtained a list of his and Thom's altitude differences, and finding there to be discrepancies up to 2′.6, he then compared them with the "maximum daylight variation expected from the effects of terrestrial refraction".[45] The result of this comparison allowed Ruggles to see that this small variable correction "may well (have) account(ed) for a good deal of the altitude discrepancies" between the two data sets; but in 4 of the 12 cases, differences ranging from 0′.1 to 1′.6, mode 0′.7, still occurred.[46] This led Ruggles to conclude that altitude measures, and the declinations dependent upon them, could be subject to a random probable error up to ± 1′ and Thom's claim, to be able to quote them within 0′.2, is to claim false accuracy.[47] This outcome provides further evidence of the theoretical difficulties encountered when researching the possibility of highly accurate alignments. It also provides further observations of the effect of cumulative errors upon final calculated declinations within some of Thom's work.

Raw data

We have seen the researcher-imposed effects upon data selection and its subsequent impact upon *calculated* data and statistical outcomes. A further enquiry into data selection should also involve a thorough examination of the raw data collected. In 1982 and 1983, Ruggles stressed the necessity of understanding the **full nature** of the data being tested. [48] Ruggles' examination of the Thoms' raw data and the site environs in 1982 led him to see the ease with which it may be possible to find distant horizon features of apparent lunar significance from an arbitrary point in mountainous country.[49]

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[43] 1983, S2. In this way too, he could constantly compare his own data with that of the Thom's and query any discrepancies at each stage.

[44] Where the subgroup is defined as that of "reliable" measurements (status A) and the assumed observing position (as discussed in 1982b) and foresight is unambiguous. Note that n=12.

[45] 1983, S8; see also Table III for altitude differences.

[46] *Ibid.*, S8.

[47] *Ibid.*, S8. Also Patrick, 1979, "A reassessment of the lunar observatory hypothesis for the Kilmartin Stones", *Archaeoastronomy*, **1,** S82.

[48] For instance, see 1982b, S21-22.

[49] 1982b, see S36 on discussion of Line 32.

Arising from this, Ruggles warns, that for a sound study, "we must regard with suspicion any foresights that are unindicated, even if viewed from an archaeological site".[50] With this warning we have come, in effect, full circle to the original idea of avoiding those hypotheses that lead us to collect raw data that may be invalid, such as those of "unindicated horizons.

In Ruggles' second paper there is a great deal more discussion on the raw data issues themselves and the foresights, in particular. There is a "consideration of the inherent uncertainties in the declinations (of the Thoms) due to the uncertainties in the **exact observing position.**"[51] Also considered are: (i) the nature of the foresights chosen; (ii) why these horizon features were chosen above others that were observable in the correct direction and from the same observing position and (iii) the Thoms' method of analysis, whereby the observed data were compared with those expected.[52]

In relation to point (ii), no selection consistency of foresights is found in the Thoms' work by Ruggles. In fact, he finds that some are almost impossible to see or do not stand out above those others nearby in the indicated range from the observing position. Others are distinctly the only feature that exists on the horizon or are the most prominent. All of them, however, have an astronomical declination. Ruggles asks "Is the overall selection of putative sightlines for the inclusion in the analysis free of subjective bias?"[53] He chooses to answer this question by running a reanalysis of the data. To do this he scrutinises all other classifiable horizon features within the lunar bands (the bands that Thom claims to be "observable" at the site), taking indications into account. He then identifies all features within the indicated azimuth range (IAR) and the adjacent azimuth range (AAR)[54], and also identifies those horizon features *outside* of the AAR. Declinations were then calculated for all horizon features listed for further statistical analysis. In this way then, Ruggles believes he had alleviated the selection bias introduced by the Thom's and prepared the way for the next stage of the investigation.

Ruggles' reassessment

We remember that the Thoms' final list of declinations was calculated using corrections (parallax and refraction) based upon which lunar event was **assumed** to be observed in the first place. We also

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[50] *Ibid.*, S36.

[51] 1983, S1.

[52] Where the expected values equals that area of the lunar phenomenon (the mean lunar standstill) flanked by the appropriate "lunar" error bars, called lunar bands by the Thoms.

[53] 1982b, S22.

[54] AAR = extends 5°either side of the IAR.

discussed that, as the "function of any sightline (was) already implicit", it would be problematic for any statistical analysis.[55] We saw too, that at each stage of the analysis the Thoms were increasing the effect of bias as they used these assumptions to calculate ε, δ_0, δ_e, (or δ_m), β (δ_0,-δ_e), Q (expected β {because of its sharing the dating assumptions})and R (residuals β- Q) respectively (where β are the observed declination values and Q the expected).[56, 57] To understand the nature of the impact of this cumulative effect, Ruggles chose to dispense with such assumptions "about refraction and parallax which are dependent upon the event assumed to be have been observed as well as any hidden predilections about the approximate date of the use of the sightlines" for his own comparative analysis.[58] In doing so, his calculations of ε, δ_0, δ_e, and the dependent value β are free of the assumptions the Thom's made.[59] Q too then, is now properly independent of any hidden predilections (deliberate, if unwitting, bias) about the approximate date of the use of the sightlines. Thus, all dependence upon the postulated function of the sightlines (e.g., major or minor standstills etc.) reverts only to the expected value Q, where the postulated function in this case is supported by the null hypothesis of no difference between β and Q.

When Ruggles substituted the new, more reliable, β values, which he calculated by using Thoms' raw azimuths and raw altitude data (as there was no significant difference between their actual raw data measurements) but relying upon his own small variable corrections[60], the difference in the significance of the residual (R) moves from the highly significant results of the Thoms to marginally significant (R = 1′.76, p=.013; i.e. at the 1.3% level).[61] Further to this result, it was shown that the lunar band width greatly effects the outcome.[62] For instance, it was found that when the band width extends just 3′ beyond the outermost targets, the significance level drops (p = .099).

The next stage of the reanalysis involves repeating the entire analytical process using all the horizon features. When this is done "all evidence" in favour of deliberate clustering around the targets (Q) within the lunar bands entirely disappears. The only event that is supported by the results is preferential clustering around solstitial declinations.[63] These results show a lack of support for the

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[55] Ruggles also points this out, see 1983, S1.

[56] Where β = observed values and Q = expected values or expected β.

[57] Let alone all the in between values of δ_1, ε_{e1}, and t_{o1}.

[58] 1983 , S15.

[59] 1983, S15-16 and 18.

[60] 1983. See section 7.

[61] 1983, S25-26. This also assumes the same ban widths. Thom used band widths 58′ - 60′, while in this instance Ruggles used 60′. See Table VIII for list of residuals quoted by the Thoms, S21-23.

[62] For definition of lunar bandwidth see A.S. Thom 1981, 24 & figure I.7.

[63] *Op cit.*, see figure 8c, S24.

data (sightlines) being indicators of complex lunar phenomena.[64], and adds additional evidence that the Thoms' results are likely to be no more than aberrations dependent upon a number of introduced researcher factors.

Existence of Lunar observations at any level of precision?

Ruggles goes even one step further in his analysis, so that, not only does he have reliable basic values for β and Q[65], he also reproduces a range of these values tailored to fit likely eventualities: eventualities in the form of "inherent uncertainties in the measured declinations and the unavoidable variations in the target values".[66] Using a statistical test devised by Freeman and Elmore[67] that supposedly allows an investigator to take these both into account, Ruggles only found limited support for sightlines that were set up after observations of a single occurrence of the lunar event, using extrapolation to determine the theoretical extreme.[68] In the final analysis Ruggles deduced that there was marginal evidence for those sightlines directly linked to <u>observable events</u>, set up in the manner described above (labelled category 2c by Ruggles). This finding was sound regardless of the inclusion of lower level archaeological status lines. Interestingly when the AAR features were excluded, that is those features extending for 5^o either side of the indicated azimuth range, the z values dropped markedly, to complete insignificance.

Ruggles felt that this suggested that the indications were more or less accurate to within 5^o. Though not emphasised by Ruggles, when one looks at table X, this trend is followed by all hypothesis categories, though hypothesis 2c had the largest drop. Secondly, at this level the table actually shows equivalent significance for Hypotheses 2A, 2B and 2C if one is looking at IAR, AAR and Status A only. So there is marginal significance too, for these groups of hypotheses, and we find, if we include IAR only, there remains a slight amount of support for hypothesis 2A, foresight types I and II, also (n=18, z=2).[69]

These further investigations into the *nature* of the small variable corrections has shown that, if not applied correctly, the effects they can have upon the raw data, and consequently the calculated data,

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[64] 1983, S26.

[65] As discussed under "Links to lunar declinations".

[66] 1983, S26. Such as observing position uncertainities, measurement errors (e.g. produced when transforming a measured profile into the hypothetical observed one); see pagesS2, S8 and S9.

[67] P.R. Freeman and W. Elmore, 1979, "A test for the significance of astronomical alignments", *Archaeoastronomy*, **1**, 89.

[68] When testing for all horizon type features and all levels of archaeological status.

[69] Type I: the lunar limb reappears momentarily in a notch; Type II: the lunar limb trickles down or up a sloping part of the horizon. z is the test statistic which allows one to test whether the result that is observed is significantly greater than that expected by chance. See *Op cit.*, 1983, S27 for discussion of this statistic and the formula.

are significant. Understanding how accuracy, clarity and underlying assumptions affect outcomes is paramount.

Ultimately Ruggles wished to see how the data were managed at each stage of the Thoms' investigation. Later, he, in collaboration with Appleton, Burch, Cooke, Few, Morgan and Norris, began a large project to *redress* the fourth ground of contention, that of raw data selection.[70] This project developed into an investigation of methodological practices for assessing the astronomical significance of alignments.[71] This meant that, by default, Ruggles had rectified much of the basic procedure of Thom's approach.

Ruggles, his work and methodology - suggested improvements

Nowhere is Clive Ruggles pronouncement of the need for statistical rigour stronger than in his work of 1984. Here, in sections I:1 and I:2 especially, Ruggles emphatically lays out the vagaries of past archaeological and archaeoastronomical research in this area. In particular, the problems of investigators' personal predilections and the influence they have on research outcomes.[72] He not only points out the problems of rigour required for the application of mathematical procedures, but discusses the rigour required for any facet or procedure within the study of ancient astronomy. He claims "it is clear that a reasoned approach is urgently needed to investigate possible astronomical influences on the design of megalithic sites".[73] Statistical rigour, it should be remembered, is not merely the condition of applying the correct test, but a series of clearly thought out methodological steps that ensure the soundness of each stage of the research, and ultimately, as we have experienced above, the reliability and validity of any mathematical applications.

So, statistical analysis itself is not an independent mathematical procedure, or a list of numerical facts, but is a process that affects, and can be affected by, other levels of investigation. In the end a statistical analysis must include a systematic approach to data collection. It is this systematic approach, more than any other, that Ruggles, and the other contributors of the 1984 work, have attempted to achieve.

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[70] C.L.N. Ruggles, (principal author), P.N. Appleton., S.F. Burch, J.A. Cooke, R.W. Few, J.G. Morgan, and R.P. Norris, 1984, "Megalithic Astronomy: A New Archaeological and Statistical Study of 300 Western Scottish Sites", *British Archaeological Reports*, **123**.

[71] *Ibid.*, 18.

[72] *Ibid.*, 16. I might point out that Ruggles attitude as to what should be 'one's approach to statistical research' may be seen to have softened somewhat over the years, as other just as important issues demanded to be addressed. However, the systematic, careful approaches to research are still highlighted by Ruggles, while statistical testing, in the mathematical sense, may not.

[73] *Op cit.*, 16.

Though Ruggles meticulously details his investigative approach in Sections 2 and 3, it is useful to delineate the main headings of his and his co-workers procedures so that we can appreciate those improvements that have substantially changed the way in which archaeoastronomy in the British Isles would be researched. Also, just as importantly, it will allow for the easy referral to these improvements later chapters.

Ruggles calls these procedures "codes of practice".[74] At each stage of the fieldwork codes of practice, that were laid down previously, are "rigidly adhered to" in data selection. [75] These codes or fixed rules which govern one's step are not based on any prior predilections, but upon sensible, rational, conclusions arising from his critical analysis of A. Thom and A.S. Thom's work in particular.

Codes of practice for data selection

In Section 2 of the 1984 study the initial site list is explained.[76] Firstly the types of features that they were to look at were addressed, then what nominated a "site" for the purposes of their study and finally a look into which areas the work would take place. To summarise: free standing megaliths were the type of Neolithic/Bronze age feature to be investigated; a site could be any collection of rings, standing or fallen menhirs and sites of menhirs, such that each of the these features are within 300 metres of each other. Exceptions to this latter definition were those monuments separated by a sea channel or not inter-visible due to natural land rises. The geographical areas of study included the Highlands and many of the islands of northwestern Scotland. Ruggles then listed his major sources and which sites were considered unsuitable for the study, the latter, therefore, being excluded from the study (Section 2:3). The reasons for their exclusion were based on four grounds. The first being archaeological grounds, namely that the sites were "highly dubious contenders" for nomination as "prehistoric", or there was evidence that they were not constructed as free standing megaliths. The second ground was the indeterminate original positions of the sites. The third and fourth were that sites were not visited due to time constraints, or unknown at the time of visiting that area, respectively. Section 3 details the classification and selection of the site data using a number of categories and/or underlying selection decisions and assumptions. These categories were devised specifically for the full understanding of the nature of the data. Details such as these also assist in the comprehension of the validity and reliability of the initial researcher's outcomes and conclusions. These categories will now be reviewed, for they are important in the ways they overcome the objections set out by Ruggles regarding Thom's work. Also, they aid the ongoing discussion of Ruggles' work and data throughout this discourse.

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[74] *Ibid.*. 20.

[75] *Ibid.*, 21.

[76] *Ibid.*, 23.

Field data - how and which data were to be collected in the field

Archaeological status of stones initially considered[77]	High Status Low Status	• erected in prehistoric times; little disturbed. • *possible* menhir. • boulder associated with "High Status stone" (not erect). • fallen menhir; not moved from were it fell.
Overall Archaeological. Status of sites considered	Status A Status B	• sites contain at least one "High Status" stone. • consists of only "Low Status" stones.
Observing position (OP) for surveying of azimuths etc.	Intrasite Intersite	• 2 metres directly behind the indicating structure • (b) 1.5 metres above present ground level. • here the backsite is a site. • centre of backsite, if more than one stone, or 2 metres behind a single stone. This ensures ground level similar to that of ground structure
Azimuth Ranges	IAR = Indicated azimuth range AAR = Adjacent azimuth range	• intrasite: range of horizon that can reasonably be supposed to have been indicated by a structure *"on the ground"*.[78] • intersite: range of horizon that can reasonably be supposed to have been included by one site as viewed by another. Assume the indicated horizon directly above foresight as viewed from OP. • 1-2^0 either side of the IAR.[79] • Edges quoted to within 0.2^0 of accuracy.[80]
	In which direction is the indication pointing?	• both directions will be considered.[81]
	To what accuracy?	• Azimuths, altitudes and declinations not considered with a greater accuracy than 0.1^0.[82]

Table 4.1: Data classifications and instructions for data gathering in the field.

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[77] By thoroughly investigating the sites archaeological status, Ruggles hopes to prevent any of the few mistakes that the Thoms encountered in identifying non-prehistoric sites etc.

[78] Therefore, following his criticisms of Thom, he has clearly marked out *which* kind of indication type he is investigating, and is also choosing to use only *one* type of indication. In this way he has prevented any of the problems associated with merging two kinds of data, themselves based on two separate hypotheses of how the sites might function.

[79] See page 60.

[80] As Ruggles explains greater accuracy is rarely justified due to the uncertainties in the deterioration of a structure since its erection.

[81] "On the ground" considerations and surrounding environmental information made it apparent during the visiting of these sites that one direction in particular, or only, could have been indicated by the site.

[82] Based on Ruggles' and others' researches in the field, measurements to this degree of accuracy are not possible.

Classifications of field data

Structures were classified in this study according to the inherent likelihood that their design and constituent parts could have operated as astronomical indicators and in accordance with their archaeological status. The first decision was to focus upon megalithic *alignments*, or rows of stones. The order of "inherent likelihood" combined with archaeological status is as follows:

1.	Alignments with ε 3 menhirs; 2 oriented slabs.
2.	Above alignments with "low status" stones.
3.	Stone pairs (not known to be part of a larger setting).
4.	Stone pairs with "low status" stones.
5.	Flat-sides of single slabs.
6.	Flat-sides of single slabs with "low status" stones.

Table 4.2: First level of organising data post-field work.

Following on from this, then, are tables taken from Ruggles 1984 which list those classifications based on these criteria for intrasite indications (Table 4.3).[83, 84].

Intrasite indications

CLASS 1	(1a)	An alignment of three or more menhirs, possibly with further low status stones which stand or could have stood in the line;
	(1b)	Two slabs that are, or can reasonably be assumed to have been, oriented along the line joining them; possibly with further low status stones which stand or could have stood in the line.
CLASS 2	(2a)	Two menhirs (not both slabs oriented along the line joining them) together with one or more low status stones which stand or could have stood in the line (in which case the IAR is taken as that defined by the two standing menhirs);
	(2b)	A slab together with two or more low status stones which stand or could have stood in line with its orientation (in which case the IAR is taken as that defined by the orientation of the slab);
	(2c)	A menhir (not a slab) and two or more low status stones, which form or could have formed an alignment; or
	(2d)	A slab and two or more low status stones, which form or could have formed an alignment which is not in the direction of orientation of the slab.
CLASS 3	(3a)	Two menhirs, not both slabs oriented along the line joining them;
	(3b)	A slab together with a low status stone which stands or could have stood in line with its orientation (in which case the IAR is taken as that defined by the orientation of the slab);
	(3c)	Three or more low status stones which form or could have formed an alignment; or
	(3d)	Two possible slabs that are, or can reasonably be assumed to have been, oriented along the line joining them.
CLASS 4	(4a)	A menhir, not a slab, together with a low status stone; or
	(4b)	A slab together with a low status stone that does not stand and does not appear to have stood in line with the orientation of the slab.
CLASS 5	(5a)	One or both of the wider faces of a slab.
	(5b)	Two low status stones.
CLASS 6		One or both of the wider faces of a possible slab.

Table 4.3: The six (6) "classes of indication" of the "on the ground" structures, as indicated by their inherent likelihood as astronomical indicators as well as their archaeological status. They will serve to assess possible intrasite indications.

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[83] (1984) *Op cit.*, §3.3, 62-3.

[84] Kind permission was given by Clive Ruggles for the reproduction of these tables.

Following on, yet again, from this level of classification of indications is a sub-system which introduces all the previous classification variables for the purpose of providing an informative label for each site-type. In this way, one will be able to know a great deal about the *nature* of a site by referring to the "site type" table (Table 4.4).

TYPE 1	A site containing at least one CLASS 1 indication.
TYPE 2	A site containing no CLASS 1 indications but at least one CLASS 2 indication
TYPE 3	A site containing no CLASS 1 or 2 indications but at least one and no more than six CLASS 3 indications.
TYPE 4	A site containing no CLASS 1, 2 or 3 indications but at least one and no more than six CLASS 4 indications.
TYPE 5	A site containing no CLASS 1, 2, 3 or 4 indications but at least one and no more than six CLASS 5 indications.
TYPE 6	A site containing no CLASS 1, 2, 3, 4 or 5 indications but at least one CLASS 6 indication.
TYPE 7	A site consisting of at least one menhir which either contains no CLASS 1-5 indications, or more than six indications of CLASS 3 or 4.
TYPE 8	A site consisting of at least one low status stone which either contains no CLASS 1-6 indications, or more than six indications of CLASS 5(b).

Table 4.4: "Types of sites" as organised and labelled by Ruggles (1984). These inform the researcher as to the overall ***nature*** *of the site: i.e. what kinds of megaliths make up the site, their arrangement, and the proportion and composition of possible astronomical indications.*

Intersite indications classifications

These indications are known and identified by the distance of the foresight from the backsight. Remembering that "indication classification" is a reflection of the likelihood that an alignment has the inherent qualities of an astronomical indication, and that foresight distance itself is a variable that can increase or decrease the ease and accuracy with which to perform such a task. Increasing the foresight distance increases the ease and accuracy while lessening does the opposite.

Class 1	Foresight never greater than 6 km and at least one menhir projecting 1′ above the horizon or ridge.
Class 2	Not Class 1; foresight greater than 3 km.
Class 3	Not 1 or 2 and foresight nearer than 1 km.

Table 4.5: "Intersite indications classifications" as organised and labelled by Ruggles (1984).

Exclusion criteria for intersite indications

As well as deciding what you want to include in a study, it is imperative to know **before** you go out into the field, what you do not want to collect! It was decided from the outset not to include stone rings, horizon distances below 1 km or IARs greater than 5^{o} in width, to reduce the amount of uncertainties within the data and for reasons of statistical propriety.[85]

[85] For an explanation, please refer to Ruggles, 1984, *Op cit.*, sections 3.3 and 3.4.

Illustration of site types

To see how this labelling works in practice, a few sites will be examined in detail. Table 6 lists a handful of sites, their basic morphological description and Ruggles' site type label. From this we can easily see that morphological similarity is no guarantee of a shared label, and, following logically from this, the same label is no guarantee that the sites share the same basic morphology. For example LH 7 (Kirkibost) and UI35 (Cringraval W) (both have the label "8", however, LH7 is a menhir and UI35 is a stone ring. Why then, do they have the same label? Examining the morphology in detail it can be seen that LH7 is a lone prostrate standing stone that is 3.5 m long; appears to have stood at its SW end. UI35 is 35 m ring made up of prostrate menhirs (up to 1.5 m) and a standing slab (0.75 m high).[86] The site-type label "8" states that "A site consisting of at least one low status stone which either contains no CLASS 1-6 indications, or more than six indications of CLASS 5(b)". To contain no Class 6 indications means that an alignment cannot be determined from within the monument itself. To contain more than six indications of a CLASS 5(b) is for the monument to have six or more orientations made up of low status stones, where low status stones can be a *possible* menhir, a boulder associated with "High Status stone" (not erect) or a fallen menhir that was not moved from were it fell (see Table 4.1). We can see from this that LH7 can be considered an "8" because no alignment can be determined from within the monument itself and, in fact, the site is only used for intersite alignment considerations with LH8 (Bernera Bridge; see Table in Appendix AB, alignment numbers 2 and 3). UI35, though it is made up of primarily of prostrate menhirs that within themselves did not reveal any form of alignment, the ring formation allowed for more than six possible alignments composed of low status stones. In this case, fallen menhirs. The site was accordingly awarded the type of "8". It should be noted for some increased clarity that being a circle for UI35 also meant its internal alignments would not be considered anyway. For the accompanying theoretical models and statistical considerations were, it seemed, too complex, and Ruggles decided at this point to put internal alignments of stone rings to one side.

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[86] See Ruggles, 1984, 102, for a fuller description.

Region	Ruggles Site no.	Main descriptor of site types - morphological	Ruggles' Site Type
Lewis/Harris	LH7	Recumbent menhir	8
	LH10	A standing menhir, fallen menhir	4
	LH16	Stone circle with cairn, stone rows, stone avenue	1
	LH18	Stone circle with inner standing stones	7
	LH22	Standing stones	3
	LH24	Standing slabs	3
	LH29	Standing stone	6
	LH36	Standing slab	5
Uist	UI6	Standing slab	5
	UI9	Standing slab, standing stone	3
	UI19	Stone row	1
	UI33	Stone circle	7
	UI35	Stone ring	8
	UI46	Standing slab	6
	UI57	Standing stone, fallen slab	3
	UI59	Standing menhirs	4
Mull	NA1	Standing stones	4
	CT2	Standing slabs	3
	CT3	Standing slab	6
	CT7	Stone rings, cairn	7
	ML4	Stone row	2
	ML9	Stone row	1
	ML15	Standing stone	7
	ML16	Standing stones	3
	ML27	Standing stone	8
	ML30	Standing stone	6
	ML31	Standing slab	5
Argyll	LN22	Stone row	1
	AR10	Standing slab	5
	AR15	Aligned slabs	1
	AR30	Prostrate slabs	5
Islay/Jura			
	JU7	Stone row, other possible remains	2
	IS5	Erect boulder	5
Kintyre	KT10	Stone row, cist	1

Table 4.6: A list of examples of site types and their main descriptors illustrating that the same basic morphology does not guarantee identical site type labelling. See Appendix AA for full description of each, columns "Remains used by Ruggles for his initial orientation considerations" and "Other points".

Statistical analyses of orientation and declination data

Having chosen his data in a structured and *a priori* fashion, Ruggles next major contribution to both archaeological and archaeoastronomical analysis was to consider tests that might be appropriate for the sound analysis of them. For the analysis of the azimuthal data, he chose the Nearest Neighbour test. Henry Neave and Keith Selkirk developed the Nearest Neighbour test in 1983 for the analysis of the distribution of points on a circle.[87] In archaeoastronomical terms, this test might be used to assess the probability that clusters of preferential orientations exist in a database of azimuthal readings. For the declination data, he chose to apply the Monte Carlo method for the production of an expected data set and distribution patterns with which to compare the observed data. In this way Ruggles could discover whether the randomly generated, expected distributions were significantly different to those found in the observed distribution, by calculating a probability statistic.[88]

As it is part of this project's *télos* to understand and determine the appropriateness of previous methods used in archaeoastronomy in western Scotland a very close assessment of selected procedures used by Ruggles can be found in the Chapters 4. It is in Chapter 4 that a thorough exegesis of circular statistics and their appropriate use is established. Ruggles' application of the Nearest Neighbour test to the western Scottish data is seen in the light of this assessment. It will be seen that another test, the Z family of tests, previously developed for use in astronomy and astro-physics, was seen to be more appropriate for the form of database produced by Ruggles and contributors to his 1984 project.

Ruggles' assessment of the declination data will be outlined in a later Chapter and the possible methodological improvements that this study was able to make are discussed.

Ruggles 1984 result summary

The 1984 study of Ruggles revealed, there was statistical evidence for the "possible deliberate" orientation of the sites. On examining the body of data he found that there was an interest in certain declinations at varying levels of orientation accuracy (3 levels of precision). At the lowest level of precision there was a strong avoidance of declinations between -15° and +15°. At the second level of precision there was a marked preference for southern declinations between -30° and –19°. indicating a possible interest in the southerly limits of the major and minor lunar standstills. Too, there was an interest in northern declinations above +27°. At the most precise level the statistically significant declinations were -30°, -25°, -22.5°, +18°, -+27°, and -33°. According to Ruggles' interpretations, -30°, +18°, and +27° may indicate an interest in the lunar standstill limits. -25° may well suggest an interest in the winter solstice whilst -33° is certainly beyond the limits of all lunar and solar activity. These outcomes, like those of his earlier works, gave no support to Thoms' conclusions for such monuments being in alignment with, or indicating, celestial phenomena to an accuracy of more than one degree. Having found these results, Ruggles then focused upon those data that revealed the most significant results. Thereby, applying the rule of valid statistical analysis that if the pattern in the

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[87] "Nearest Neighbour analysis of the distribution of points on a circle", *University Nottingham Research Report*, 1983, 5-83.

[88] See 'Comparing the observed and expected distributions' later in this thesis for an explanation of how this works.

data as a group are not due to chance then one can examine the clusterings around focus points in more detail. He had established that "certain coherent groups of sites were found to feature predominantly" in the above preferred declination intervals.[89] These sites were found in the geographical areas of Mull and mainland Argyll. By selecting only class 1 and class 2 sites he found that the great majority of these were oriented in the south between the declinations-31° and -19°. This range of declinations represents, to within a degree or so, the possible values of the southerly limit of the moon's monthly motions at different points in the 18.6 year lunar cycle. Ruggles put forward a hypothesis to be tested. If these alignments were set up at arbitrary points in the cycle (that is, there is no detectable pattern/interest that could be determined within this range of the cycle itself) we would expect *a scatter* of declination points between -30 and -19 degrees. Using a new data set from the same area it was found to fit the general pattern of declinations falling between -30° to -19°. With "a grouping of indications within a degree or so of -30o and a second grouping centred upon -23°".[90] This shows that the points within the range are not arbitrary. Therefore providing support for the hypothesis put forward by Ruggles. The interpretation of these outcomes was that, as this range of declinations exists in the 18.6 yr. cycle, the "construction of [these] deliberate orientations within this range need not have involved nightly observations of the moon in a given month, but could have occurred by observing the rising or setting of the moon nearest to the ... solstice".[91]

The greatest benefit of the form of methodology applied by Ruggles is that you can feel reasonably confident that the information and trends that are presented by your data in the analyses are not due to chance factors. This in turn allows one to produce valid conclusions if the evidence is interpreted correctly. Also, further viable hypotheses can be created to be investigated at a later date. Having said this though, the statistical approach only gives us power to spot overall trends amongst a large body of data. Superficially similar sites may have in fact had complex, differing and changing functions. As Ruggles points out in his 1984 conclusion, we will be missing any considerations of variation or detail. Ruggles also points out that an hypothesis must precede data collection which can be very difficult in archaeology and history where your research is usually restricted by what you are able to find in either in archaeological records or archives in the first place. However, though he feels that statistics gives us no guidance in our use of the background knowledge of the cultures that may be relevant to our investigation, it is important to remember that it is our background knowledge that leads us to the questions that we wish to test in the first place. Background knowledge then, is never really left out of the equation in the way many researchers fear.

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[89] C. Ruggles , 1988, "The stone alignments of Argyll and Mull: a perspective on the statistical approach in archaeoastronomy, in Clive Ruggles (ed) *Records in Stone: papers in memory of Alexander Thom,* pge 234.

[90] *Ibid.,* 235.

[91] *Op cit.,* 234.

Further Methodological development

Research involves the continual improvement of procedures so that investigations provide us with as much new or improved information about "our" data as possible. In an investigation such as this, one can either narrow or broaden the approach used in the previous research, using the previous findings as a base upon which to work. In regards to the western Scottish sites above one might narrow or broaden the geographical or archaeological fields, or the methodological focus. Ruggles' next steps after the 1984 project were to continue narrowing both the geographical and archaeological fields[92] but broaden his methodological approach.[93] These are be discussed briefly under 'Ruggles' and colleagues' new studies in the area of north Mull' below.

Ruggles' and colleagues' new studies in the area of north Mull

It has been seen that from the 1988 study, a more detailed pattern could be discerned in Northern Mull and the Kilmartin Valley area of Mid-Argyll. It appeared that all lone single alignments indicated a southern declination within a bout a degree of -30, the southern most rising & setting at major standstill (postulated as the primary declination). Added to this, where 2 alignments were found in close association or built into the same site, one was oriented near -30 and the other within a degree or 2 to -24. "This overall pattern was not explicable by non-astronomical factors such as orientation parallel to the lie of the land".[94]

North Mull Project

The North Mull project was set up to "improve the quality of data for archaeoastronomical research by excavation and to recover evidence for dating and cultural associations that was totally lacking in this area".[95] It also incorporated data and information on the potential use of particular horizon distances and prominent hill summits for the purposes of viewing astronomical targets from the position of the monuments.

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[92] To Mull and Argyll, then Northern Mull.

[93] Where Ruggles addresses the point that there had been "a great deal of talk about the precision of alignments and statistical rigour, (but) very little about the nature of the sites themselves and the people who built them" (*ref.* 1), 18-19.

[94] R D. Martlew, and C.L.N. Ruggles, 1996, "Ritual and Landscape on the West Coast of Scotland: an investigation of the Stone Rows of Northern Mull", *Proceedings of the Prehistoric Society*, *62*, 119.

[95] *Ibid.*, 119-120.

Site Location, Landscape and Astronomical targets

Horizon Visibility

The North Mull Project examined the astronomical potential of a number of alternative locations. They were chosen by generating spatially pseudo-random points identifying positions in the landscape that satisfied a variety of locational criteria (other than astronomical) in common with the sites themselves.[96] The outcome of this part of the project was that "there was a conscious effort on the part of the builders to locate the North Mull rows according to horizon visibility criteria that were not easy to achieve given the general topographical constraints in the area".[97] It can be seen here that landscape is now being considered as a variable in archaeoastronomical research.

Ruggles' &Martlew's 1992 project extended the North Mull investigations. It found that some sites built to make use of *secondary peaks* or groups of peaks, associating them with the southernmost moonrise nearer the *minor* standstill or the rise and set of the *solstitial sun.*[98]

More detailed outcomes of these sections of the project are discussed in Chapter 9 of this current work, along with a comparison of this current work's results and interpretations in Chapters 9 and 10.

Visibility and Directionality 1993,1996, 1997

Ruggles et al. (1993, 1996) employed viewshed analysis in the study of bronze age monuments on the island of Mull, western Scotland, extending the idea of visibility to include prominent horizon features and astronomical events. Prehistoric stone rows add the idea of *directionality* to viewshed analysis, possibly aligning with landscape features to 'pinpoint' relevant astronomical locations such as points where the moon rises and sets.[99]

Further to this, Ruggles' and Martlew's paper "Ritual and Landscape on the West Coast of Scotland: an investigation of the Stone Rows of Northern Mull" shows the importance of using excavations to answer on site questions as well as applying horizon analyses applied. The horizon was examined in

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[96] Ruggles, Martlew and Hinge, 1991, "The north Mull project (2):the wider astronomical potential of the sites, *Archaeoastronomy*, **16**, (JHA, xxii), S51-75.

[97] Ruggles, 1999, *Astronomy in Prehistoric Britain and Ireland*, Yale University Press, London. 119.

[98] Ruggles and Martlew, 1992, "The North Mull Project (3): prominent hill summits and their astronomical potential", *Archaeoastronomyu*, **17**, (*JHA*, xxiii)., S1-13.

[99] M.J. van Leusen, Viewshed and Cost Surface Analysis using GIS (Cartographic Modelling in a Cell-Based GIS II). In: J.A. Barcelo, I. Briz and A. Vila (eds), New Techniques for Old Times – CAA 98 – Computer Applications and Quantitative Methods in Archaeology: proceedings of the 26th Conference, Barcelona 1998. British Archaeological Reports S757, Oxford, 1999, pp. 215-223. Quote from § 3.1.1.

directions other than those along the alignment in order to explore factors that might have influenced the choice of orientation.[100]

The final work of regarding the North Mull project is that of viewshed analyses of the Bronze Age Cairns in the area. The interesting outcome of this work was the siting of cairns in order to have a large viewing area of the sea. Once more the study used appropriate statistical procedures in the form of Monte Carlo testing and statistical analyses so that the observed data from the cairns could be compared to random points in the landscape, in order to test for the likelihood that the observed data could be explained by chance factors. The outcomes regarding the large viewing areas of the sea do not appear to be able to be explainable by chance.[101]

Current developments

This current study, unlike Ruggles future work, *initially* extends the investigation of those sites of western Scotland by *narrowing* the methodological focus somewhat to the form of statistical analyses used in assessing the orientation data. In this initial narrowing of methodological focus we will look at new ways to assess the azimuthal data of the sites (Phase 1). The next phase of the project (Phase2) expands both the methodological and geographical foci. The former is done by developing known experimental methods for use in archaeoastronomy and landscape archaeology. These are the creation of appropriate hypotheses, techniques to produce *regionally specific* expected distribution patterns of declinations and the adaptation of known statistical tests. The latter will be done by incorporating expansive areas of Ordnance Survey elevation data for the entire area of western Scotland, to deduce the regional astronomical significance of the sites. The innovation of this phase is the use of such a large landscape data base as well as a horizon profile program that generates horizon profiles from this Ordnance Survey data. The use of this program is discussed further, but it must be noted that the program was written by Dr. Andrew Smith of the Department of Physics and Mathematical Physics at the University of Adelaide, South Australia.

Though Phase2, with its consideration of the surrounding geographical and astronomical environment, clearly acknowledges that a consideration of monuments out of context is not wise, Phase3 further addresses this point. While it is not our intention to follow Emma Blake's (1999) aim to locate a narrative of cultural identity formation through studying the emergence and elaboration of pre-historic

[100] R.D. Martlew and C. Ruggles, 1996, *Op cit.*, 117-131.

[101] P. Fisher and C. Farley, A. Maddocks, and C. Ruggles, 1997, "Spatial Analysis of Visible Areas from the Bronze Age Cairns of Mull", *Journal of Archaeological Science*, **24**, 581-592.

Scottish society, other elements in the surrounding archaeological and geographical landscape are considered.[102]

The final and largest phase of this project (Phase3), then, maintains the same geographical focus as Phase2, however, it greatly expands the archaeological focus to all known Neolithic and Bronze Age monuments to study the possibilities of an integrated cosmological system that spanned across time and space. Methodologies based upon GIS techniques, such as viewshed analyses, and known statistical procedures were chosen. The innovation regarding this section was four fold: (i) the amount of location and site data used, namely the entire list of Neolithic and Bronze Age monuments in western Scotland accessed from the Royal Commission of Ancient and Historical Monuments of Scotland (RCAHMS), (ii) a program that could run viewshed analyses in parallel on many machines, thus cutting down computer time by many, many months. (iii) The notion and creation of directional viewsheds programmes to be used in GRASS. These programs, however, are not discussed specifically for they were not written by the current author, but only used in order to complete the viewshed analyses. Having said this, however, as the author created the idea and parameters, as well as designing the necessary algorithms for a directional viewshed, the applicability and reasons for doing so are discussed further in Chapter 8, Phase 3 methodology. These programs were written by Dr. Ken Simpson of the Department of Physics and Mathematical Physics at the University of Adelaide, South Australia. The final innovation, (iv), is the use of 3-D landscape visuals for each unique Ruggles (Group 1) location, created from the Ordnance Survey data. These views are used to contribute to the interpretative analyses that took place after the statistical outcomes were known. The program that produced these very useful visuals was written by Dr. Andrew Smith of the Department of Physics and Mathematical Physics at the University of Adelaide, South Australia.

The emphasis upon elevation data and other archaeological sites obviously leads to a consideration of the assumptions and methods within landscape archaeology. It is to these we shall turn in the following chapter.

By using these fresh and distinct methods it is hoped that new light will be shed upon the possible interest of the builders in astronomical phenomena and the cosmological concepts or belief systems of these same peoples and, perhaps, those who came before and those who came after. The innovation for the project as a whole can be seen by the amount of interpretative analyses done for research in archaeoastronomy in combination with statistical applications.

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[102] E. Blake (1999), "Identity mapping in the Sardinian Bronze Age", *European Journal of Archaeology*, **2** (1), 35 - 55.

Chapter 5

Landscape Archaeology, the use of GIS and the experimental method

Location and Visibility

> Simply put, visibility can be regarded as a key factor in attempting to [determine] why a particular site is in a particular place, rather than all the other places it might have been located.[1]

In their Ljubljana paper, quoted above, Mark Gillings' and David Wheatley discuss visibility as a variable which, when manipulated, is used to discover the impact that view and vision may have had upon "the *structuring of archaeological landscapes*". It is obvious, then, that visibility, a key to seeing, should be a persistent feature of archaeoastronomical research.[2]

We have seen an overview of selected archaeoastronomical research which naturally incorporated visibility in their work, including Thom (1955, 1967, 1971 and 1980), Ruggles (1984), Ruggles with Martlew and Hinge (1991) and later, Gruffydd and Medyckyj-Scott (1993), and with Medyckyj-Scott (1996). Also, Martlew with Ruggles in 1993 and 1996, and so forth. Other important research in archaeoastronomy includes Burl's 1981 work on chambered tombs and the 'astronomy of death' and his work on the standing stones of Northern Ireland (1987).[3] The former investigated the interest of prehistoric groups in the moon and 'the reasons for their watching'.[4] Mackie's research focusing upon Brainport Bay, Minard, Argyll investigated the site and the possibility of its alignment indicating the midsummer sunrise (1985 and 1988). Barnatt and Pierpoint investigated the location of the stone circles

[1] M. Gillings and D. Wheatley, "Seeing is not believing: unresolved issues in archaeological visibility analysis", in B. Slapsak, (ed), *On the Good Use of GIS in Ancient Landscape Studies*, Ljubljana, *in press.*

[2] Peter Fisher, 1997, *Op cit.* **24,** 582.

[3] A. Burl, 1981, "By the light of the cinerary moon": chambered tombs and the astronomy of death" in Ruggles, C.L.N. and Whittle, A.W.R. (eds), *Astronomy and Society During Britain in the Period 4000-1500 BC.* Oxford: BAR (British Series 88).

A. Burl, 1987, "The sun, the moon, and megaliths: archaeoastronomy and the standing stones of Northern Island", *Ulster Journal of Archaeology*, **50**, 7-21.

[4] *Ibid.,* 243.

on Machrie Moor, Isle of Arran, and its connection to astronomical phenomena (1983).[5] All of these studies, of course, incorporate the underlying notions of vision and visibility.

Visibility as a feature of other forms of archaeological research

Visibility, or what can be seen from where, has influenced much archaeological research that has seen itself as remote from archaeoastronomical considerations. Roese's research on Welsh menhirs discovered an inversion of the visibility theme, that monuments were placed in areas which avoided hilltops and ridge crests, giving them, perhaps, a sense of concealment or rather a deliberately low visual priority.[6] In his study of Neolithic barrows in North Marden, West Sussex, Drewett concluded it was possible that a relationship between barrow size and their visible area was in evidence. The Neolithic barrows were positioned so that their field of view overlooked the River Cuckmere, and away from the downs whereas other barrows in the same region had less prominent river valley views.[7] Barnatt's study of Bronze Age settlement sites (1987), felt that intervisibilty was the key to the positions of the hillforts in the Derbyshire Peak District.[8]

The development of formal methods for visibility analysis

> With the notable exception of astronomical alignments, the analysis of visibility almost entirely escaped the quantitative revolution of the New Archaeology ... New Archaeology rarely had "the will or the tools to develop **formal methods** for visibility analysis.[9]

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[5] E. Mackie, P.F. Gladwin, A.E. Roy, 1985, "A prehistoric calendar site in Argyll?", *Nature,* **314,** 158-61.

E. Mackie, 1988, "Investigating the prehistoric solar calender", in Ruggles, C., 1988, *Records in Stone: Papers in memory of Alexander Thom.* Cambridge: CUP.

J. Barnatt and S. Pierpoint, 1983, "Stone circles: observatories or ceremonial centres?", *Scottish Archaeological Review,* **2,** 101-15.

[6] H. Roese, 1980, "Some aspects of topological location, of Neolithic and Bronze Age Monuments in Wales 1: Menhirs. *Bulliten of the Board of Celtic Studies, 28,* 645-655.

[7] Drewett, P., 1986, "The excavation of a Neolithic oval barrow at North Marden, West Sussex, 1982". *Proceedings of the Prehistoric Society,* **52,** 31-51.

[8] J. Barnatt, "Bronze Age settlement of the East Moors of the Peak District of Derbyshire and S. Yorkshire.", *Proceedings of the Prehistoric Society, 53,* 393-418.

[9] M. Gillings and D. Wheatley, *Op cit.*, in press. See Renfrew (1979), pages 13-20. Formal methodology, here, refers to the scientific or experimental method as defined in chapter 1 of this work and, discussed in more detail in relation to viewshed analysis below.

There were some exceptions to this. Fraser in his 1983 work, *Land and Society in Neolithic Orkney,* designed his study with very specific variables to be investigated, *including* standardised *types of visibility.*[10] By standardising this variable it was possible to repeat the methodology as well as obtain clear outcomes.[11] Basically, Fraser investigated cairn location in relation to ten landscape variables, as well as possible relationships between these and other monuments or sites. The ten variables used in his locational analysis were: geology, soils, land use capability, topography, vegetation, altitude, visibility from location, drainage, ease of approach and the nature of the nearest coast. His other site types were four settlements, two henges and individual standing stones. As well as these things he considered the possible existence of boundaries by taking into account demarcations in and around the cairns.

His standardise types of visibility were quantified as, less than 500 metres for restricted, 500 metres to 5 kilometres for intermediate and greater than 5 kilometres for distant. Each of these were considered in relation to *orientation.* Within this visibility analysis, Fraser looked at monument orientation with respect to the surrounding land and sky and gave some consideration to astronomical influences upon cairn location. His results showed that all forms of visibility displayed a similar pattern with distant visibility having the most pronounced of orientation patterns. The latter showed azimuth distributions peaking at 140° (Southeast), a minor peak at 270° (West) and a trough or avoidance at 0° (North).[12] In regards to these findings, and the other artefact and locational analyses, Fraser concluded that the Neolithic inhabitants of Orkney positioned their chambered cairns in those places that allow certain solar observations, and here could meet and celebrate changes in the season. Noticeably, Fraser used the terms 'space' and 'place' in his conclusions to unify a variety of artefact and locational relationships. In agreement with Gillings and Wheatley, we are seeing the use of visibility within Fraser's work as a *cultural variable.*

So here we have quantifiable variables being used to examine cultural practices and symbolism in the Neolithic. It should be noted that another variable that has been considered is that of *DIRECTION.* Though often used in association with archaeoastronomy and morphological research, we see the rise in the use of direction as a corollary consideration of visibility and its intentional attendant association as a *cultural indicator.*[13]

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[10] D. Fraser, 1983, *Land and Society in Neolithic Orkney.* Oxford: British Archaeological Reports (British Series **117**).

[11] See Fraser (1983), 298-303.

[12] Fraser, *Ibid.*, It is very interesting to note avoidance of specific directions in other studies and this shall be highlighted in the relevant 'Discussion' sections of this work.

[13] Major morphological research that took into account direction via the assessment of the orientation of tombs, was the vast work(s) of Ruaidhrí de Valera and Seán Ó Nualláin, (1961, 1964, 1972) *Survey of the Megalithic Tombs of Ireland*, Stationary Office, Dublin.

Fraser's work is considered a refinement of Renfrew's 1979 study.[14] This study

> involved repeated observations from fixed points in the landscape that were collated to produce maps with overlapping zones of decreasing/increasing visibility. The resulting patterns of intervisibility between cairns were then used as quantified variables ... to explain the observed patterns of cairn locations.[15]

The conclusions of this work also saw evidence for the use of demarcation of land or at the least some form of boundary 'flag' system, that identified, or delineated, discrete territories or activity areas in the wider landscape through the location of cairns. Here location was seen as a significant quality of the cairns and visibility was seen as a significant variable for those whose choice it was to place them.

It is important to note Gillings' and Wheatley's comments regarding Fraser's and Renfrew's use of intervisibility and the connection of intervisibility to the notions of a 'field-of-view' and 'line-of-sight'. They see these works as applying heavily simplified concepts of vision, yet anticipating those visibility analyses that chose to apply GIS to their archaeological research.[16] In addition, these concepts of vision were further simplified for they were "always recorded with respect to *locations fixed in the landscape*".[17] This is interesting because, though a site may be fixed, what is viewed may not be, and neither, perhaps, might be the viewer. Some of these of these points are addressed in the results section of Phase 3 and the final discussion. Now, fascinatingly, in relation to the first of these points, astronomical phenomena aren't fixed themselves but can be represented as a fixed point on the horizon via the variable, declination. However, this variable, though connected to a fixed formula, is mutable over time, latitude, altitude of observer and numerable smaller variables, as described in an earlier chapter. Like fixed variables though, these are quantifiable and possible to use in rigorous studies, and thus reproducible, methodologies.

Evans, in his discussion regarding place, space and perceptions of landscape, called for the creation of an index of visibility and the appearance of features in the landscape.[18] He proposed a concept of 'visual

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[14] Renfrew, C. (1979), *Investigations in Orkney*. London: Society of Antiquaries. See Gillings and Wheatley, *Ibid.*

[15] *Op cit.*, section "Quantifying vision", *in press.*

[16] *Op cit.*

[17] *Op cit.*

[18] C. Evans, Tradition and the cultural landscape: an archaeology of place, *Archaeological Review from Cambridge* **4 (1)** (1985) 80-94.

ranges' framed by topographic features, which mirrors closely the pre-existing notion of field of view or viewshed. He also laid emphasis upon how sites and monuments interacted as a visual network which was seen as a potential factor in their historic generation.[19]

The studies of Bradley (1991), Bradley, Harding &Matthews (1993), and Bradley, Harding, Rippoon &Matthews (1993) have also utilised systematic field sampling in their studies of locating rock art sites in Argyll and Cumbria. In these studies the area which is visible from each of the rock art sites was estimated in the field. They then systematically compared this with the area visible from selected locations, which were themselves located at regular intervals away from each site. This latter group of viewing points acts as a "control" sample for each archaeological site. This control sample therefore does not cover the entire landscape, but, as Fisher *et al.* point out "the fact the area visible from the rock art sites is larger than the area visible from the control sample gives some statistical rigour to the hypothesised relationship between the site and visibility."[20]

Taking these control samples and using them appropriately in the analysis, as done in these studies, assists in the determination of whether it was barrows of an area having a high degree of intervisibility, or the same barrows being visible from the surrounding landscape, that was the contributing factor in their location. These control samples are, in effect, a way of investigating the background values of the landscape in the study area. The section on 'Experimental method' in this chapter discusses the importance of this methodological point in more detail, particularly in relation to viewshed analysis.

Viewshed/line-of-sight analysis

> ... there is also a more serious reason for reviewing current archaeological applications of viewshed ... - archaeological arguments that are ultimately, if only partly, based on their outcome become invalid if they have been improperly applied or if the results have been wrongly interpreted.[21]

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[19] Evans, 1985, *Ibid.,* 84.

[20] *Op cit., 1997, 584.*

[21] M.J. van Leusen, 1999, *Opcit.,* 215.

Principles and Applications

What is it?

Viewshed is a term used in GIS computer-based research. They are the outcome of applying specific algorithms that ask the question: 'if an individual is standing at point (A) in a particular landscape or terrain, what sections of the terrain could this individual see?' Viewsheds are, then, characterised by establishing visibility between locations, or lines-of-sights.[22] Locations forming the viewshed of an area are connected by straight rays in three-dimensional space to the location of the 'viewer' or set of viewers (See Figure 5.1).[23]


[24]

Figure 5.1: Representation of visible regions for the observer in a landscape.

Figure 5.1 shows the ways in which visibility may be prevented by topographic relief (elevation) and surface objects (vegetation, buildings and so forth) forming obstructions, whilst Figure 5.2, below, is a stylised map of the output of the query illustrated in Figure 5.1. The maps actually used for such computer-based research are called Digital Elevation Models (DEM) or Digital Terrain Models (DTM). Collecting elevations and referencing them to corresponding points in the mapped area create DEMs. These elevations add a Z value to the ground's X and Y horizontal co-ordinates, and allow some software to produce 3-D versions of terrain maps.[25]

Figure 3.3 is an illustration of how GIS software 'thinks' about the same question put forward at the beginning of this section, namely 'if an individual is standing at point (A) in a particular landscape or terrain, what sections of the terrain could this individual see?' Viewshed algorithms output a binary response (0,1) in the form of a data file. The zeroes and ones tell us whether an area is in-view or out-of-

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[22] David P. Lusch and Lois G. Wolfson (Principal Investigators), *Introductory Land & Water Learning Module*, Institute of Water Research, Michigan State University. http://www.iwr.msu.edu/edmodule/gis/disview.html. Last Revision: January 28, 1997.

[23] *Ibid.*

[24] *Ibid.*

25 Further details regarding Digital Terrain Models can be found below in the section 'Software limitations and other issues in the application of GIS'

view; conventionally, 1 is in-view and 0 is out-of-view. This can be translated into a raster map to create a visual output for ease of reference, but it is the numeric output that is used for thorough comparisons and analyses of the areas. Later we shall discuss in detail what these forms of methodological analyses might be and the preferred ways to go about them. Now we shall see what problems archaeologists have tried to solve using this software.

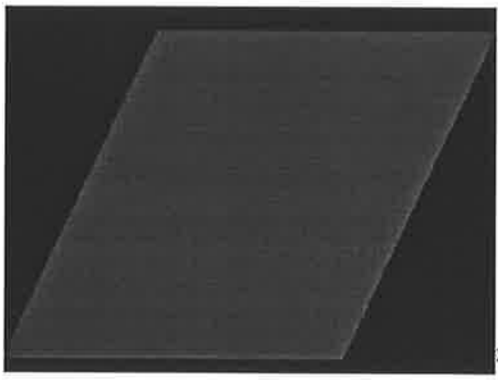
[26]

Figure 5.2: A stylised viewshed developed from the information given in Figure 5.1

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[26] David P. Lusch and Lois G. Wolfson, *Op cit.*

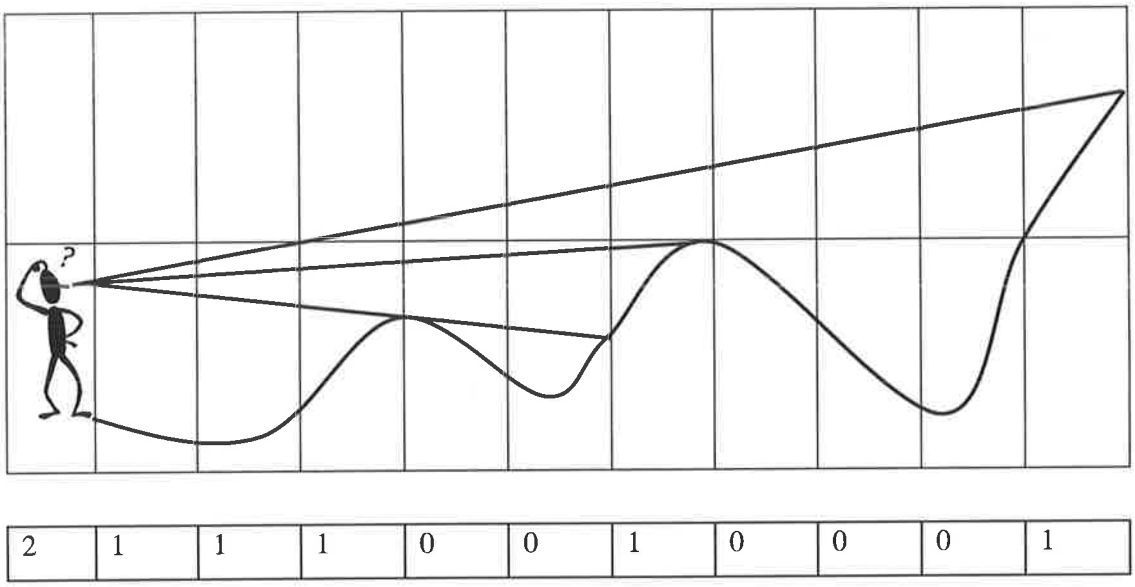

Figure 5.3: The determination of the binary viewshed. This illustration shows us which parts of the terrain *are visible to the viewer. 2 indicates the viewer, 1 area in view, and 0 out of view. The areas viewed are determined by the software, by considering the viewer's location and height and the elevation of the terrain.*

Applications of Viewshed use in archaeology

There are various forms of Line-of-Sight (LOS) applications including single (1 site), and multiple (2 or more sites). "Single viewsheds indicate whether any two points are intervisible and which area is visible from a particular point (not necessarily at the same time)."[27] There are also cumulative viewsheds (CVS), or 'times seen' maps, as introduced by Wheatley, where the resultant map "encode(s) whether a portion of land is in view as well as how often it is in view", as well as directional viewsheds, which have the ability to assess the directionality within a viewshed, as designed by David Wheatley and Mark Gillings in *Vision, Perception and GIS: developing enriched approaches to the study of archaeological visibility*[28]. In other words, it is where more than one viewer or viewing area is designated, and these individual locations within the viewshed are assigned a value indicating the number or density of visual connections.[29]

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[27] van Leusen, §3.1.

[28] Wheatley, 1995, Cumulative viewshed analysis: a GIS-based method for investigating intervisibility, and its archaeological application, in G Lock and Z Stancic eds., *GIS and Archaeology: a European Perspective*: 171-186.

Wheatley, D. and Gillings, M.,2000, "Vision, Perception and GIS: developing enriched approaches to the study of archaeological visibility.

[29] David P. Lusch and Lois G. Wolfson, *Op cit.*

Archaeologists have used these applications, as Van Leusen implies, to discover social indicators that rely upon communal or shared ***focus***.[30] What is usually tested for is whether a particular point or points in the DEM (place or location in the landscape) was chosen so that a particular set, or sets, of points (area) could be seen. As discussed earlier in this chapter such foci may themselves be literal indicators of more complex social phenomena, such as in territorial markers or cosmological symbols/signifiers. Very interestingly, and quite suitably, the notion of viewshed analysis has the **corollary** of being able to study those areas that **are not visible** from a particular location. The advantage of this is that one can investigate the notion of hidden contexts of a society. Van Leusen points out

> (w)here as one particular viewshed will show which areas are hidden from view from a particular vantage point, multiple viewsheds (could) highlight areas hidden from view from a *class* of monuments, with the potential of having a regional significance (and) cumulative viewsheds (could) refine this idea by giving a measure of how hidden particular locations are, enabling us to rank these locations by degree of seclusion.[31]

Examples of applications in archaeology

We have seen already the examples of the use of multiple and cumulative viewsheds in archaeoastronomy in the works of Ruggles, Medyckyj, and Gruffydd (1993) and Ruggles and Medyckyj-Scott (1996), and lastly in the work of Fisher, Farley, Maddocks and Ruggles' "Spatial Analysis of Visible Areas from the Bronze Age Cairns of Mull" in 1997. Each of these studies, to varying degrees, looks at the likelihood of the location of a monument being influenced by, or influencing, a wider area as well as what the landscape as a whole might have meant to the contemporary populations. These studies show that viewshed analysis may also be helpful in establishing the confirmation of cultural identity.[32]

Jacobson, Meachan and Cutting also used multiple viewshed analysis in their study based in the Altay Mountains, and cumulative viewsheds have been used by Gaffney, Ostir, Podobnikar and Stancic (1996b), Wheatley (1995, 1996b), and with Lake, Woodman and Mithen's pilot work on Mesolithic sites

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[30] *Ibid.*,§1.2.

[31] *Op cit,* §3.1.

I would add that not only could one investigate a class of monument but also, naturally, the locational variables of the viewing point – such as those used by Fraser (1983), namely: geology, soils, land use capability, topography, altitude, visibility from location, vegetation, drainage, ease of approach and the nature of the nearest coast.

[32] To use a phrase by van Leusen, *Ibid.*, §3.1.

on the Rhinns of Islay initiating the very much welcomed version of an automated random sampling option for cumulative viewsheds (1998).[33] In fact, Wheatley's 1995 study introduced the use of CVA.

In the same way as the visibility analyses discussed above "the basic viewshed can be used to derive properties of the visible areas, relating to such activities as hunting and security".[34] Examples include, Krist and Brown 1995 for the former and Madry and Rako's 1996 study of the Celtic road network in the Arroux valley in Burgundy and Loots, Nackaerts, and Waelkens work on the Hellenistic City Defence System at Sagalassos, Turkey, for the latter[35].

As van Leusen has pointed out, the concept of viewshed calculation has been refined in order to study ***intervisibility*** to determine whether sites might be part of the *same* 'system'. Such work has been carried out by Haas and Craemer, 1993, Gaffney and Stancic, 1991a, 1991b, Gaffney, Stancic and Watson, 1995.

It should be noted that though there is a long list of studies mentioned, it is by no means complete, further, no critical analysis or commentary has been made. Selected commentary can be found below under 'The experimental method' and 'Software limitations and other issues in the application of GIS' for other archaeological studies.

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[33] Gaffney, V, K Ostir, T Podobnikar and Z Stancic 1996b "Spatial analyses, field survey, territories and mental maps on the Island of Brac", *Archeologia e Calcolatori* **7**: 27-41.

Jacobson, E, J Meachan and D Cutting, 1994, "Patterns on the Steppe: Applying GIS to the Archaeology of the Altay Mountains", *Geo Info Systems* **4** (3): 32-45.

M.W. Lake, P.E. Woodman and S.J. Mithen, 1998, "Tailoring GIS Software for Archaeological Applications: An Example Concerning Viewshed Analysis", *Journal of Archaeological Science,* **25,** 27-38.

[34] van Leusen, 1993, *Op cit.*

[35] Van Leusen, P. M., 1993, Cartographic modeling in a cell-based GIS, in J Andresen, T Madsen and I Scollar (eds.), *Predicting the Past. Computer Applications and Quantitative Methods in Archaeology 1992*, pp. 105-124, Aarhus: Aarhus University Press.

Krist, F. J. and D. G. Brown, 1995, "GIS Modelling of Paleo-Indian Period Caribou Migrations and Viewsheds in Northeastern Lower Michigan", *Photogrammetric Engineering and Remote Sensing*, **60**, (9): 1129-1137.

S.L.H. Madry and L. Rakos, 1996, Line-of-Sight and Cost-Surface Techniques for Regional research in the Arroux River Valley. In: H.D.G. Maschner (ed.), *New Methods, Old Problems: Geographic Information Systems in Modern Archaeological Research.* Center for Archaeological Investigations Occasional. Paper No. **23**, Southern Illinois University at Carbondale, pp. 104-126.

Loots, L, K Nackaerts, and M Waelkens, forthcoming, "Fuzzy viewshed analysis of Hellenistic city defence systems at Sagalassos", Turkey, in *CAA97*.

The experimental method

Some current considerations

Many of the criticisms in the field of Landscape Archaeology and, to some extent Archaeoastronomy, are well rehearsed. Nevertheless, some of the general issues will be briefly discussed here. The criticisms considered are primarily aimed at the lack of rigorous analysis.

What critics want

What many critics of GIS analysis are looking for is the connection between visualization and statistical analyses such as Lock and Harris (1992) and Kvamme (1995). Kvamme summarises this quest:

> simple statistics cannot convey the essence of spatial pattern in the same way that an effective graphic can. At the same time, statistical tests can inform us of the existence of (a) pattern when it is difficult or impossible to visualise, and even if we can see (a) pattern we may wish to obtain objective measures of its (existence and of its) strength. Both approaches complement each other ... [36]

In agreement with Lake *et al.* many recent claims about prehistoric landscapes could have been strengthened by the use of more rigorous methodology.

However, it should be noted that rigorousness should not overshadow or refuse to incorporate other forms of investigations such as certain phenomenological approaches, like Tilley's or Cummings.[37] Rather a more holistic approach is needed which incorporates knowledge and answers from many fields, creating a firmer and richer form of understanding. Tilley's 1994 discussion of Neolithic monuments in south-west Wales is a case in point. Tilley suggests that a monument at Longhouse, Carreg Samson, was located so as to be intervisible, that he does not provide the number of other locations in the landscape, which are also intervisible, weakens his conclusions. However, if he had been able to establish that there were few

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36 Kvamme, K.L., 1995. "A view from across the water: the north American experience in archaeological GIS". In: G. Lock and Z. Stancic (eds), Archaeology and Geographical Information Systems: a European Perspective. Taylor & Francis, London, pp. 1-14.

37.Tilley, C., A Phenomenology of Landscape: Places, Paths and Monuments, Berg, Oxford.

Cummings, V., 2002. All cultural things: actual and conceptual monuments in the Neolithic of western Britain. In C. Scarre (ed.) Monuments and landscape. London: Routledge alternative intervisible locations, Tilley's conclusions would have been strengthened and the outcomes deemed significant (remember too, that Fisher *et al.* also cite a list of investigator's flaws in this area as well as the positive points of their research in the area).

To create such a complementary approach between vision and statistics we must begin with the creation of testable hypotheses.

Testable hypotheses

The use of statistically testable hypotheses is not uncommon in spatial analysis or archaeoastronomy. Their use, however, in landscape archaeology and viewshed analysis, in particular, appears less often. Importantly, it is the possible derivation of firm statements of significant associations that suffers[38] The advantage of designing testable hypotheses is, then, that we can be more certain of both our results and their interpretation. Additionally, we will gain a greater understanding of the nature of our data, our methodologies and our enquiries by the sheer fact that we have had to produce very specific questions to provide very specific answers.

To create statistically testable hypotheses, certain properties of observed or gathered data are compared to those of a hypothesised (modelled) or real population (this may be a 'parameterised' real population). These latter populations are often called 'control groups', 'expected populations/distributions' or 'background values'. The expected distribution is that distribution which would occur if nothing other than an interplay of <u>chance</u> factors were responsible for its formation. When the resultant outcome of <u>no significant difference</u> is found between the control and the observed data it is said that the observed data is also likely to be the result of <u>chance</u> factors.

Knowing whether or not an event or an occurrence is due to chance factors leads to stronger and more reliable results and empowers our interpretations. Added to these, it allows us to determine further hypotheses that may help to disentangle more complex issues. Ultimately this may lead to a project that could encompass richer theoretical and methodological considerations. Fisher *et al.* (1997), Lake *et al.* (1998) and Wheatley and Gillings (2000) took up this opportunity in their applications of viewshed technology. Gaffney *et al.*, however, "fail most noticeably to compare the areas visible from those sites and the intervisibility among those sites with any form of <u>sample control</u>".[39]

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[38] Fisher *et al.* 1997, *Op cit.*, 582

[39] Fisher *et al.*, 1997, *Op cit.*, 583

Some research has revealed specific errors that may be encountered when background values are not considered. In 1995, Wheatley's study of the spatial relationship between barrows in the Stonehenge and Avebury areas revealed a correlation between viewsheds and elevation. Referred to as the *'view to itself' effect*.[40] Here, for instance, viewsheds taken from high points in the landscape will tend to include relatively many other high points such as ridges and peaks. A sample of viewpoints drawn from such locations will therefore preferentially 'see itself'.[41] According to Wheatley, this effect can result in the number of sites observed, in his case barrows, to occur in a particular viewshed being always one higher than it should be, leading to misinterpretation of statistical results. Wheatley rightly cautions against equating such statistical correlation with causation.[42]

Related to this is *the 'viewshed radius effect'*.[43] Van Leusen recently conducted some simulations that show that the size of the viewshed radius has a profound effect on the distribution of visibility index values across the terrain.[44]:

> For *any* set of points (including archaeological objects), choosing a small radius will result in a 'preference' for the lower elevations (valley bottoms) occurring in the study area, whereas choosing a large radius will result in a 'preference' for the higher elevations (peaks and ridges).

An example of this effect can be found in Lock and Harris' 1996 study of Neolithic long barrows in the Danebury region.[45] These long barrows, it was concluded, seem to be selected in order to 'alert people crossing the surrounding ridge tops'. According to Van Leusen, this 'rim effect' may be entirely due to the choice of viewshed radius.[46]

These examples alert us to the fact that outcomes may lead us to unclear, indecisive or possibly incorrect conclusions. It is, as van Leusen states:

> no longer sufficient just to report on the properties of the viewsheds generated for groups of archaeological monuments - archaeological relevance depends on such viewsheds being sufficiently

[40] Wheatley, D., 1995, Cumulative viewshed analysis: a GIS-based method for investigating intervisibility, and its archaeological application, in G Lock and Z Stancic eds., *GIS and Archaeology: a European Perspective*: 171-186.

[41] Definition taken from van Leusen, 1999, §3.2.

[42] *Ibid*, 180.

[43] van Leusen, 1999, §3.2

[44] Gaffney and Van Leusen forthcoming

[45] van Leusen, 1999, §3.2.

[46] van Leusen, 1999, §3.2.

different from the background visibility properties (background values or expected distributions) of the study area.[47]

The creation of expected distributions of viewsheds

"There is no predetermined method for finding the statistical significance of the area visible from one location as opposed to another"[48]

In GIS the influence of landscape factors cannot really be understood from a single model. This is because the topography of the landscape varies. Thus any model or expected distribution will be "dependent on site-specific terrain" (Fisher 1997:584).

Naturally, as viewsheds are affected by terrain, we have to determine "what is the likelihood that the observed pattern of visibility is an artefact of the surrounding landscape or topography, rather than anything else?" The most accurate, but time consuming, approach would be to create viewsheds for all locations within the Digital Elevation Model (DEM) through full intervisibility analysis. From these parameters the population of the viewsheds could be calculated.[49] As both, Fisher *et al.* (1997) and Lake (1998) point out, such a method is quite prohibitive for most researchers, either due to lack of computing power, time or landscape data.

A more suitable, and still very reliable, approach would be to create viewsheds from randomly sampled viewing locations. This will allow one to build a representative sample of the viewsheds of the entire landscape,[50] from which an expected distribution can be generated. An example of this applied technique can be found in Fisher *et al.* and is described below (1997:584). Terrain must be seen, then, as a condition or a 'background visibility property' as referred to by van Leusen (1999:§3.2).

Using the Monte Carlo method for the creation of background or 'expected' populations

The Monte Carlo method allows for a subset of the possible population of viewsheds of an area, such as those areas visible from a set of archaeological sites (our observed data), to be compared with a set of pseudo random data (mock expected data) that in effect mimics the form of viewshed one would expect if

[47] *Op cit.,* 1999, §3.2.

[48] Fisher *et al.*, 1997, *Op cit.,* 584.

[49] Fisher *et al.*, 1997, *Op cit.,* 584.

[50] Lake *et al.*, 1998:34.

the null hypothesis was true. A null hypothesis, in a simple viewshed scenario, might be "viewing location is not linked to viewing high points in the terrain". The pseudo random viewsheds would reflect this by containing more than 95% (say) of evenly distributed elevation data that would been available in the terrain under study. If there is a significant deviation between the observed data and the mock expected data then the former distribution of viewing points is said to be non-random and not due to chance factors.

To calculate the probability statistic that accompanies such comparisons one might ask: "how many of 'x' pseudo random viewsheds have more elevations above 'z' in view with than that of our observed viewsheds"? So, if we discover that 30 expected sites have more elevations above 'z' in view than the observed then it is said to be significant at the 30/560 level or .048 % level. That is, we have discovered that the number of elevations above 'z' in the pseudo random viewsheds is significantly less than that found in the observed viewsheds. We can conclude from this that the number of elevations above 'z' in the observed viewsheds is greater than that we would expect by chance. Naturally, such a simple statistic can be used to compare expected distributions created from the real population also.

As Peter Fisher *et al.* (1997) state, Monte Carlo testing "offer(s) a method with significantly reduced, but not trivial, amounts of computer analysis". An added advantage, especially in archaeology, is that a relatively small value of **n** can be used in Monte Carlo based hypothesis testing.

Lack of rigorous statistical analysis

Peter Fisher *et al.* state categorically that (if GIS is used) ... then rigorous statistical analysis should and can be applied, but usually is not (1997: 582). Added to this is the concern of misleading interpretations and conclusions caused by the use of GIS "without (the) understanding of the underlying spatial and statistical processes" (1997: 581). If one does not understand the mechanics of either the GIS software or data there could be a 'House of Cards' effect whereby the correct procedures and statistical analyses will not be applied, results will be irrelevant and interpretations ultimately of no consequence. One might even have to ask of oneself "have I designed my hypotheses around what I thought GIS software could do?"

Once more, spatial analysis and archaeoastronomy have led the way in the use of statistical tests. Ruggles and contributors in the 1984 study used Monte Carlo testing (probability statistic) and the Nearest Neighbour Tests. Monte Carlo testing has also been used by Sumner (1988) to study the Merrivale Stone Row, and Fletcher & Lock employed this method in the search for post-built rectangular structures at

Danebury hillfort (1984). Patrick and Freeman (1988) applied the clustering analysis known as 'SNOB' to Ruggles' 1984 dataset.

Viewshed studies, which have employed statistical analyses, include Wheatley's (1995) and Mark Lake *et al.'s* (1998) applications of the Kolmogorov-Smirnoff test. More specifically, Wheatley used Mark Lake *et al.'s* work to discuss the use of Kolmogorov-Smirnoff test to select a suitable sampling.[51] Fisher *et al.* use Monte Carlo testing and, Wheatley and Gillings use quantitative statistical analyses without statistical tests.[52]

Wheatley's 1995 project, for instance, in examining the distribution of Neolithic barrows in Wessex to determine whether the intervisibility between barrows is significantly greater than that between non-site locations and barrows, completed a viewshed analysis for each barrow and then added the results together. This allowed him to determine how many barrows could be seen from each cell in the landscape, and thus whether the barrows intervisibility was greater than that one might expect by chance. Also Mark Lake *et al* (1997) discuss the use of Kolmogorov-Smirnoff test to select a suitable sampling.

Interpreting results

Concerns of simplification

Wheatley and Gillings discussed the idea of implicit assumption of temporal concordance and the tendency to group monuments together on broad typological grounds for the purposes of viewshed and intervisibility study.

They wish to point out that this implicit assumption and grouping of monuments would cause a fusion of data with different cultural and chronological qualities. These may be unwittingly investigated as the deliberate condition of "a single, coherent plan".[53] Naturally, this condition could affect the soundness of one's experimental design, along with the reliability of the raw results and the validity of one's interpretation. These issues are relevant for other areas of archaeological investigation.

Having said all of this though, if there is an awareness of these issues, appropriate hypotheses, and the accompanying experimental designs, can be made.

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[51] 1998

[52] *Op cit.*, 1997 and *Op cit.*, 2000, respectively

[53] Wheatley and Gillings 2000: §?

It is also important to note that monuments undoubtedly persist over time as significant landscape and social features.[54] To discover, however, whether we have grouped together, or not, those monuments that represent the same tradition we must test this hypothesis rather than accept it uncritically.[55] And so we have come full circle, returning to the concerns of testable hypotheses.

[54] Wheatley and Gillings 2000: §4.6.

[55] *Ibid*, §4.6.

Software limitations and other issues in the application of GIS

No viewshed is completely reliable[56]

Whilst we are focusing this discussion upon viewsheds in particular, there are number of isssues that effect viewshed function and accuracy.

The Digital terrain model

Visibility analysis in GIS uses Digital Elevation (DEM) or Digital Terrain [DTM] Models of the real or prototype landscape or terrain. They are representations of cartographic information in digitised format. These models, which are not the actual terrain, do not mirror all the deviations, depressions, hillocks or possibly even tops of hills, in their design. This is because the elevation measurements of the actual terrain used to make these models are *usually* only taken at regular intervals; say every 10 or 50 metres. British Isles instances include the Ordnance Survey models, 1: 10000 Landform® PROFILE and 1:50000 Landform® PANORAMA, respectively. Such a model could be of the form of a raster grid (altitude matrix) in which the values in the cells are taken to be regularly spaced samples from the actual terrain:

> In raster data the entire area of the map is subdivided into a grid of tiny cells. A value is stored in each of these cells to represent the nature of whatever is present at the corresponding location on the ground. Raster data can be thought of as a matrix of values (Figure 5.4).[57]

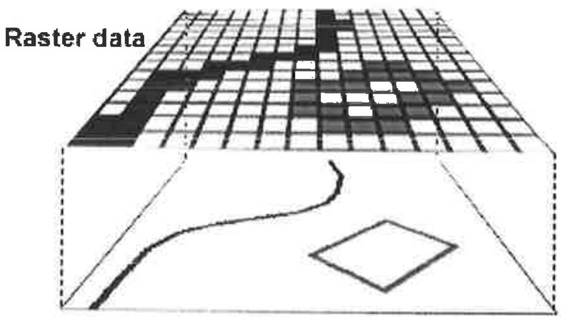

Figure 5.4: Representation of raster data.

[56] P.F. Fisher, 1996, Reconsideration of the viewshed function in terrain modelling, *Geographical Systems* **3**, 56.

[57] http://www.ordsvy.gov.uk/getamap/ "bout the GIS files" 1.2 Introducing raster and vector. aster data

The model could be a vector representation of these same elevations. "In vector data the features are recorded one by one, with shape being defined by the numerical values of the pairs of xy coordinates".[58] Here a single pair of coordinate values defines a point and a line is defined by a sequence of coordinate pairs defining the points through which the line is drawn. An area is defined in a similar way, only with the first and last points joined to make a complete enclosure.[59] Vector data can be thought of, then, as a list of values, as shown in Figure 5.5.

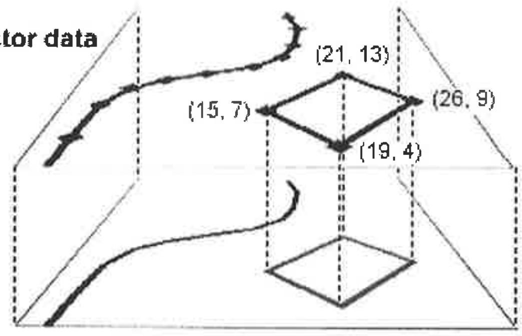

Figure 5.5: Representation of Vector data.

For elevation data a form commonly used is the Triangulated Irregular Network (TIN). In this case, triangular faces are derived from the Delaunay triangulation of spot-heights or survey points.

As these models do not mirror the real landscape exactly, any analyses using such models must take these shortcomings into account because they will affect the outcomes and the knowledge base extracted from these. As Wheatley and Gillings correctly point out "The quality and accuracy of the elevation model is a critical concern in deriving reliable, quantified estimates about the visibility and intervisibility of archaeological sites."[60] Therefore we must consider how model accuracy is affected by data accuracy. Data may come from scanning and digitising maps, as in the 1:50000 Landform® PANORAMA data. This means that the details of the landscape that can be extracted from the paper maps is somewhat less than that taken directly from, say, contours directly extracted from GPS usage. Added to this, are the issues of elevation measurement intervals: (i) remembering that the DEM is a set of discrete measurements of elevation taken from a continuous surface it becomes apparent that the concordance

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58 *Ibid* Vector data

59 *Ibid* Vector data

60 Wheatley and Gillings, 2000, *Op cit.*

between it and the real terrain is not complete and (ii) the distance between these discrete measures or data intervals (resolution), is variable between models, anywhere from 10-1000 metres again implying that the smaller the distance between these measures the more likely the similarity between DEM and the actual topography of an area. To summarise, "uncertainties in the DEM are a function of the inherent limitations of the model used, coupled with the quality of the data used in its construction".[61] Ultimately, the less concordance between model and reality, the less specific and tight will be the visibility hypotheses that can be tested.[62]

The terrain model and viewsheds

Naturally all these issues effect viewshed creation, or rather which areas will be chosen as being seen or not seen by an observer in the actual landscape. Fisher, as well as discussing the points made above, deals with how these issues, and others, impact upon the form of a viewshed created.[63] However, as Wheatley and Gillings point out, "the accuracy of the elevation model is not related in any simple way to the accuracy of visibility predictions".[64] This is for two reasons. Firstly, small variations in topography near to the viewer are far more likely to have large effects than similar variations further away. Secondly, hilltops and crests are far more important in the determination of visibility than valley bottoms or the sides of hills.[65] This has implications both for the choice of elevation model and the methods used to process it. There is a clear need to ensure that the elevation values recorded in a given model are particularly accurate at hill crests and this, in turn, implies that mean-filtering of elevation matrices to reduce noise is highly undesirable when visibility analysis is to be undertaken. Although the attenuation of 'noise' in an interpolated terrain model is beneficial in many situations (derivation of aspect, for example) most noise attenuators (including mean filters) have the effect of attenuating the areas that most characterise hillcrests. Put simply, mean filtering elevation matrices tends to lower the tops of hills and raise the bottoms of valleys – precisely the worst possible outcome for inferences about visibility.

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[61] J. Wood, 1996, The Geomorphological Characterisation of Digital Elevation Models. Unpld PhD Thesis. Leicester, 21, in Vision, Perception and GIS: developing enriched approaches to the study of archaeological visibility, ***, §5.1.

[62] See also C.G. Monckton, 1994, An Investigation into the spatial structure of error in digital elevation data. In: M.F. Worboys (ed.), Innovations in GIS: selected papers from the First national Conference on GIS Research UK. Taylor & Francis, London, 201-211.

P.F. Fisher, 1991, "First experiments in viewshed uncertainty: the accuracy of the viewable area", *Photogrammetric Engineering and Remote Sensing* **57,** 1321-1327.

P.F. Fisher, 1994, "Probable and fuzzy models of the viewshed operation". In: M.F. Worboys (ed.), Innovations in GIS: selected papers from the First national Conference on GIS Research UK. Taylor & Francis, London, 161-175.

[63] P.F. Fisher, 1991, *Op cit.*; P.F. Fisher, 1994, Op cit.; P.F. Fisher, 1995, "An exploration of probable viewsheds in landscape planning", Environment and Planning B: Planning and Design **22**, 527-546.

[64] *Op cit.,* §.3.2

[65] van Leusen, *Op cit.,*

For discussions of algorithms employed in the calculation of viewsheds see Fisher 1996, Loots *et al.* forthcoming; Nackaerts *et al.* forthcoming.[66]

Other problems of reality and the current project

Van Leusen asks, is a calculated viewshed sufficiently congruent with the real viewshed? Many topics have been considered thoroughly by other GIS reviewers in relation to this including Van Leusen's 1999 work. It is not necessary to detail here all the issues and problems associated with viewshed analyses. Suffice to say, that these topics can be reviewed easily by reading Gillings and Wheatley's forthcoming Ljubljana paper[67]. Issues that dominate viewshed critical analyses include the influence or effects of object-background clarity, line of sight and reciprocity, the palaeoenvironment, vegetation, mobility of people in a setting or across a landscape and temporal and cyclical changes to visibility. However, the concern of edge effects is directly related to this study and shall now be considered.

Due to a lack of availability of digital data, for reasons of non-existence or lack of funds, the actual viewshed is generally large relative to the study region (especially if their radius is unconstrained), they tend to 'fall off the edge' of the region.[68] The problem of this for single viewshed analyses is that vital information may be missed for correct and reliable conclusions to be drawn about the nature of any of the variables within the viewshed that are being tested. For example, in the current study, the number of sites within and with out a viewshed are considered as informative variables for investigations into the reasoning behind monument location. If the observed viewshed is smaller than the true or real viewshed, this will affect the number of sites actually being observed by the study. Consequently, the conclusions will actually be unreliable. The present study overcomes this problem by having available digital data for the area of western Scotland that lies well beyond the viewsheds of the sites concerned. Added to this variable of sites within a viewshed, is that of directionality. Gillings and Wheatley's paper "Seeing is not believing" introduced a new way to assess whether a specific *a priori* LOS direction is of more significance than all other LOS directions within a given viewshed. This work shall do this also.

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[66] P.F. Fisher, 1993, Algorithm and implementation uncertainty in viewshed analysis, *International Journal of Geographical Information Systems* **7 (4)**, 331-347.

P.F. Fisher, 1996b, Reconsideration of the viewshed function in terrain modelling, *Geographical Systems* **3**, 33-58

Loots, L, K Nackaerts, and M Waelkens forthcoming, Fuzzy viewshed analysis of Hellenistic city defence systems at Sagalassos, Turkey, in *CAA97.*

Nackaerts, K, G Govers and L Loots. Forthcoming, The use of Monte Carlo techniques for the estimation of visibility, in *CAA97.*

[67] In press, "Seeing is not believing: unresolved issues in archaeological visibility analysis", in B. Slapsak, (ed), *On the Good Use of GIS in Ancient Landscape Studies.* Ljubljana.

[68] van Leusen, *Op cit.,* § 3.2.2.

We have seen how important visibility has become in archaeological research. It is hoped that the above discussion highlights the convenient and helpful uses of viewshed applications in visibility analyses of prehistoric societies. It is this project's intention to modify and apply them to create a rigorous and enlightening outcome.

The following chapters describe the project's methodologies and results for each of the three phases of the study.

SECTION THREE

METHODOLOGICAL INVESTIGATION, APPLICATION AND RESULTS

Chapter 6

Phase I - Finding the right test for archaeological data (cluster analysis)

Investigation, comparison and use of circular statistics

Overview

This chapter temporarily narrows the methodological focus to the form of statistical analysis most appropriate for the assessment of azimuths or orientation data. In particular, that form of data collected in geographically and chronologically broad ranging studies of the British Isles. This section includes considerations on data that researchers in archaeoastronomy or landscape archaeology should know and understand before they endeavour to choose a statistical test. Described in detail are some tests used in directional analyses to date. A comparative investigation of these statistical tests follows, illustrating to which data patterns each test is most sensitive. It will be shown that when a test is particularly sensitive to a pattern, it is said to be more powerful at detecting this kind of pattern and more likely to produce a significant result when that test is applied to it. Basically, the kinds of departure from the null hypothesis of uniformity that each kind of test is particularly sensitive to are being investigated. In this way it can be said which test is superior, and why, for use in archaeoastronomy or landscape archaeology.

The general aims of this section were to understand the nature of the Ruggles' (1984) database, and the nature of the tests used by him. Further, the determination of the suitability of those tests for (i) answering his hypotheses and (ii) the nature of the database, was required. Finally, the search for an alternative test would be necessary if it was shown that the statistical tests used by Ruggles in 1984 were not entirely suitable, and to then apply this new test to the same database. Thereafter, the reassessment of Ruggles' astronomical hypotheses would follow in Phase II of the project.

Data Considerations

The first factor to consider when choosing the correct test is to examine the nature of the data. The first set of data that this project analysed was the orientations of monument alignments from Ruggles database (1984). In archaeoastronomy and landscape archaeology azimuths, declinations, altitudes etc. are dealt with, all of which are angular values representing directions. Direction is usually measured by angles ranging from 0^0 - 360^0.[1] An **azimuth** measurement is the number of degrees around the horizon from North that a position is found. Figure 6.1 shows this clearly for one point, where the circle symbolises the horizon around the observer who would be placed at the centre. The arrow indicates the direction of the point measuring 168^0 from north, where 168^0 is the azimuth. Azimuths, it is known, are cyclic in nature, where 0^0 and 360^0 are the same place on the horizon. Due to this, assessments involving circular statistics are used.

Analyses that wish to test for cultural similitude at some level inevitably have a tendency to combine site types and chronological zones. This could happen knowingly or otherwise. Earlier, the concern of Wheatley and Gillings was mentioned regarding the possible implicit assumptions of temporal concordance and the tendency to group monuments together on broad typological grounds. It has been previously mentioned that if one is aware of these issues one can still combine one's datasets wisely and design one's experimental analyses accordingly. The important thing is to know your database.

Ruggles was aware that " before there is any point in carrying out a statistical test, we need to accumulate enough data ... to give a reasonable hope of a definitive result" (1984:19). Thus if one wishes to apply a test validly, you need to have a reasonable number of sites. To overcome this, and other statistical concerns mentioned here, it is often better to maintain your database *in toto*, rather than dividing it into units of differing site types and so forth too readily (Higginbottom and Clay, 1999:S44).

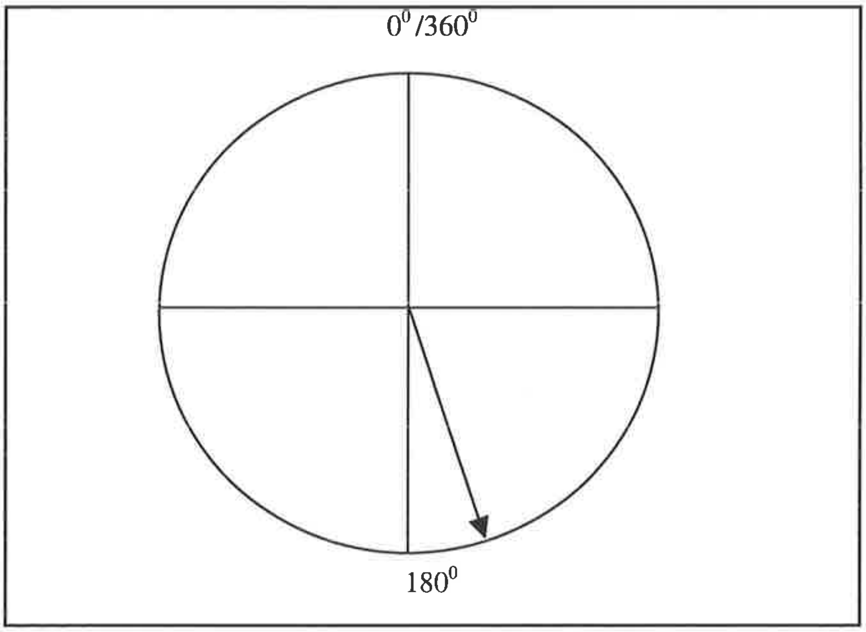

Figure 6.1: Here is an example of an orientation measurement taken from due North. An orientation measurement is an angular value called an azimuth.

[11] Batschelet, E. (1981), *Circular Statistics in Biology*, . 3. (Academic Press, London)

As well as for reasons of statistical propriety, monuments become grouped together deliberately for the testing of specific hypotheses. In archaeoastronomy, for instance, when looking for evidence of the orientation of monuments, researchers may be looking for a trend that may have indeed crossed the time zones, as well as distinct site types. Under these conditions, when choosing site types, those sites that are likely to share some cultural connections should be selected. They may appear, from the archaeological evidence, to be part of a larger social tradition, such as the building of monuments out of stone. This does not mean that one is *sure* that they do share further traditions, it is just that it is more likely, given that they already share similar qualities. It is the job of the investigation through the choice of the correct test to find out whether this is so.

There is a serious problem that arises out of the use of such combined databases, however, namely the possible appearance of data uniformity. By uniting such a broad selection of data types, one may well hide any trends or patterns that may exist. For instance, if looking for the clustering of site orientations towards a particular direction along the horizon, having a database that is compiled of a variety of datasets may well hide this pattern. Each set may be facing a different direction (whether this variety of directions is deliberate on the part of human agency is not yet the issue). This fusion of datasets, in creating a "uniform database", is likely to drown out any clustering signals. So we could possibly conclude from such a database that no patterns exist, when in fact they might.

On examination it was found that the data Ruggles and his collaborators had collected was combined of differing site types as well as those of differing ages.[2] Ruggles' first hypothesis asked if the sites showed any preference for facing a shared direction, or clustering in orientation, measured in number of degrees from north (azimuth). It was decided *a priori* by Ruggles to apply the question to the database as a whole and then to each of the geographical regions [3]

The nature of the Nearest Neighbour test – the best test for the job?

As implied above, the nature or form of the database affects the kind of questions that can be asked of it, and, to some extent directs which tests that can be used to answer these questions.

The orientation of the free standing stone monuments was tested by Ruggles using the Nearest Neighbour Test (NNT). Remember that Henry Neave and Keith Selkirk developed this test for the

[2] As Ruggles himself points out.

[3] *Op cit.*, 1984, 19.

analysis of the distribution of points on a circle.[4] The "sum of nearest neighbour distances (was) studied as a statistic for testing if n points on a circle ... are distributed uniformly randomly against alternative hypotheses of clustering or over-regularity".[5]

The statistic (t) is the sum of nearest-neighbour distances and is calculated, firstly, by measuring the distance from each point in turn to its nearest neighbour along the circumference. These distances are then summed and divided by the circumference of the circle. t may be any value between 0 and 1. The expected value of t under the random hypothesis is 0.5; whereas less than 0.5 indicates clustering and greater than 0.5 indicates regularity.
From this information it would seem that the test was appropriate for the hypotheses being tested. However, before commencing trials this test, other directional forms of assessment were investigated, namely the Rayleigh test and the Z_m^2 family of tests.

The Rayleigh Test for unspecified mean dierction

The Rayleigh test was developed by Lord Rayleigh in 1894[6] and applied by him to the study of the migration of birds[7]. Batschelet gives a brief history of this test and some good pointers in his well known *Circular Statistics in Biology.*[8]

Original Purpose

Its original purpose was to test whether the pattern of angular data obtained differed significantly from randomness. It was designed to enquire whether or not there was statistical evidence for directedness or one-sidedness in the data.[9]

How does it work?

The Rayleigh statistic ($\bar{R}$) is based on a vector calculation. To calculate the $\bar{R}$-statistic, the Rayleigh test basically constructs a "mean vector" from all the angles it considers and determines how far away this final point is from the origin. If the resultant vector (the mean resultant length) is short, it can be seen to be working its way back to the zero point and indicates that there is no directional preference found in the data. If the resultant vector is long, it has worked its way away from the zero point

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[4] Neave, N.R. and Selkirk, K.E., 1983, "Nearest Neighbour analysis of the distribution of points on a circle". University of Nottingham Research Report, 05-83.

[5] *Ibid.*, 05.

[6] Rayleigh, Lord (1894), *Theory of Sound*, **1**, . 35. (McMillian and Co., London).

[7] Elton, S.D. (1989), *A Search for Celestial Sources of the VHE Gamma-Ray Emission.* PHD Thesis -University of Adelaide.

[8] *Op. cit.*, 56.

[9] *Ibid.*, 55.

indicating that there are many vectors pointing in the same direction(s) which indicates that a significant non-uniformity is to be found in the data. The $\overline{R}$-statistic is basically the resultant vector. To illustrate how it is done, without actually making any calculations or drawing conclusions, assume there are 3 points placed around a circle, the directions they are pointing in are described by the angles A, B and C (Figure 6.2). Each line from the centre of the circle to the data points is considered to be 1 unit length or a unit vector.

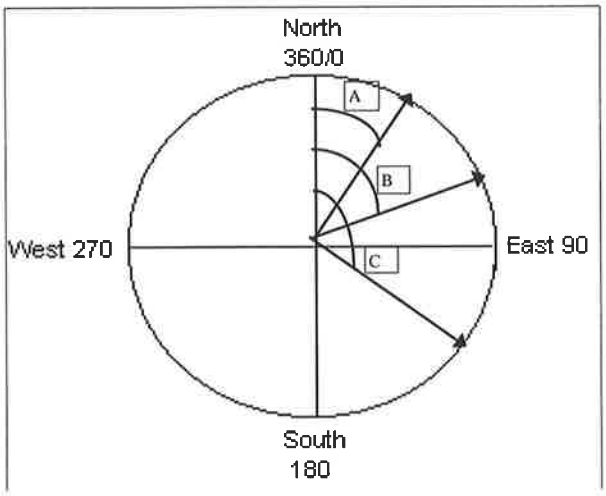

Figure 6.2: Example of building the $\overline{R}$ statistic from first principles or vectors – step 1.

The technique is to add one angle to the preceding angle using vectors. In Figure 6.3 a vertical line is drawn through point A, making this equal the 0^0 point on the circle, and from this the angle equal to that of angle B is measured, and represented with a unit vector, then the procedure is repeated. A vertical line is drawn through the new point B, making this equal the 0^0 point on the circle, and from this we measure the same number of degrees away from it as angle C equals, and represent it with a unit vector. Finally we join the last point, C in this case, to the point of origin. This line (dashed) is the resultant vector, and its "length" is representative of the data's significance for non-uniformity.

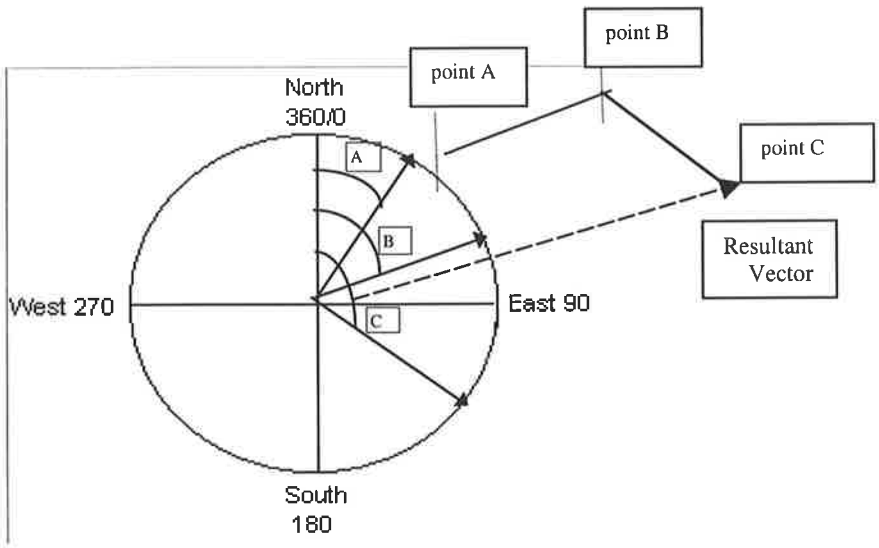

Figure 6.3: Example of building the $\overline{R}$ statistic from first principles or vectors – step 2.

Once the $\overline{R}$-statistic ('clustering indicator') is found, it must be determined whether or not it is significant by calculating, or accessing from a table, the significance probability and comparing them. If the $\overline{R}$-statistic is greater than the significance probability, or critical value, then you can reject the null-hypothesis. The critical value states what the probability is of $\overline{R}$ occurring, or a measure of the likelihood of the obtained value of $\overline{R}$. For example, if $P = 0.05$, then there is a 5% chance of the observed level of clustering happening by chance from a uniform distribution of directions.

Statistical operations

The length of this resultant vector, $\overline{R}$, is given by:

$$\overline{R} = \frac{1}{N}\left\{\left[\sum_{i=0}^{N-1}\cos\theta_i\right]^2 + \left[\sum_{i=0}^{N-1}\sin\theta_i\right]^2\right\}^{\frac{1}{2}},$$

where θ_i are the azimuth angles for the N data points.

If $N \geq 100$, the probability[10], (P), of obtaining a particular value for $\overline{R}$, under the null hypothesis, is evaluated by using $2N\overline{R}^2$ distributed as χ_2^2. Expressed as:[11]

$$P\,(\geq 2N\overline{R}^2 | \mathrm{H_o}) = \exp(-\mathrm{N}\overline{R}^2),$$

or more simply represented as

$$P = \exp(-\mathrm{N}\overline{R}^2).$$

Basically therefore the χ_2^2 tables are used to compare $\overline{R}$, or Rayleigh statistic, with the numbers in the table to "calculate" the probability of obtaining this score by chance.

If the number of events is small, ($N < 100$),[12] the probability (P) of obtaining a particular value of the Rayleigh power at least as large as Z ($\Pr(\geq Z \mid H_o)$), is calculated by:

$$P = \exp(\text{-}Z)[1+(2Z\text{-}Z^2)/(4N) - (24Z - 132Z^2 + 76Z^3 - 9Z^4)$$

[10] Fischer (1993) suggests $N \geq 50$, 70, whereas Elton (1989) suggests $N \geq 100$, 106.

[11] Elton (1989), equation 4.13, 106.

[12] Once more, Fischer suggests $N \leq 50$ by the fact that he earlier suggests $N \geq 50$ for the previous calculation, 70.

where $Z = (N\overline{R}^2)$[13] and Z is known as the Rayleigh Power.

This explains how the probabilities, or critical values, are calculated so that one can understand the links between this and the Rayleigh Statistic. One can actually obtain the critical values from tables in various texts. Batschelet (1981) informs us that tables were published for Z by Greenwood and Durand (1955), and that more accurate and enlarged tables of the critical values of $\overline{R}$ and /or Z can be found in Stephens (1969)[14] and in Zar (1974)[15]. Batschelet himself has a table based on Papakonstantinou (1979)[16] for the $\overline{R}$ statistic and its associated critical levels.[17]

Advantages and Disadvantages of the Rayleigh test

The advantages:

The order of the sequence of vectors is immaterial for the $\overline{R}$-test (Fischer: 1993, 31 shows how). This means that one can add new data without it affecting the statistical outcomes. It is very powerful in detecting broad, uni-directed peaks in the data, and the concentration of directions around the mean direction.

The disadvantages:

The mean angles that this test is based upon, however, are "statistics that are ... meaningful only for unimodal/single preferred directions"[18]. Many situations in Archeaoastroastronomy and archaeology call for the investigation into the possibility of multimodal/multidirectional phenomena (illustrated as multi-peaked functions in histograms). The $\overline{R}$-test's insensitivity to these situations (see Fischer 1993 for examples: 70,71), is exacerbated if the peaks are separated by 180° especially if the number of events in the opposing directions are approximately the same. This is because the opposing vectors associated with the twin peaks tend to cancel each other (see vector illustration), thereby producing a small value for the resultant vector ($\overline{R}$ statistic). The $\overline{R}$-statistic's extreme values, therefore, do not necessarily describe the extreme phenomena of clustering versus uniformity. It is, in fact, distribution

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[13] Z is represented by *P* in Elton.

[14] Stephens, M.A. (1969) Tests for the randomness of directions against two circular alternatives, *Journal Amer. Statist. Assoc.*, ***64***, *280-289.*

[15] Zar, J.H. (1974) *Biostatistical Analysis, Table T.* (Prentice Hall, Englewood Cliffs, N.J.)

[16]Papakonstantinou, V. (1979)Beitr(a..)ge zur zirkul(a..)ren Statistik. Ph. D. dissertation. University of Zurich, Switzerland.

[17] Table H, 334 -335.

[18]Batschelet, E. *Op. Cit.,* 21.

specific where $\overline{R}$ =1 implies that all the data points are coincident, but $\overline{R}$ =0 does **not** imply uniform dispersion around the circle.

In such situations it is sometimes advised to use tests of variance or standard deviation to discover, perhaps, the spread of your data and thereby gain greater insight into the obtained $\overline{R}$ statistic, but this in no way helps us to capture and label data as significant that is multi-modal (i.e. has well-defined modal-groups, or, where 2 or more areas occur with coincident data points). In situations which might require such considerations as this, it would be more appropriate to use a test that allows for a greater number of clustering groups in the set of data than one and that allows for peaks or clusters in opposing directions.

The Z_m^2 set of tests for unspecified mean direction[19]

Background

As with archaeoastronomy and landscape archaeology, astronomy deals with azimuths, declination, altitudes, etc., all of which are angular values representing **directions** in a plane. It was considered to be of some interest to apply tests that were in use in the fields of astronomy and astro-physics, where statistical tests[20] are also conceived with the concept of direction in mind. The Z_m^2 test is familiar in the fields of astronomy and astrophysics for the detection, for instance, of non-uniformity in the directions of incoming cosmic rays. Briefly, this test determines whether the observed pattern of orientations is consistent with the assumption that each orientation is equally likely to be anywhere between 0 and 360 degrees, or whether that assumption can be plausibly rejected. The Z_m^2 tests do not test for a specific direction, they only tells us whether or not uniformity exists.[21] If a test determines that the null hypothesis (uniformity in this case) can be plausibly rejected, one might reasonably infer that clustering might be the alternative hypothesis (H_1). Purely by inference, then, we might plausibly conclude that if the null hypothesis is rejected, such sites may have been deliberately designed and built to create the clustering effect.

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[19] The Z_m family of tests was brought to the attention of the author by Roger Clay, Department of Physics and Mathematical Physics, University of Adelaide.

[20]

[21] There are directional tests related to the Z_m set of tests that can be applied to subsets of the data if it is determined that significant clustering does exist.

Properties overview

The Z_m^2 statistic (as it is also known) was first examined by Gerardi et. al. in 1982 as an analysis tool for application in high energy astrophysics experiments.[22] The Z_m^2 family of tests was chosen because of its applicability to circular data and its sensitivity to multidirectional data[23]. The latter is related to its ability to overcome the serious problems of the vector sum method, or the Rayleigh test, upon which it is based, which can cancel out data points naturally occurring in opposite directions.

Properties in detail

The Z_m^2 test, or more truly, the Z_m^2 set of tests, are used primarily for the investigation of the uniformity or non-uniformity of data. Like the "Nearest-Neighbour" test they are not dependent upon the absolute position of the peaks[24] around the circle, and like the Rayleigh test, the order of the sequence of the angles is not relevant. .[25]. The advantage of the Z_m^2 being based upon the Rayleigh Test, then, is that by using *vector addition*, where the *order of the sequence of vectors is immaterial*, the reference direction itself becomes immaterial.[26] These tests, then, are truly independent of the reference direction from which the orientations (θ_i) are measured.

The Z_m^2 is an extension of the Rayleigh test - the Z_1^2 test in fact is the Rayleigh Test in the case where m =1, indicating the tests sensitivity to unidirectional data (one peak). The Z_m^2 family of tests, unlike the Nearest Neighbour and Rayleigh tests are particularly sensitive to the peaks/clusters in the angular distribution, and the width of these peaks/clusters in the data-base. The Z_m^2 family of tests are a number of tests where m can be equal to the number of peaks in the data-base being tested upon. The parameter m is also associated with the width of these peaks or clusters, where $m = 2$ is sensitive towards 2 **broad peaks** moving up to $m = 10$, which is generally considered to be sensitive to **narrower** and more **numerous** peaks. Each variant of the Z_m^2 test is more likely to detect significance in 'one' particular form of data than another: the form of data determines which of the Z_m^2 tests is best to use. The Z_m^2 tests greatest claims are that they can be used to investigate multimodal or multidirectional data <u>and</u> they can be applicable to more than one form of data.

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[22] Gerardi, G., Buccheri, R., and Sacco, B. <u>Proceedings of COMPSTAT 82</u>, Physica- Varlag, (Vienna IASC, 1982), 111. In S.D. Elton, <u>A Search for Celestial Sources of very High Gamma-Ray Emission using the Cerenkov Technique</u>. (Ph. D. Thesis, University of Adelaide, 1989)

[23] Elton (1989), *Op cit.* 108.

[24]

[25] Ruggles (1984), *op cit* mentions the vector sum method's shortcoming in section 12.3.1, 244.

[26] N.I. Fisher, <u>Statistical Analysis of Circular Data</u>, (Cambridge: Cambridge University Press, 1993), 30-31.

The Z_m^2 score is based on the same kind of vector calculation as the Rayleigh test (Z-vector or $\overline{R}$ -vector for the Rayleigh Test). In fact it is simply a summation of twice the Rayleigh Power (Z), evaluated for *m* peaks where the number *m* indicates the number of the peaks in the data. The number of peaks, by default, indicate the width between the peaks expressed by:

$$w(\text{width between peaks}) = 360^{\circ}/n(\text{no. of peaks})$$

$$\text{e.g. } w = 360^{\circ}/4$$

$$w = 90^{\circ}.$$

Z_m^2 is defined by:

$$Z_m^2 = \frac{2}{N}\sum_{j=1}^{m}\left\{\left[\sum_{i=0}^{N-1}\cos j\theta_i\right]^2 + \left[\sum_{i=0}^{N-1}\sin j\theta_i\right]^2\right\}$$

where N is still the number of events, such as orientations and θ_i is the azimuth of the *i*th orientation.[27]

Basically the Z_1^2 test (Rayleigh Test) extends to a Z_2^2, Z_3^2 ... Z_{10}^2 test in the following way. For a Z_2^2 test the angles are simply multiplied by 2 and the Z_1 test applied, Z_3^2, the angles are multiplied by 3 and the Z_1 test applied and so on. The test, if programmed into the computer, factors all of this in. You will not have to do this yourself. The expansion, however looks like this, using the Z_2^2 as an example:

$$Z_2^2 = \frac{2}{N}\sum_{j=1}^{2}\left\{\left[\sum_{i=0}^{N-1}\cos j\theta_i\right]^2 + \left[\sum_{i=0}^{N-1}\sin j\theta_i\right]^2\right\}$$

$$= \frac{2}{N}\left\{\left[\sum_{i=0}^{N-1}\cos(\theta_i)\right]^2 + \left[\sum_{i=0}^{N-1}\sin(\theta_i)\right]^2 + \left[\sum_{i=0}^{N-1}\cos(2\theta_i)\right]^2 + \left[\sum_{i=0}^{N-1}\sin(2\theta_i)\right]^2\right\}$$

or very simply

Z_2^2 = Z_1 test + Z_1 test (where the angles (θ) *are multiplied by* 2)

As with the Rayleigh test if the number of events is not too small the Z_m^2 statistic is distributed as χ_{2m}^2. The probability statistic can therefore be determined from the χ^2 tables, calculating degrees of freedom (*df*) by χ_{mx2}^2

[27] S.D. Elton, Ibid. formula 4.16, 107.

The β - test for n < 100[28]

This is a variant of the Z_m^2 statistic especially designed for small data-bases. As the Z_m^2 statistic is only distributed as χ^2_{2m} for n ≥ 100, one is not able to use to the χ^2 tables to look up one's probability levels when n is small. The β - test was designed to overcome this inconvenience so that researcher's could have a statistic that was i) equivalent to Z_m^2, ii) distributed as χ^2_{2m} for n < 100 and, therefore, iii) be used with the χ^2 tables.

The formula for the β - test is $\beta = -2\sum_{j=1}^{m} \ln\alpha_j$,

where α_j, *with j running from 1 to m,* equals the chance probabilities for obtaining the *m* values of $2N\overline{R_j}^2$. The chance probabilities for obtaining the *m* values of $2N\overline{R_j}^2$, that is αj, for n < 100 is calculated in the following way:

$$\alpha j = \exp(-P)\ 1 + \frac{(2P - P^2)}{4N} - \frac{(24P - 132P^2 + 76P^3 - 9P^4)}{288N^2} - \frac{(1440P + 1440P^2 - 8280P^3 + 4890P^4 - 87P^5 + 45P^6)}{17280N^{3-}}$$

where $P = N\overline{R_j}^2$.

To show those who are interested in the relationship between the β - test and the Z_m^2 test , another way of writing the formula for Z_m^2 is

$Z_m^2 = \sum_{j=1}^{m} 2N\overline{R_j}^2$, where $\overline{R_j}$ is the Rayleigh statistic for the jth harmonic;

$$\overline{Rj} = \frac{1}{N}\left\{\left[\sum_{i=0}^{N-1}\cos j\theta_i\right]^2 + \left[\sum_{i=0}^{N-1}\sin j\theta_i\right]^2\right\}^{1/2}.$$

The relationship between the Rayleigh statistic and the Z_m^2 can also be seen here.

[28] Formula and description taken from Elton, S.D., Ibid., Formula 4.19, 108.

Comparing the NNT and the Z_m^2 - family of tests

Both the Nearest Neighbour test and the Z_m^2 family of tests appear to have qualities or properties that would make them suitable for consideration. To see which might be the best test for the orientation database used by Ruggles, the outcomes of applying each test to a variety of database types were compared. This is known as comparing the performance of each test. These databases were randomly generated with the addition of various levels and types of clustering.

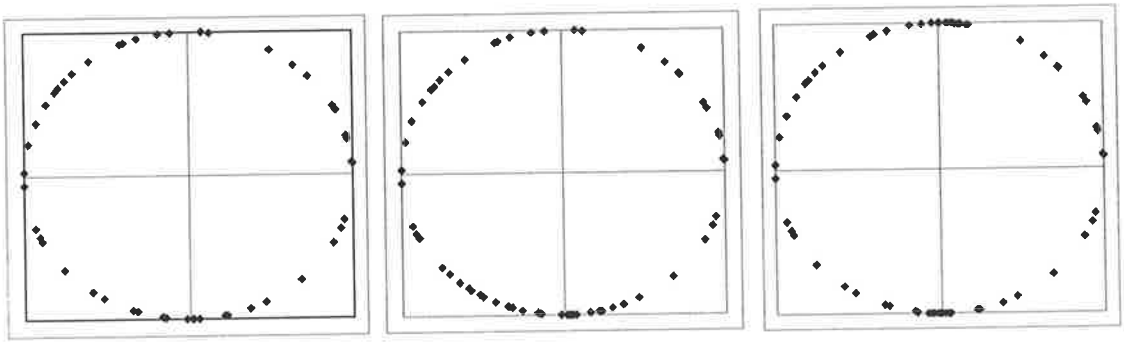
The performance of the Nearest Neighbour test

On performing comparative computer simulations to investigate the behaviour of the NNT it was found that the levels of significance derived from the NNT were indeed closely linked to the form of the generated databases. It was found that, in general, the NNT test performs well at detecting clusterings if there is no background "noise". It performs poorly, however, in the detection of relatively small clusterings that are superimposed upon a uniformly distributed background, as one might expect to find in the real database of Ruggles. This means that it is possible for the NNT to accept the null hypothesis of "no significance difference" when it should be rejected. Which means it may reject the hypothesis that supports probable clustering in the orientation measurements of megalithic sites when it should be accepted.

The performance of the Z_m^2 tests: a more appropriate test for the job

On performing comparative computer simulations to investigate the behaviour of the Z_m^2 tests it was found that this group of tests, although not without its limitations, is generally more effective at detecting small clusterings which are superimposed upon a uniformly-distributed background than the NNT.

The following examples illustrate the above points. The plot in Figure 6.4(a) represents a randomly generated *uniform* database only. The statistical result of all tests is as expected - no clustering is detected by either test groups (see Table 6.1).



Figures 6.4 (a), (b) and (c):

In figure 6.4(b) a single broad cluster has been added to the uniform dataset of 6.4(a), whereas in figure 6.4(c) two narrow clusters have been added. When the NNT is run again on these two databases, it is found that the NNT scores are not significantly different from Figure 1(a), however, the scores for the Z_m^2 family of tests can be seen to be significantly different from Figures 1(a) and 1(b) and 1(c). The Z_2^2 test is able to detect both the broader peak and the narrower peaks and thus seems more successful at revealing these sorts of clusters. Note that the Z_{10}^2 test, however, was only able to detect the narrower peaks, as expected. This further illustrates the advantage of using the Z_2^2 test in the early stages of megalithic database investigations.

	Figure 1a		**Figure 1b**		**Figure 1c**	
Test Type	Statistical Score n=50	Probability of obtaining score by chance	Statistical Score n=62	Probability of obtaining score by chance	Statistical Score n=57	Probability of obtaining score by chance
NNT	**0.500**		**0.521**		**0.513**	
Z(1)[29]	0.090	95.596	5.126	7.707	0.272	87.291
Z(2)	0.626	**96.008**	10.164	**3.775**	11.752	**1.930**
Z(10)	10.694	**95.378**	24.424	**22.438**	51.581	**0.013**

Table 6.1: Comparing the outcomes of the NNT and the Z_m^2 *family of tests*

Comparison Conclusion

It has been seen how the two tests perform when applied the same databases. The outcomes indicate that the Z_m^2 family of tests will statistically overcome background noise due to the inclusion of different site types or similar sites, built over a long period of time, or long periods apart. The test should also cope with the possibility that some 'cultures' during the time span of megalithic building

[29] Remembering that the Z(1) is equivalent to the Rayleigh test.

may not have had an interest in orienting sites at all during a particular epoch (increasing the likelihood, or adding to the creation, of a uniform background). Unfortunately the NN method has been found not to be such a test. It does not have the power to detect probable orientation clusters subsumed within a noisy or uniform background.

The Z_m^2 family of tests is, then, a more suitable test to apply to the database of Ruggles and contributors (1984). It is unlikely that one could conclude from the outcome that no patterns exist when in fact they might if we apply the correct form of the Z_m^2 family of tests to the database one has. Naturally if one applies too narrow a band of clustering (like m=8 or 10) to a broad band of clustering(s) one might do so, and if one applies m=2 inappropriately to narrow bands of clustering one may also do so. Examining the data, and comprehending the nature of it and one's hypotheses, will help to minimise these errors.

The Z_m^2 family of tests will be applied to the Ruggles orientation database and a comparison of these results with those of Ruggles will be made in the following chapter.

Chapter 7

Phase I results: orientation of free standing megalithic sites

The following reports on the methodology used and the results gained when the Z_m^2 family of tests was applied to the database of Ruggles (1984).

Methodology

Data description

There are 276 orientations in the raw database of Ruggles. These are from 125 unique sites (189 monuments) finally accepted after the rigorous selection criteria were applied to over 300 sites.[1,2] Of the 276 orientations, 56 are "single" orientations and 220 are "paired". Paired orientations indicate the same alignment in opposite directions (e.g. 195° and 15°). This was due to the absence of definite indicators of the preferred or intended direction.

Data preparation

For the analysis, only one of each orientation "pair" was used. This was achieved by arbitrarily choosing the angle that was less than 180°.[3] Having done this, of course, we cannot just add these selected angles to the data-set of the single angles because this includes angles above 180°. It is important to treat each member of the data to be analysed in the same manner. To achieve this, each of the single orientations was assigned its own partner by adding 180°. A pair of orientations indicating the same alignment in opposite directions was thus produced for each original data point

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[1] Ruggles (1984), op. cit., page 59 for site source list.

[2] ,Ibid., see table 2.1 for full reference list, pages 27 - 42.

[3] Methodologically speaking this can be considered as equivalent to Ruggles' data-base called "Pairs". See page 229 of Ruggles (1984?) for the explanation of the data preparation.

thereby mimicking the original pair data-set (e.g. a single orientation of 210° would be assigned an angle of 30°). To equate completely the single and paired orientation groups, all those angles less than 180° were extracted from the singles as above. These were then combined with the selected angles of the paired group to make a "new" complete database. We now have then, 166 angles less than 180° that are treated in a consistent way.[4]

To allows the application of a statistic that is dependent upon circular data, all the angles were multiplied by two so that the data will descry a full circle (0° - 360°), not just 0°- 180°. The data extraction and multiplying procedures do not affect the statistical tests in any way, such as producing bias, nor do they effect its rigour.

This means, though, that such data preparation wipes out any of the extra site information (where it is available) of a preference for one of the two directions for the original 56 "single" orientations. The reason for selecting the data in this way was to erase, in the very first instance, any influence of human decision (human decision, in this case, would be the choosing of the direction of an alignment by assessing the structure itself and/or the surrounding area). One must do this to get an unbiased statistical confidence level because adding any human decisions will affect the confidence level in an unknown way.

These sets of analyses, therefore, are merely looking for any kind of clustering without any specified direction, and therefore without any kind of presumption as to the nature of the monuments. This produces a sound statistical base upon which to build further archaeoastronomical research because the basis, or founding concept, of archaeoastronomy is the premise of deliberate orientation. Once this has been established statistically one can move onto the next level of complexity of one's hypotheses, such as particular directions based on archaeological evidence or information.

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[4] 56 orientations from the singles and 110 from the pairs.

The tests

The Z_m^2 family of tests was chosen because of its applicability to circular data and its sensitivity to multidirectional data. The test has the ability of overcoming the serious problems of the vector sum method, or the Rayleigh test, and that the reference direction is immaterial.[5]

The Z_2^2 - test for n > 100

It was decided, *a priori*, to apply the Z_2^2 in the first instance. In astronomy the Z_2^2 test can be used when an investigator is looking for general trends because it is powerful enough to pick out broad areas of activity or clustering, easily, but also has the power to be able to respond to narrow features. The Z_2^2 test is most conveniently used where databases are large.[6]

The β - test for n < 100[7]

Remembering that this is a variant of the Z_m^2 statistic where the number (n) is less than 100 in the data-set being tested. When using this test, the same m was chosen *a priori* as that for the Z_2^2 - test. *m here, then,* also equals 2.

The application

As implied above, to reassess data in a truly unbiased way, one must start from first principles. In this case, "first principles" means testing whether there is any clustering at all in the data. The first step then, was to test the database as a whole. If the results were to show some significance, it was decided to divide the database into geographical divisions for 3 reasons. Firstly, to see to what degree the more sensitive Z_m^2 tests would detect clustering for those same geographical areas found in Ruggles' assessment. Secondly, it seemed appropriate to keep the data divided into the same groups

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[5] N.I. Fisher, Statistical Analysis of Circular Data, (Cambridge: Cambridge University Press, 1993), 30-31.

[6] N.I. Fisher, Op cit.. When describing the Rayleigh test, upon which the Z_2^2 formula is based, Fisher suggests that for calculating the probability factor, n should be greater than 50 (page 70). S.D. Elton, (1989) Op. Cit.. (ref. 19) (Ph. D. Thesis, University of Adelaide), suggests n > 100 for the Z_2^2 test, 108.

that would need to be used for the statistical tests on the declination data. Each of the geographical divisions falls into slightly different latitudinal zones. The conversion from local coordinates (azimuth and elevation) to celestial coordinates (declination and right ascension) depends on the latitude and longitude of the observer or site. Naturally, then, latitude is an important consideration in any later declination tests, for if we placed all the local coordinates together we could wash out all the local effects. The third reason was that their geographical divisions/placement might represent ancient cultural divisions. These latter divisions will be dependent, however, upon unknown social emphases of what astronomical phenomena are important.

It should be noted that the maximum probability level chosen in advance for rejecting the null hypothesis was 0.1. This level was used and accepted by Ruggles (1984). It was therefore seen to be appropriate in the comparisons of statistical outcomes between that study and this.

Results

Entire data-base (Z_2^2 - test)

When looking at the entire sample, minor statistical evidence for the rejection of the null hypothesis (uniformity) was found (Z_2^2 = 8.58, n=166, p < .1). The alternative hypothesis of clustering, therefore, has been accepted. It was decided from this that it was worthwhile to continue the investigation of the data using regional analyses.

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[7] Formula and description taken from Elton, S.D., Ibid., Formula 4.19, 108.

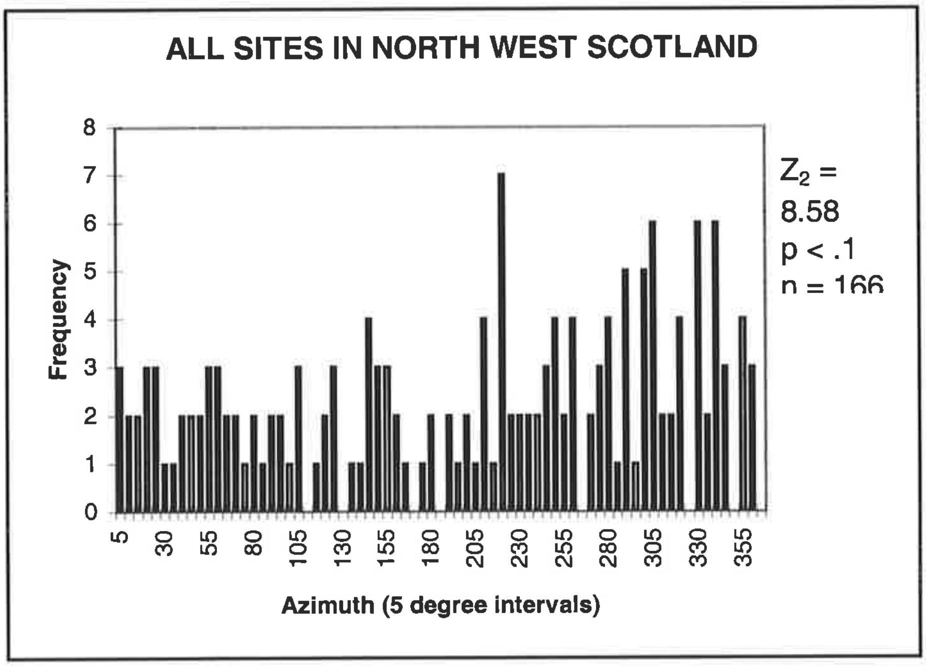


Figure 7.1: All sites sampled for first statistical analysis.

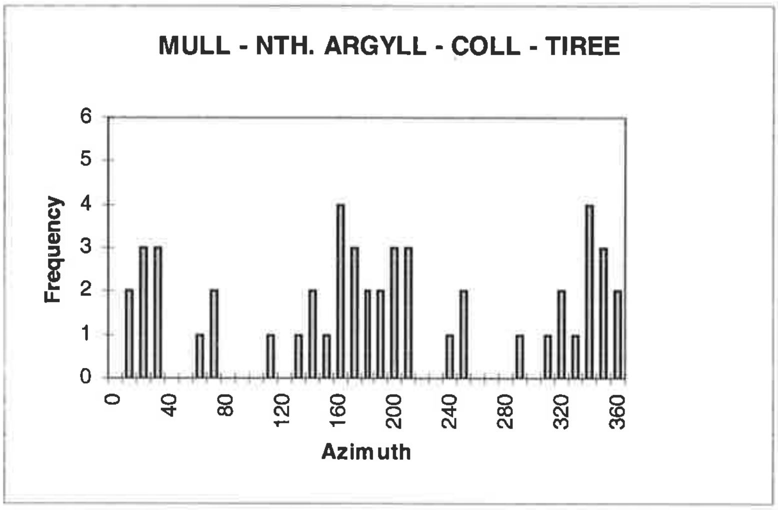
Results by region (*B*-test)

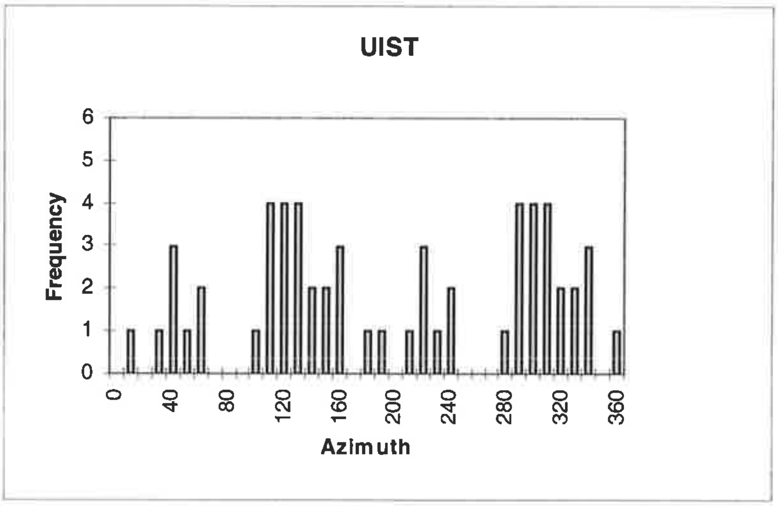
Very significant trends were found for the regions of Uist ($B = 15.93$; $p < .005$) and Mull ($B = 11.51$; $p < .025$). Trends of minor significance were detected for Argyll ($B = 8.99$; $p < .1$) and Islay ($B = 8.4$; $p < .1$). At this level of investigation Lewis/Harris and Kintyre were the only regions that did not reveal any evidence for the rejection of the null hypothesis (uniformity).

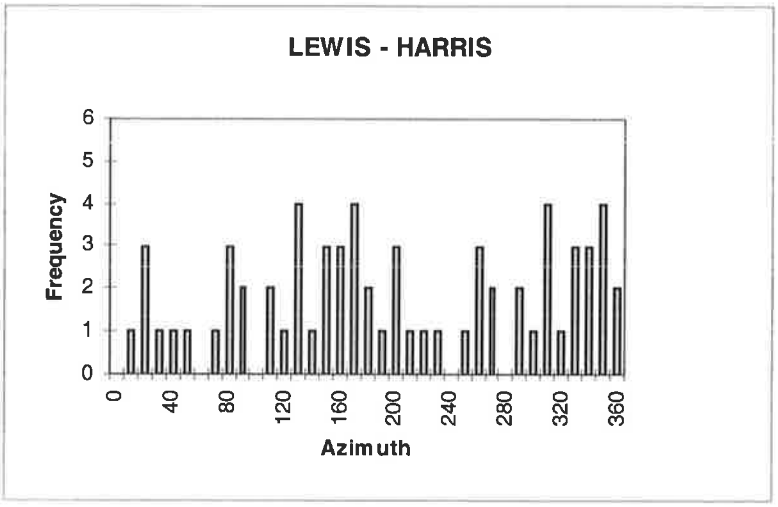
Regions	n of orientations	*B*	p[8]	df
Uist	29	15.93	***p* < .005**	4
Mull	25	11.51	***p* <.025**	4
Argyll	27	8.99	***p* < .1**	4
Islay	25	8.40	***p* < .1**	4
Lewis/Harris	33	5.55	*P* > .1	4
Kintyre	27	0.41	*p* > .98	4
total n	166			

Table 7.1: Region results in order of significance { where n = number of orientations, B = Beta-score, p = the probability of obtaining B by chance and df = the degrees of freedom, defined as (m x 2)}.

Figures 7.2a to 7.2f illustrate the orientation distributions of each region under investigation.







Figures 7.2a - c: Converted orientations by region in latitude order- from south to north

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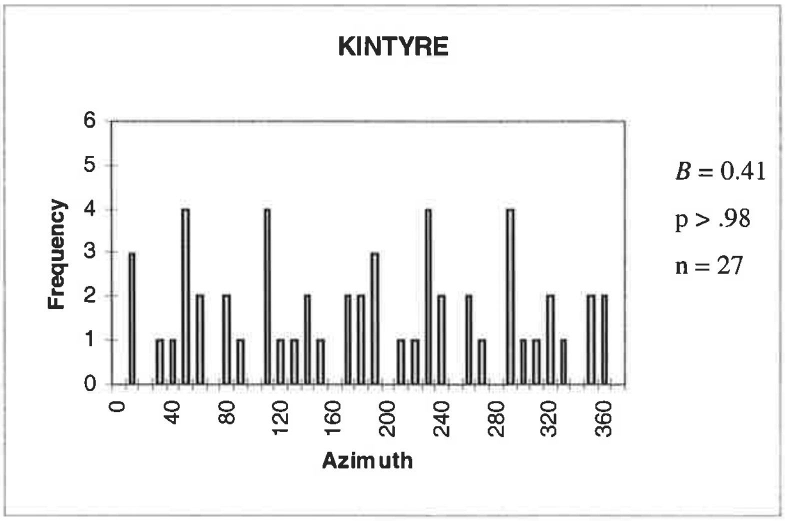
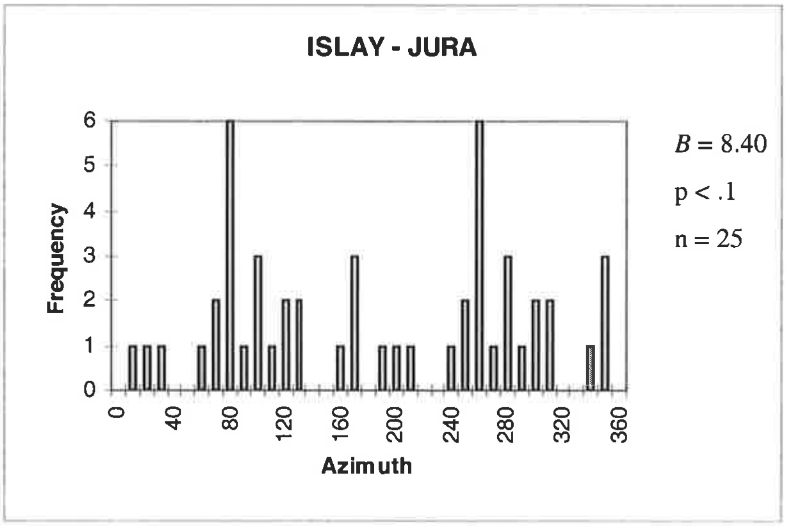
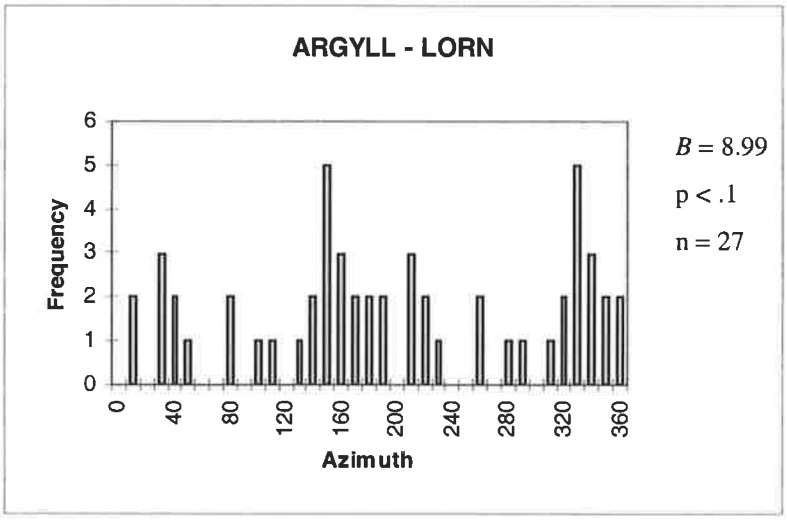
[8] Using χ^2 tables.







Figures 7.2d - f: Converted orientations by region in latitude order cont.

Within the major geographical regions

If one looks closely at the data-set, it will be seen that small adjacent geographical areas have been included in the analyses of the major geographical regions. The author did this so as to maintain a database consistent with that of Ruggles for data analyses comparisons, but also because the number of orientations in the smaller regions were so few they should not have statistical tests performed upon them separately. As the areas were very close to the major regions, and usually shared the same latitude, Lorn being the exception, it was considered acceptable to include them in this stage of analyses. This conjoining of smaller areas was as follows for the above analyses:

(i) Islay included Jura; Jura's n of orientations = 8.[9]

(ii) Argyll included Lorn; Lorn's n of orientations = 3.

(iii) Mull included the isles of Coll and Tiree and the area of North Argyll;

n: Coll = 3; Tiree = 2; Nth Argyll = 2. Total added n of orientations = 7.

Having gained these results it was decided that it would be very interesting to know how much influence the outer or adjacent areas might have had on the main geographical "centres". To do this the adjacent areas were extracted and the *Beta* tests re - run. These results were then compared with the original.

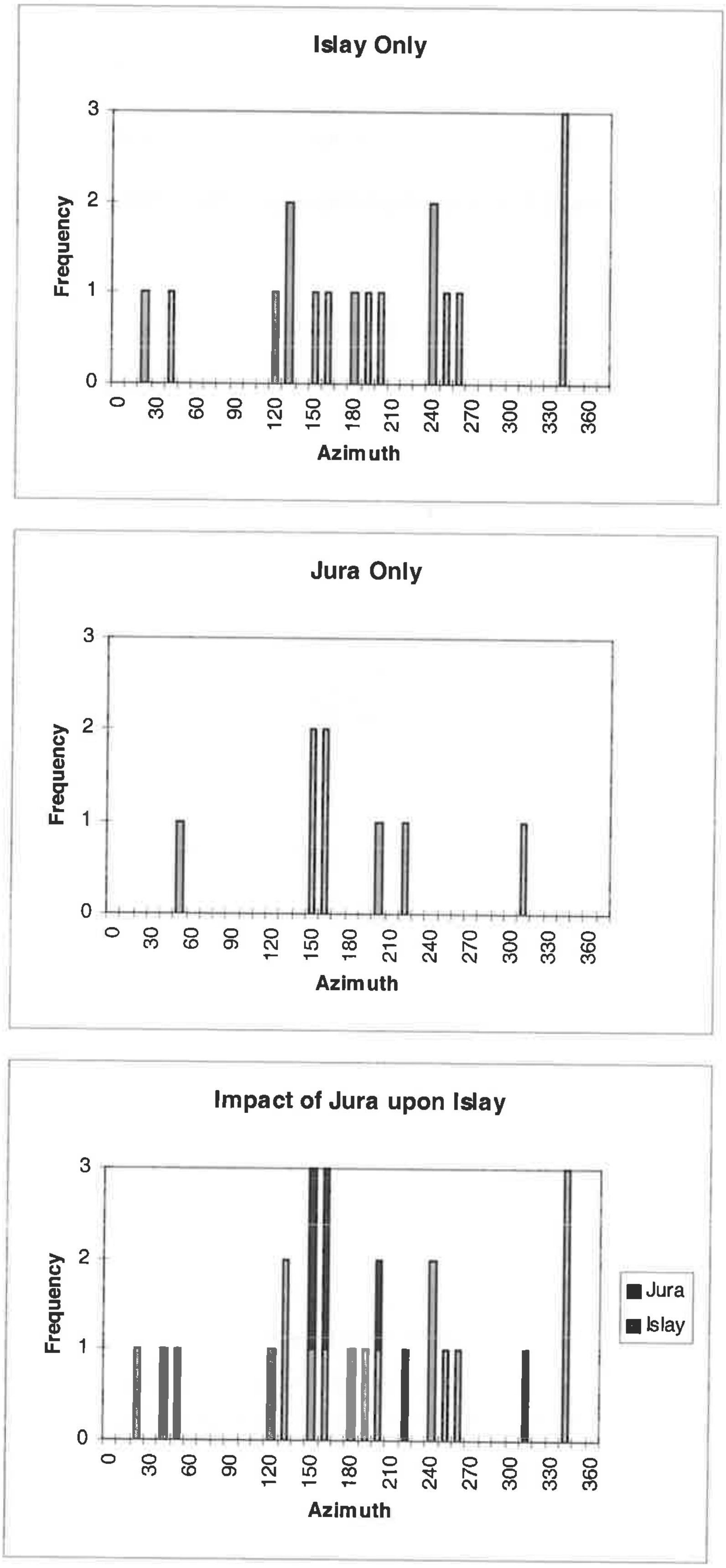
Region	**n**	**Original** *B* **- score (include adjacent areas)**	p	**New** *B* **- score (without adjacent areas)**	p
Argyll only	24	8.99	$p < .1$	9.08	$p < .1$
Mull only	18	11.51	$p < .025$	8.34	$p < .1$
Islay only	17	8.40	$p < .1$	2.76	$p > .1$

Table7.2: B - tests of main regions without adjacent areas:

[9] These numbers (n) refer to the final data-base as described in "Data preparation".

Comparing the previous *B* - results, we can see that Lorn has very little impact upon the statistical score of Argyll (9.08 as compared to 8.99). The same cannot be said of the impact of Coll, Tiree and Nth. Argyll upon Mull, nor Jura upon Islay (8.34 c.f. 11.51 and 2.76 c.f. 8.40, respectively).

If there is little influence of the smaller area upon the larger, it indicates that the orientation range, and orientation, of the data in the smaller area are about the same as the larger. If the influence of the smaller area can be seen to **increase** the statistical score, and that increase is substantial, then one can deduce that the orientations of this smaller area must cluster around the peaks of the larger region. It appears that the peaks are given greater weight. This is seems to be the situation with Islay. Figures 7.3a to 7.3c demonstrate this point clearly.



Figures7.3a - c: The impact of Jura upon Islay.

Discussion

The results primarily show two things: that there is a greater extent of clustering than previously detected in the stone rows of western Scotland and the majority of this can be detected at the first level of statistical investigation.

Comparing the results of the Z_m^2 and related tests with the Nearest Neighbour Test it can be clearly seen that the former have a higher detection rate than the latter. The Z_m^2 family of tests detected significant levels of clustering for 4 out of the 6 geographical regions, as well as the entire data-base, whereas only 1 region was detected by the NNT (see Table 7.4 below).

Nearest Neighbour Test				**Z_m^2 + *Beta* analyses**				
Regions	**n**	**t**		**Regions**	**n**[10]	***Z/B***	**p**[11]	**df**
Entire Data-base	165	.513	N/S	**Entire Data-base**	166	8.58	**$p < .1$**	4
Uist	29	.437	N/S	**Uist**	29	15.93	**$p < .001$**	4
Mull	24	.578	N/S	**Mull**	25	11.51	**$p<.025$**	4
Argyll	27	.553	N/S	**Argyll**	27	8.99	**$p< .1$**	4
Islay	25	.345	**.05**	**Islay**	25	8.40	**$p < .1$**	4
Lewis/Harris	33	.549	N/S[12]	**Lewis/Harris**	33	5.55	$p > .1$	4
Kintyre	27	.520	N/S	**Kintyre**	27	0.41	$p > .98$	4

Table 7.4: Comparing the Nearest Neighbour's and the Z_m^2 + Beta *analyses at the first level of investigation (using the Pairs data-base from Ruggles*[13]*)*

[10] It has been duly noted by the author that the number of orientations is different from Ruggles by 1, arising, it seems, from the difference n for Mull. It has not been possible to determine why this was so.

[11] Using χ^2 tables.

[12] Lewis/ Harris, was found to have significant clustering when only those sites with the closest horizons were included the analysis. $\underline{t} = .274$, $p < .05$ - see below.

[13] As stated earlier the Pairs data-base and preparation is essentially the same as this investigation's, it is therefore appropriate for statistical purposes to compare these results with each other.

Ruggles NNT results

Clustering was only detected by the NNT when the database was subdivided or reduced.[14]

Argyll

Argyll, for instance, was shown to have significant clustering when 1) members of pairs of orientations with the nearest horizon were omitted and/or 2) the onsite and intersite indications were analysed separately and 3) the breakdown of the "indication status" of alignments begun[15,16]:

i) Pairs - Onsite	Classes 1 - 3	n = 11	t = .313, p < .1
	Classes 1- 2[17]	n = 11	t = 3.13, p < .1
	Class 1	n = 9	t = .221, p < .025
ii) Furthest horizon - Onsite	Classes 1 -3	n = 11	t = .264, p < .05
	Classes 1 -2	n = 11	t = .264, p < .05

Mull

Mull was seen to display a minor trend for regularity when the onsite and intrasite indications were assessed separately: Pairs; onsite; t = .643, p < .1(n = 18). This regularity tendency appeared to "strengthen" as the orientations were further subdivided by "indication status" down to classes 1 - 3. Only once classes 1-2 within the "furthest horizon" group were tested was clustering found.

[14] No significant results were found for any of the regions within the intersite division.

[15] See Ruggles (1984), op. cit., pages 62-63 for the definitions of the 6 classes of indications.

[16] Argyll was also shown to have significant unnatural regularity when only the closest horizons of each orientation pair was omitted: t=.631; p < .5, n=27.

[17] There are actually no class threes.

Unfortunately the n is below 10, which means these results for azimuths are not highly reliable by the time we have reached this level of the analyses.

i) Pairs - Onsite	All Classes	n = 18	Regularity: t = .643, p < .1
	Classes 1-4	n = 12	Regularity: t = .712, p < .025
	Classes 1 - 3	n = 11	Regularity: t = .741, p < .025
ii) Furthest horizon - Onsite	Classes 1 -2	n = 6	Clustering: t = .264, p < .05

Islay

As table 5 shows, both the B-test and the NNT statistically supported the Islay data at this initial level of inquiry. As Islay has a highest peak in its main clusters, more so than any other region, and its minor clusters have very few data points indeed, the NNT may have been more able to detect this clustering pattern more successfully than for any of the others.

Uist

By far the strongest outcome of this investigation is the high *B*-score and immense probability weighting given to the region of Uist for clustering. The strangest thing is that the NNT did not detect any clustering at any level of its analysis. Looking at the histogram (fig. 7.2b) does not shed any light as to why this might be so. This NNT result is particularly interesting considering that the *Beta* detection so clearly suggested that clustering was present.

Kintyre and Lewis/Harris

The B-test, like the NNT, did not detect any significant trends for clustering at this initial level of analysis for either Kintrye or Lewis/Harris. As with the regions above, once the data were divided into subsets for the NNT, some very significant results appeared. For Kintrye, however, the n's were very small - namely 7 and 6 (out of a total of 27) - for the following results:

Furthest horizon	Classes 1-4	n = 7	$t = .227, p < .05$
	Classes 1 - 3	n = 6	$t = .167, p < .025$

These small numbers make the statistical outcomes, in themselves, fairly unreliable.

The Lewis/Harris NNT results fall prey to the same statistical problems of small n's except for:

Furthest horizon - $t = .274, p < .05, n = 12$,

where no other sub-division has occurred. Here n = 12 and is deemed as being above the base-line of acceptability, assuming, of course, that the NNT caters for small numbers in the first place. The other positive result for Lewis/Harris has an n of 5.[18] Though this result is interesting in that it may be detecting a pattern, and certainly it shows the likely effect of this subdivision upon the orientations, taken on its own, it is too unreliable to be used as significant and sound evidence for clustering.
It might just be mentioned here that Ruggles (1984) did not solely rely on the NNT tests for his analyses. Those tests were the first stages of the statistical investigations before moving onto detailed declination analyses.

Regional summary of NNT vs Z-test outcomes

What can be stated conclusively then, is that there is very strong statistical evidence for clustering in Uist using the β - test, whereas no clustering was discovered at all for Uist in the 1984 azimuthal

[18] For distant horizon and Pairs data-sets within classes 1-2, and 1 only. However, as L/H has no class 2 sites the results can be considered as one and the same.

investigation. Further to this, the strength of evidence for clustering in Mull is far greater than that detected by the NNT even when the region was subdivided for use by the NNT. Only once classes 1-2 within the "furthest horizon" group were tested was a minor trend for clustering found by the NNT ($t = .252$, $p< .1$, $n=6$). Unfortunately, too, the n is below 10, which means these results are not highly reliable by the time we have reached this level of the analysis.

To a lesser extent, the strength of clustering in Argyll also seems to have found support using the β - test. Interestingly, the minor trend of Islay found with the β - test, was seen to be weaker than that found by the NNT at the first level of the analyses. Investigations to date have suggested that this may be due to the data distribution of Islay, which may demonstrate a high "peak to noise" ratio as a whole.[19] As soon as the data were divided into subsets (i.e. reduced), however, this trend could no longer be supported by the NNT. Lewis/Harris was also found to have significant clustering using the NNT, but, again, only when the data were reduced by excluding those sites with the closest horizons from the analysis: $t= .274$, $p < .05$, $n=12$. Following further data reduction, presumably accompanied by a number of trials, support for clustering in Lewis/Harris only appeared when n was reduced to 5.

Summary of phase 1: chapters 4 and 5

When data extraction or subdivisions were not applied to the data, the nearest neighbour method that Ruggles applied did not find any support for clustering in the separate regions, except for Islay. However, when the closest horizons were excluded, and/or the regions were subdivided according to orientation type (inter/intra) and indication status (class), statistical support for these regions began to emerge. This was further supported by tests carried out on declination data by Ruggles.[20] The B - test however, clearly detected clustering in 4 of the 6 regions at this level, using the maximum accepted level of probability of 0.1. The Z_2^2 test also detected clustering for the data-base as a whole. This is as we might expect considering that the Z_m^2 family of, and related, astronomical tests indeed appear

[19] The answer to such queries will be dealt with in "Astronomical Statistics for Archaeoastronomy: their nature and application" (ref. 16).

[20] Ruggles' declination analyses did not show the support that might have been expected for the predominance of sites with the furthest horizon, given the results of the azimuthal tests.

to be more sensitive for detecting general clustering in large and small astronomical data sets (of azimuths).[21]

If the majority of the clustering patterns can be detected at the first level of statistical analyses, an investigator will be able to reduce any associated statistical penalties. Using the Z_m^2 family of, and related, astronomical tests, fewer statistical penalties would be incurred, as those tests are more powerful and further testing is less necessary. This reduction in statistical penalties allows an investigator to draw conclusions about the data with <u>a greater degree of confidence</u>. Also, only hypotheses determined *a priori* may be truly tested statistically and their outcomes quoted as "hard evidence". Any further statistical analyses on the same data base will have associated penalties.

Phase I of this project has addressed the demand of Wheatley and Gillings to test the hypothesis of "whether we have grouped together ... those monuments that represent the same tradition ... rather than accept it uncritically".[22] We have indeed found support for the likelihood of a similar tradition within the database, that of the deliberate orientation of monuments. We can now use the same database to test for more complicated behaviour, namely the orienting of sites for the purpose of indicating celestial phenomena.

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[21] See Chapter Four. This investigates the behaviour of each test by comparing their performance on simulated data. It also compares a statistical tests previously used in orientation assessments.

[22] *Op cit.*, 2000, §4.6.

Chapter 8

Phase II Declination Methodology

Incorporating the natural environment: Horizons and astronomical connections

The next phase of this study was designed to determine whether the regional orientation differences found previously were astronomically linked/significant. However, whilst maintaining a strong interest in astronomy, the natural landscape is taken into account.

To discover whether these regional orientation differences were astronomically linked/significant, it was necessary to calculate their corresponding declinations and investigate whether or not the *distribution* of these *observed* declinations could be attributed to chance factors.

The horizon

The horizon is the most distant, and thus final, point people can see. The horizon itself, then, may be of particular significance to the builders of the monuments. Moreover, it may be related to the sites' orientation. Theoretically, it was chosen to consider the horizon an extension of the monuments, where the monument is the backsight, to view and indicate the direction in which the phenomena may lie, and the horizon, the foresight, upon which the phenomena appear. In this way, it was hoped to avoid any inappropriate placements of boundaries at this early stage of the study. What will be discovered from this stage of the assessment are two things: (i) whether particular forms of horizons, as indicated by their elevation, azimuth and location (easting and northing), were of interest to the builders of the monuments and (ii) if so, whether these preferred forms were of astronomical significance.

Naturally, such a theory is also an extension of the astronomical assumptions that have been made. Namely, that the study of Neolithic/Bronze Age astronomy in the British Isles is based upon the assumption that the ancient peoples were interested in celestial bodies as they rose and set along the horizon.

Methodology

To discover whether the directions the monuments faced had any astronomical significance, the coordinates of the points on the horizon indicated by the monument (elevation and azimuth) were converted to a declination (declinations are values given to the paths along which celestial bodies travel).[1] These observed or calculated declinations were then tested to see whether they were equivalent to those declinations for celestial bodies, and, if so, whether or not what was discovered was purely a chance occurrence. It is known, for instance, that the horizon altitude and therefore the horizon shape is a variable that affects the value of the observed declination. Horizon shape, then, was a variable that had to be controlled for. In regions that have very undulating horizons it becomes even more imperative to investigate the impact that a horizon shape may or may not have on declination assessment. This form of assessment has not been practicable before due to the large amount of contour data required to test the influence of landscape shape upon the outcomes of any investigations into astronomical interest. Such data allowed us to test whether the outcomes of our astronomical inquiries were due to the chance factors of landscape shape rather than the possible deliberate choice of the builders to choose a particular *form* of horizon.

With generous support from the Ordnance Survey, United Kingdom, it was possible to initiate a major pilot study that allowed for the assessment of the likelihood that an indicated astronomically significant observed declination, or group of observed declinations, was not just an artefact of the surrounding horizon shape or profile. The Ordnance Survey provided the contour data for every region in the west that was under initial investigation, as well as neighbouring regions.[2] See Figure 8.1 for the 164 tile maps obtained for the study. Having this landscape data allowed the consideration of monuments in their geographical context also (Figure 8.2).
To discover whether the observed declinations *were* artefacts of horizon shape, the likelihood of an astronomical declination occurring by chance at any other place on the entire horizon profile of every single alignment was calculated. This would allow the determination of the statistical significance of the results. Using programs written and tested by Andrew Smith, it was possible to generate the horizon profile of each alignment numerically and graphically from the digital elevation data (see Figure 8.3 for graphic example). In producing a horizon profile, each horizon had to be 'viewed' from the National Grid Reference (NGR) point of each alignment for which an orientation reading

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[1] Loosely speaking a declination is calculated using 3 pieces of information: direction (orientation in degrees from north), altitude of horizon and latitude of observer.

[2] Landform PANORAMA Digital Height Data at nominal 1:50 000 scale (Licence no. ED 0178A).

was assigned by Ruggles.[3] Determining which NGR went with which alignment was not always obvious from the site descriptions in Ruggles' report so the author calculated some by plotting.

The creation of the 2D Horizon Profiles by A.G.K. Smith

According to Smith "since the NGR may not correspond to an actual data point in the DTM, the ground height at this point (was) obtained using bilinear interpolation of the DTM data".[4] The wireframe model was then mathematically transformed into a 360 degree view from the observer's position, taking into account the effects of the curvature of the Earth and atmospheric refraction.[5] The observing position used was 2 meters above the ground height.

For these horizon profiles, all parts of the transformed wireframe were discarded except that part which forms the boundary between the land and the sky.[6] The elevation and linear distance of each point along the horizon were then interpolated for azimuths with a regular spacing of 0.01 degrees. The azimuth and the NGR (converted to latitude) of each site or alignment, as well as the altitude of each horizon point, allowed for the calculation of declinations and the creation of the horizon profiles.[7] Another way of expressing this is that each elevation point along the entire horizon profile was *converted* to a declination. Here a converted declination indicates the trigonometric path of a celestial body that crosses the horizon line at the point of elevation. These calculations took into account atmospheric refraction, which bends light whilst it passes through the earth's atmosphere, the amount of visual distortion decreasing with altitude.[8]

With these calculations, the atmosphere itself was assumed perfectly clear. For though a landscape feature in the region of 100 kilometres distant would most likely be obscured by atmospheric haze and completely invisible to the human eye, this feature would still block any light of an astronomical source behind it.[9] Thus, importantly, a landscape feature would still visually affect the rising and setting of an astronomical body even though the landscape itself might not normally be visible to a human observer. Interestingly the observer might, from time to time, be able to see the feature as a silhouette when backlit by a bright source such as the Sun or the Moon (or perhaps infer the existence

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[3] 1984, *Op. cit.*

[4] A.G.K. Smith, *Overview of the Landscape Rendering Software used in the Archaeoastronomical Investigations*, forthcoming.

[5] *Ibid.*

[6] *Ibid.*

[7] Some testing by the author was required of Andrew Smith's coordinate converter that converted eastings and northings to Latitude and Longitude.

[8] Åke Wallenquist, 1968, *The Penguin Dictionary of Astronomy*, 33.

[9] Smith, *Op cit.*

of that feature as a bright star disappears behind it).[10] For these reasons, the assumption of perfect atmospheric clarity is justified. In the early stages of the research, panoramic photographs taken by Charles Tait in places in western Scotland were used to deduce the initial accuracy of the profile programme (see Figure 8.4 which is a panoramic photograph of the same National Grid Location as Figure 8.3 Girvan).[11]

Creating a model of expected declinations

Once all the horizon profiles were generated, each was sampled at the uniform intervals of 0.1 degree in azimuth, extracting the corresponding elevation and horizon distance for each of these azimuth points.[12] The azimuth and the NGR (converted to latitude) of each site or alignment, as well as the altitude of each sampled horizon point, allowed for the calculation of declinations along the horizon profile.

This process produced a number of declination data files with 3600 declinations each. Initially the number of declination files is equal to the number of *unique NGRs*. However, for statistical accuracy, the number of declination files should equal the number of orientation measurements, not the number of NGRs. Therefore, each horizon profile for every single *orientation* listed had to be included whether it had the same horizon profile as another orientation or not. For example, a unique NGR may represent an alignment made from a simple row of stones (say Stones a-c) that gives no clear indication as to which way the alignment should be viewed, from Stone a or Stone c. One would have, therefore, two orientation measurements for this alignment, say $30^0$and 210^0, and, as the stones are so close, they are associated with the *same NGR*. Hence the list of declinations associated with a particular horizon profile may have to be included more than once in the statistical analysis. Once all this was done, every single declination file was then concatenated according to each geographical region (Mull, Argyll, Lewis/Harris, Uist and Islay) to produce 6 ultimate declination files.

With these calculated declinations a model of what the *expected* declination spread would be under the null hypothesis for each major geographical area was created (that is, the distribution of declinations we would expect to get if there was no preferred declination. With these, the *observed* pattern of declinations was compared, remembering that the observed declinations are associated directly with the azimuth readings (orientations) of the site alignments for each region.

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[10] Smith, *Op cit.*

[11] Charles Tait is a photographer based in Orkney.

[12] The program for this extraction was designed and tested by Andrew Smith.

The observed distributions

Each indicated horizon "point" is actually variable in width and thus is not a point at all but a linear range or *window* along the horizon. To assist in understanding the indications, Ruggles divided the indicated azimuths, and thus their corresponding declinations, into 2 sections: the inner azimuth range (IAR). These consist of 2 values which mark the inner indicated range by the monument (the monuments axis), and the AAR, which indicates the furthest possible boundaries on the horizon that the monument could possibly be indicating (1984). For statistical analyses the *mid-point* of these declination windows were used.

Distribution analysis - landscape considerations

This part of the assessment allows us to compare directly the observed declination pattern with the expected one for each geographical area. By doing so we can determine whether or not the horizon was given any consideration when the monuments of western Scotland were built. If such consideration was given, it will also allow us begin our foray into the likelihood that the free-standing stones in western Scotland were built with rising and/or setting astronomical phenomena in mind.

Pilot project and the search for possible astronomical alignments

This project is considered a pilot because, although it is on a large scale, we are using Landform PANORAMA Digital Height Data at nominal 1:50 000 scale[13]. Apart from other difficulties, this low-resolution data can cause problems where horizons are closer than 250 metres. Using grid heights that occur every 50 metres means that we can only look at testing possible astronomical alignments within sensible, broad bandwidths along the horizon. Though this does not cause a problem with the observed data, it will affect the elevations that are calculated from the DTMs and therefore the expected distribution.

As these observed data are more accurate or specific than those data calculated from the widely spaced DTMs, investigating astronomical phenomena within *narrow horizon bandwidths*, such as 1^0, would be inappropriate and invalid. Once we have determined which regions are likely candidates for closer investigation it may then be possible to obtain Landform PROFILE at the 1:10 000 scale, which will allow us to compare like with like (i.e. with the same or similar amount of variance).

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[13] We used the Digital Terrain Models (DTMs), created from Ordnance Survey's `Landranger®' paper maps.

The Kolmogorov-Smirnoff test

It was decided *a priori* to use the Kolmogorov-Smirnoff (K-S) test to compare the two distributions due to its pilot project status. This test, being non-parametric, imposes fewer constraints about the parameters of the populations from which samples are drawn. Moreover, the K-S test, like the Smirnoff, under the conditions that the population is assumed to be continuous, is distribution free.[14]

However, though the K-S test has the advantages of specifying fewer conditions, it is quite a weak test and thus may accept the null hypothesis when it should be rejected. Also the very nature of declination data is known to lead to a bi-modal distribution, and the K-S test is known to be insensitive to bi-modal distributions. [This is because it treats a bimodal distribution as two single mode distributions and though recognising there is twice as much data, it computes the same maximum deviation (the K-S statistic), or difference between the expected and observed distribution, whether there are two modes or one.] To obtain a more realistic estimation of the chance probability it was necessary to fold the data at the zero degree (0^0) point, so that we had all positive readings for declination. Remembering, at this point, specific declinations or groups of declinations are not at issue here, only the *differences between the distributions* of the declinations.[15]

Astronomical considerations

This part of the assessment allows the direct comparison of small widths of observed declinations with those of the expected. This allows the determination of whether or not there may be an interest in particular declination ranges by the constructors of the monuments and whether these are astronomically connected.

The statistical test to be used in the binned declination comparison

In order to run the K-S test, the observed and expected declination data had to be binned. The bin sizes were determined by the minimum number(n) that could be placed within a single bin for sensible statistical comparison whilst maintaining a valid spread of data across declinations. Known declination dimensions, or widths, of astronomical phenomena further guided the assessment. Five-degree bins were chosen. It was upon these bins of the *unfolded* distribution that the next test was run.

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[14] C. Mitchell, *Terrain Evaluation*, (1991, 2nd edition), 157.

[15] It was necessary to scale the expected distribution to have the same total the number(n) of events as the observed distributions for the test to be applicable.

There is a way of calculating the chance probability of *n* occurring *within* a bin. The poisson distribution allows us to compare the observed distribution with that of the expected, despite n being small. The Poisson probability distribution was used to calculate the probability of observing n sites in a bin where m are expected.[16]

[16] For large (approx. greater than 30) values of n, the Poisson distributions well approximated by the normal distribution.

Ordnance Survey Panorama Tiles

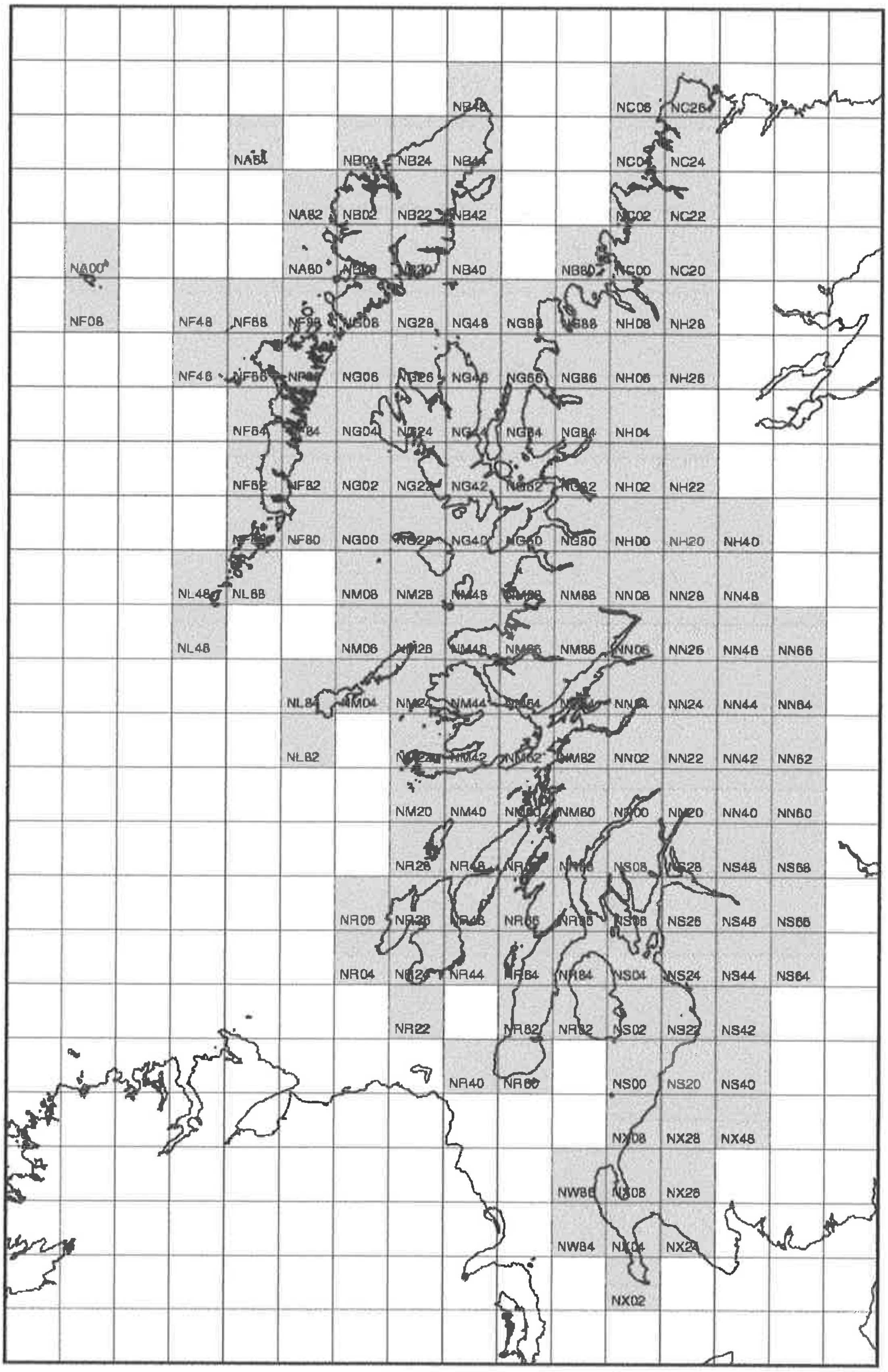

Figure 8.1: Illustrating the 164 tile maps obtained for the study. Software designed by Andrew Smith. Based upon the Ordnance Survey 1:50 000 Landform PANORAMA map with permission of the Controller of her Majesty's Stationery Office © Crown Copyright

Figure 6.2: Topographical map created by Andrew Smith for this project using a programme designed by him. Based upon the Ordnance Survey 1:50 000 Landform PANORAMA map with permission of the Controller of her Majesty's Stationery Office ã Crown Copyright..

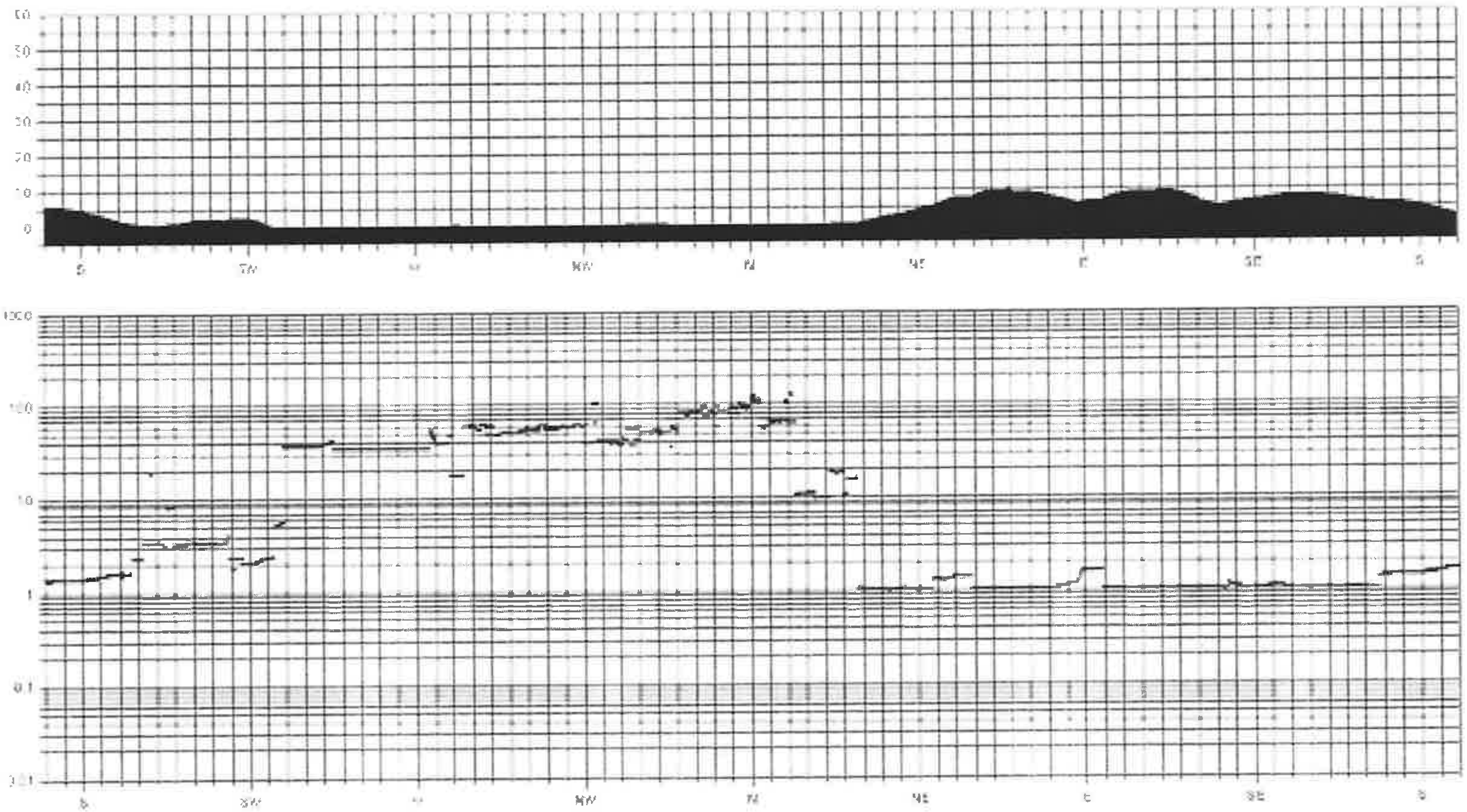

Figure 8.3: Example of a 2D Horizon Profile of Girvan, Scotland.

Figure 8.4: Photograph taken at Girvan, Scotland. Photographer Charles Tait. . Based upon the Ordnance Survey 1:50 000 Landform PANORAMA map with permission of the Controller of her Majesty's Stationery Office ã Crown Copyright.

Chapter 9

Phase II Declination Results

Astronomical indicators: cultural connectors and separators

Result overview

Kolmogorov-Smirnoff test

The expected distribution of the declination data is non-uniform (Figure 9.1). The K-S test revealed that three of the six observed horizon profiles differed significantly from the expected under the null hypothesis, namely those of Mull, Argyll and Islay (Table 9.1). For the regions of Uist, Lewis/Harris and Kintyre, however, we must accept the null hypothesis, for no significant difference was found.

REGION	*P*	SIGNIFICANCE
Mull	**0.00817**	YES
Argyll	**0.00593**	YES
Islay	**0.00105**	YES
Uist	0.20815	NO
Lewis/Harris	0.65137	NO
Kintyre	0.96539	NO

Table 9.1: Kolmogrov-Smirnoff probabilities, where p = probability.

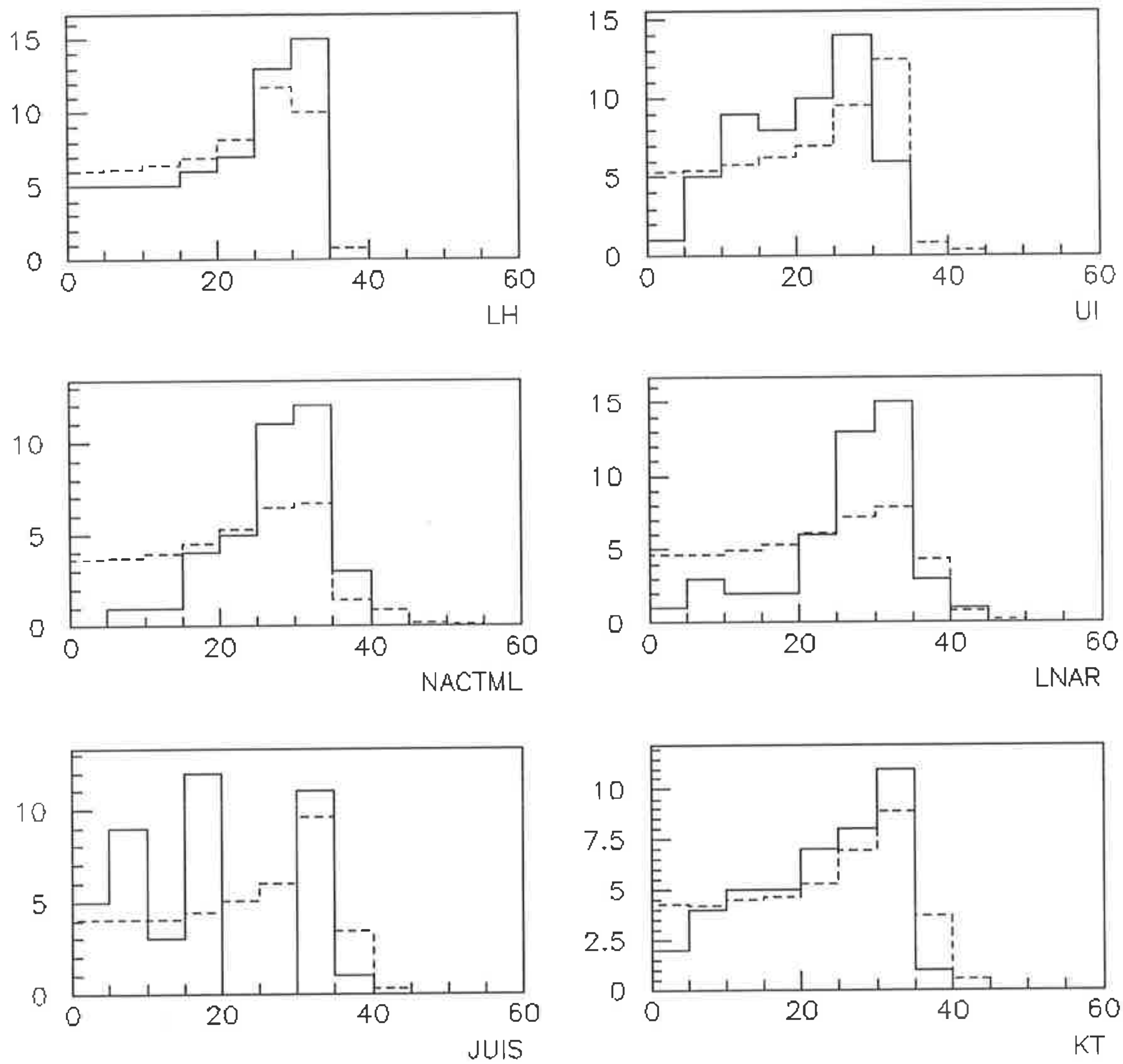

Figure 9.1: The distribution of declinations for each region. The expected distribution is shown in dashed lines and the observed distribution is solid. Remember it was necessary to scale the expected distribution to have the same total the number (n) of events as the observed distributions for the test to be applicable.

The binned declination comparisons

Poisson statistics were used to compare the actual horizon ranges of focus with those of the expected. The expected pattern being a normal distribution *within* bin-widths. Table 9.2 shows the significant Poisson - distribution results of the individual bin analyses, where *p is the probability* of outcome. It can be seen that when comparing the individual bins (5 degrees) of the horizon distributions, particular observed declination ranges of Mull, Argyll and Islay were found to significantly deviate from the expected bins (Figure 9.2, Table 9.2, columns 1 to 3).

Mull appears to have a stronger interest in the Southern part of the sky whereas Argyll appears more focused on the Northern. Islay's significant ranges, on the other hand, are more evenly spread. It should be noted too, that there are declinations recorded as significantly avoided or "shunned." Namely, -5^0 to $+5^0$ for Uist, -10^0 to $+5^0$ and 10^0 to 15^0 for Mull, -15^0 to -10^0 and 15^0 to 25^0 for Argyll and -20^0 to -30^0 and 20^0 to 30^0 for Islay (Table 9.2, column 4).

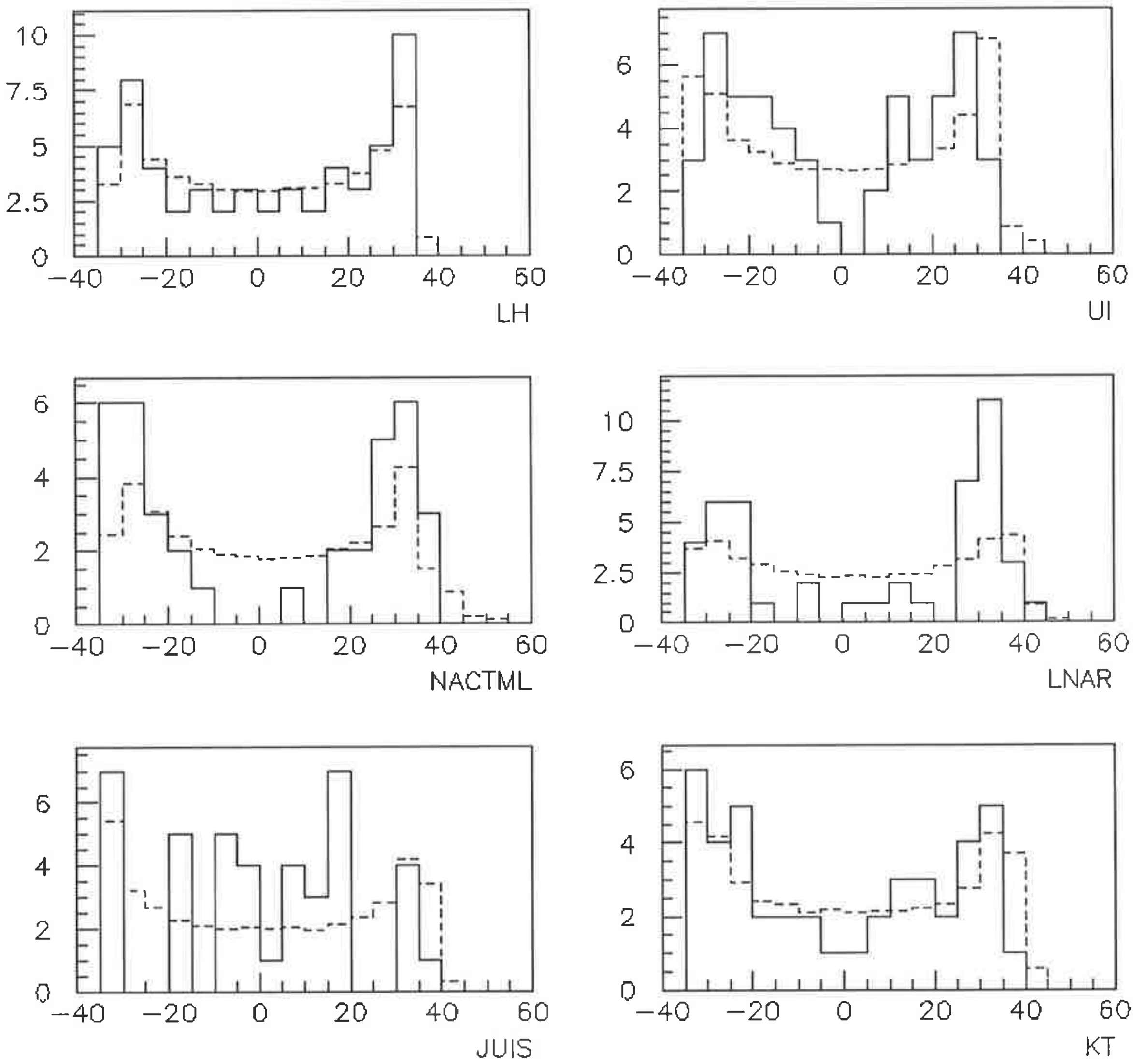

Table 7.2: Poisson distribution outcomes used for the individual bin analyses. The expected distribution is shown in dashed lines and the observed distribution is solid. For large (approx. greater than 30) values of n, the Poisson distribution is well approximated by the normal distribution.

Region	Significant declination bin-widths in degrees	*p*	Possible astronomical phenomena	Ranges significantly avoided
Mull	-30 - -35 (southerly)	**0.025**	Lunar (Major standstill)	
	-25 –-30 (southerly)	0.095	Lunar (Major standstill)	
	25 – 30 (northerly)	0.077	Lunar (Major standstill)	
Argyll	-20 - -25 (southerly)	0.062	Solar (Winter solstice)	-15 – -10 (southerly)
	25 – 30 (northerly)	**0.026**	Lunar (Major standstill)	15 – 20 (northerly)
	30 - 35 (northerly)	**0.002**	Unknown – but indicates densest part of Milky Way	
Islay	-15 - -20 (southerly)	0.051	Lunar (Minor standstill)	-20 - -30 (southerly)
	-5 - -10 (southerly)	**0.035**	Solar (flanking Equinox)?	
	0 - -5 (southerly)	0.096	Solar (flanking Equinox)	
	0 - 5 (northerly)	0.095	Solar (flanking Equinox)	
	15 - 20 (northerly)	**0.005**	Lunar (Minor standstill)	20 - 30 (northerly)

Table 9.2: The three regions that demonstrate possible interest in astronomical phenomena. Probabilities in bold are where* p *< 0.05, others are where* p *< 0.1.

Discussion

Gazing at the horizon: distribution evidence?

The results of the declination distribution assessment, along with the previous azimuth orientation assessment, revealed that for the areas of Argyll, Mull and Islay, the horizon was a significant consideration in the positioning, and perhaps design, of the monuments. The Uist orientation data showed a very strong interest in the deliberate orientation of monuments (B= 15.93; p< .005), however, general interest in the horizon is not supported by the K-S tests. Discussion of this will follow later.

At this stage of the research, we can only outline *possible* interests in astronomical phenomena. As mentioned in the 'Phase II Methodology' the elevation data does not allow us to calculate exact expected horizon profiles thus disallowing higher resolution comparisons. What can be said, though, is that there is sound evidence for an interest in specific horizon areas corresponding to particular declination ranges (Table 9.2, column 3). The indicated declinations of the monuments in Mull (Nth. Argyll, Coll & Tiree) have strongest statistical support for the southerly range -30^0 to -35^0; along with the flanking range of -25^0

to -30^0 having minor support. For the former range, the declination windows for 5 of the 6 indications, span from -30.4^0 to -32.6^0, and for the latter, the declination windows for 4 of the 6 values range from -28.2^0 to -30.1^0. The northerly declination range 25^0 to 30^0 also has minor support and it should be noted that *all* the mid-declinations investigated in this range fell between 28^0 and 29.85^0 degrees with the windows ranging from 27^0 to 30.2^0. As this is the case, it is tempting to infer that all of the observed declinations may indicate an interest in the Major standstill of the moon which is approximately +28^0 and -30^0 during the second and third millenniums BC.

When taking into account the azimuths corresponding to each declination we discover that for all the declinations within the -30^0 to -35^0 and -25^0 to -30^0 ranges, exactly half are focused upon a rising phenomenon, and half upon the setting for each range. The geographical position of these indicated ranges may also have some social significance. Of the ten back-sight sites, 4 are on Coll/Tiree (CT 1,2,7,9) and 4 are in Northern Mull (ML1,2,4,11). This spread is similar for 25^0 to 30^0, where 4 of the 5 back-sight sites reside in the same areas (ML 10; CT 1, 3, 9).
Argyll's significant declination ranges include -20^0 to -25^0, 25^0 to 30^0 and 30^0 to 35^0. The southerly indications (-20^0 to -25^0) fall around the solar rising and setting positions at the solstice, 4 about the midwinter sunrise and 2 about midwinter sunset (+/-24^0 = solstice). The orientations associated with the northerly declinations of 25^0 to 30^0 maybe indicating an interest in lunar phenomena towards the Major standstill (+28^0), in the same way that Mull's may have. The corresponding declination windows range from 23.3^0 to 30.6^0, with 5 of 7 falling above 26^0.

The range of 30^0 to 35^0 is a little perplexing from the solar-lunar perspective, for 11 of the 13 declination windows have a minimum value above 32.2^0 degrees. They therefore fall mainly outside of the range of a probable interest in the sun's and the moon's movements. There is some anthropological evidence for a society focusing on the "negative" areas of the sky (i.e. areas *without any* celestial objects). However it seems unlikely given there is already a concentration upon these 2 major objects in this region, that there may also be a deliberate attempt to avoid *all* lunar and solar events.[1] The most likely celestial phenomena of interest along the horizon that can be hypothesised, at this stage of the project, is the Milky Way. At these latitudes and this declination range it has a great concentration of bodies and is very striking in appearance

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[1] This is the hypothesis that Ruggles et al (1984) propose, 277.

Islay's ranges are most unusual in that the significant ones fall within those very ranges that Ruggles found an overall avoidance for in western Scotland, namely -15^0 to $+15^0$ degrees. It is known that $-5^0$to $+5^0$ in declination flanks the equinox points of east and west, and can be loosely calculated by dividing the horizon in half between solstices (which is a simple arc in shape). The $\pm15^0$ to $\pm20^0$ range may indicate an interest in the Lunar phenomena of the minor standstill. Interestingly Islay significantly avoids all solstitial ranges by completely shunning the -30^0 to -20^0 and 20^0 to 30^0 ranges. There is no simple explanation or hypothesis for the range -15^0 to -10^0.

On the theme of specific *phenomena* preclusion, it should be remembered that there *is* a significant avoidance of the ranges -10^0 to -15^0, and 15^0 to 20^0 and 20^0 to 25^0 in the region of Argyll. The latter two suggest that Argyll is avoiding the northern Minor Lunar standstill and the Solstice). Whilst Mull has a disinterest in -5^0 to $+10^0$ and 10^0 to 15^0, suggesting a deliberate avoidance in the Equinox overall. Uist has significant avoidance between -5^0 to $+5^0$ and 30^0 to 35^0, which may imply a lack of regard for the equinox and the Milky Way.

Conclusion

There are significant regional differences in the orientation and placement of the monuments. It appears that deliberate choices have been made in each region as to what the monuments are supposed to indicate and thus which direction they should face. There are still many unanswered questions or quandaries. If Uist has the highest statistical significance for the deliberate orientation of the western monuments studied here ($\beta = 15.93, p < .005$), what are the monuments "facing" if the horizon is of no apparent general interest (K-S probability = 0.20815)? These results from the area of Uist tell us that something else altogether was of significance, or of more significance. Islay, also, has quite a complex pattern of declination ranges and it would do well to investigate other possible reasons or further evidence for the preferred orientations and horizon indications.

At this point of the project it is not safe to assume that these indicated sections of the horizon were as important as the monuments themselves. However, it would be reasonable to suggest that there is some evidence that the horizon was seen as a significant factor in their construction, and may have even been seen as an extension of them. The appearance of the monument may have induced the appropriate cultural connections to the celestial phenomena or even the horizon. The monument could have been then, a representation of the sacredness of these things. The possible connection between the monument, the landscape and the phenomena can now be seen.

Chapter 10

Phase III Methodology

Orientation and visibility analysis

Abstract

This chapter intends to demonstrate the connection between all Phase III methodologies. It is believed that this part of the project fulfils the minimum requirements of those critics who rightly demand the incorporation of systematic project design and quantitative analysis in the application of viewshed technology.

Introduction

To begin the investigation two equally important questions demand to be asked. The first is, 'is the relationship I have seen between monument, horizon and astronomical phenomena a continuous one across the landscape?' That is, are there any other areas or objects between the monuments and the indicated phenomena that participate in this relationship? To begin checking these hypotheses I searched for other social indicators in between the free standing stones and their horizons. The social indicators chosen were all other Neolithic and Bronze Age monuments not included in the 1984 study of Ruggles' and contributors (see "The 'secondary sites'" below for an explanation of this procedure). Putting forward the simplest hypothesis first, then, "a spatial relationship, in the form of clustering, exists between the Ruggles sites and other Neolithic or Bronze Age objects or places" (hypothesis 1). More specifically, "there is a possible alignment of the Ruggles sites, the indicated horizon or phenomena and other Neolithic or Bronze Age features"(hypothesis 2).

The second question asks, "does the connection between monument, horizon and astronomical phenomena also contain an extra visual component?" Might there not be a visual connection between the freestanding stones, the phenomena, the horizon and *other* Neolithic or Bronze age features? There are two hypotheses here. Firstly, "there is a significant number of other Neolithic or Bronze age sites

(Group2 sites) that might be seen from the locations of the Ruggles' sites (Group1 sites) (that is, found within the non-directional viewsheds of the Group1 sites)" (hypothesis 3). Secondly "the Group2 sites are significantly located within the Group1's directional viewsheds the axis of which is directed by the orientation of the Group1 sites" (hypothesis 4).

Finally, the investigation requires that I query the visual connection between all Group1 sites within a specific region with their visually associated Group2 sites. The question being asked is "do the Group1 monuments within the same region share any specific view of the same Group2 monuments?" The general hypothesis here states: " a significant proportion of Group1 sites share the same viewshed area(s)". More specifically: " a significant proportion of Group1 sites share the view of the same Group2 sites" (hypothesis 5 – cumulative viewshed - CVA). Naturally the issues of amount and type of Group2 sites may arise.

The first set of hypotheses (1&2) is based upon the importance of alignments to the culture(s) of the megalith builders in western Scotland. This is supported by the evidence from Phase 1 of this project and Ruggles' research. The second group of hypotheses (3&4) is reliant upon the line of sight drawn between the monument (backsight) and the horizon points (foresight), in which an interest was also verified. The latter is, in fact, a variant of the alignment hypothesis.

Ultimately, I am trying to determine the likelihood that these other Neolithic or Bronze age sites were connected to the same cosmological belief system(s) as the free-standing stone sites that were initially assessed.

The 'secondary sites'

The original database was a list of all sites recorded in the National Monuments Record for Scotland for western Scotland, consisting of 26,611 entries in Microsoft Access format. It was determined that to extract Neolithic and Bronze age sites methodically, whilst maintaining a high level of certainty as to their dates, only clear class criteria in the CLASSSUB field could be used. I included all sites that would be classified as a Neolithic or Bronze Age site by the RCAHMS whilst excluding any with an additional tag of "POSSIBLE" and "NIL ANTIQUITY" or other attributes that indicated the same.[1] Some sites have

[1] For instance if a field descriptor has single quote marks around it (''), this indicates that the site is not "antique". It has yet to be established whether any of the sites included in the study have been excluded by Ruggles *et al.* (1984, 45 ff) under their category 'Highly dubious contenders for prehistoric sites'. Their decisions were made upon visits to the sites themselves and reviewing reports other than those of RCAHMS. This will be investigated before the main project is finalised.

more than one CLASSSUB label and these were taken into account. Site reports, on the other hand, were not yet taken into account, as an objective method for their use has not been fully developed.

Non-mobile, large finds are generally included in the study at this stage as it is more certain that they were to be positioned on or close to the spot they have been found today. That is, their occurrence at some place is unlikely to be accidental unlike, say, a sword, piece of jewellery or a pot *might* be due to loss, etc). The only small finds that were included were urns/cinerary urns and cremation sites, and only these, if found in combination with cists and/or cairns. This was done for dating purposes, to ensure that any site labelled CAIRN or CIST could be dated fairly surely to the Bronze Age. Cup and ring markings are difficult to categorise but as their creation can give a natural site (like an unworked stone slab) monumental associations, they were included. Also, they were not seen as small finds due to their common association with worked standing stones and so forth. Note too, that they are clearly identifiable in the RCAHMS field of CLASSSUB. Site types included can be found in Table 10.1. Other categories that might commonly be associated with either of these times were not included, for they were also used to describe similar sites from different periods. These include enclosures, mounds and hut-circles.[2] As alluded to earlier it is hoped to develop a sound methodology with which I can use the site reports to determine the nature of some of the missing sites, so that they can be included in future analysis.

Overall, then, sites that may have been used as settlement sites at any point would not be included, nor would small finds that may have been deliberately placed. As a result only "large finds" that are usually considered as ritualistic have been extracted.

Barrow, **1**	Carn **2**	
Cairn, urn, **2**	Cairn, cinerary urn, **2**	Cairn, cist, urn, **2**
Cairn or cist and cremation, **2**	Chambered Cairn, **3**	Cup and ring marking, **4**
Henge, **5**	Ring-ditch, **6**	Stone alignment, **7**
Stone circle, **8**	Stone setting, **9**	Standing stone, **10**

Table 10.1: This shows the categories chosen for the extraction of sites from the RCAHMS database.

First site	**n**	**Second site**	**n**	**Total of all**

[2] Cursus had one entry and was not included in the statistical analysis due to an oversight. This one entry will not affect the statistics, but the site will be included in the closer analysis of site types, and their associations and placements in relation to one another, in the future. Its RCAHMS numlink is 109 413, and its easting and northing, 184500, 693300, respectively.

type code		types code		site types
1	24	**1**	0	24
2	34	**2**	2	36
3	158	**3**	0	158
4	514	**4**	24	538
5	2	**5**	0	2
6	6	**6**	0	6
7	0	**7**	2	2
8	59	**8**	4	63
9	139	**9**	2	141
10	311	**10**	6	317
Total	1247		**40**	1287

Table 10.2: Number of site-types within Group2 sites. This table does not list the combination of the actual sites on location.

Note, too that some locations had more than one site type. See Table 10.2 for the number of each.

It is clear to the author that the Group2 sites are various in age and type. Despite the fact that I am looking at site layout in relation to Group1 sites, the hypotheses do not in anyway propose or rely upon the order of the Group2 sites' appearance. The order of the sites' appearance on the landscape, therefore, is not at this point accounted for. It was clear that age could not be strongly controlled for at this stage, for the entire RCAHMS data set. Therefore it was decided that an in depth study of these issues, as a possible key to the order of appearance of sites, must be considered at a later time (post-thesis). However, site type and location will be somewhat considered in the final discussion

Hypotheses and the appropriate tests

The aim is to find evidence (*or otherwise*) of spatial regularity and/or the possible deliberate organisation of space via monument placement.

Hypothesis 1 asks:

(i) are there any clusterings of Group2 sites, about the Group1 sites?

Hypothesis 2 asks:

(ii) are there any clusterings of Group2 sites, about the Group1 sites, in the directions indicated by the Group1 sites' orientations?

Hypothesis 3 asks:

(iii) what is the percentage or proportion of Group2 sites that exist within the Group1 sites' 360 degree viewsheds? Or what is the number of Group2 sites "seen" within the hit cells versus the non-hit cells?

Hypothesis 4 asks:

(iv) what is the percentage or proportion of Group2 sites that exist within the Group1's directional viewshed, as indicated by the Group1 sites' orientations?

As mentioned above, it is required to know if these patterns are significant, that is whether they were due to chance factors. Probability analyses will determine this.

Obtaining the observed data

Five sets of information are required:

(i) the orientations (azimuth values) of the Group1 sites'

(ii) the co-ordinates (eastings and northings) of the Group1 sites

(iii) the co-ordinates (eastings and northings) of the Group2 sites

(iv) a non-directional viewshed of each Group1 site.

(v) a directional viewshed of each Group1 site.

The first two sets of data were part of the original databases of Ruggles and RCAHMS. The third fourth and fifth, naturally, need to be created.

The orientations

The orientations obtained from the Group1 sites for Phase II will be applied to hypotheses 2, 4, 5. Group1 site data sets for hypotheses 2 and 4 will also be produced from the original Ruggles database but produced in the following way:

There are 276 orientations for the Group1 sites, often more than one orientation per site (n of sites=125). There are also two formats for the orientations: intersite or intrasite and one-way or two-way. From these the orientations can be coded into four groups of: intersite/ one-way, intersite/two-way, intrasite/oneway or intrasite/two-way. Intersite is where the orientation is formed by the intervisibility of the two sites, and is usually "where two sites form an indication of two ranges of horizon, one in each direction"(Ruggles, 1984:66).

It was decided to use only the one-way orientations in the first instance for the following reasons:
(i) to be sure of the intended direction that was to be sighted along;
(ii) so that they could be used to create future expected distribution(s), assuming that significant outcomes were obtained. Further, all the 2-way alignment distributions that were used in the first set of cluster analyses in Phase I (where one of two alignments was chosen at random), can be compared to the new expected distribution created from the 1-way alignments.

Here the expected distribution will be illustrating a situation where more than chance factors are responsible for the outcome. In relation to hypothesis four then, if it is found that the distributions are the same for the 1-way and 2-way orientations, the latter can also be said to display a significant percentage of Group2 sites in the directional viewshed areas. The testable hypothesis would be: there is no significant difference between the two distributions.

Group2 sites clustering – hypotheses 1 and 2

Testing Hypothesis One

To determine the occurrence, or not, of significant clusters of Group2 sites about the Group1 sites the Z_m^2 family of tests was applied to the data for query (i), as stated under "Hypotheses and the appropriate tests".

The Z_m^2 test determines whether the observed pattern of orientations is consistent with the assumption that each orientation is equally likely to be anywhere between 0 and 360 degrees, or whether that assumption can be plausibly rejected. Thus the concept of expected distribution is built into the test.

Testing Hypothesis Two

Hypothesis two asks 'are there any clusterings of Group2 sites, about the Group1 sites, in the directions indicated by the Group1 sites' orientations'? I already have the location of the Group2 sites about the Group1. From this I need to make a data cut of those Group2 sites that fall close to the orientation line of the Group1 sites. I then compare the number of these Group2 sites that fall inside the nominated bandwidth with the number that falls without, to test whether or not there is a significant difference between the two. If there is, then it would be fair to say that there is a significantly greater number of Group2 sites that are positioned in relation to the orientation of the Group1 sites than not.

The Viewsheds – hypotheses 3 and 4

A report of selected viewshed methodologies and associated theoretical bases can be found in Chapter 6.

The viewsheds for hypothesis three

To obtain the viewsheds GRASS 4.3 is to be used and the function employed is r.cva._ It was explained by Mark Lake to the author that the use of the CVA routine (r.cva) for the LOS analysis was preferable as LOS (r.los) routine in GRASS truncates the height of the observer to the nearest metre whereas r.cva does not (personal communication).

When using r.cva for LOS assessment each site file can only have one set of co-ordinates which represents a single site. The procedure is to run r.cva for every site, and with the "visibility from" rather than "viewsheds of" [= -f] option chosen. The non-directional LOSs, then, were created in this manner. The directional LOS creation incorporated this technique with some additions.

The viewsheds for hypothesis four - directional LOS

Directional viewsheds are not possible using a single function in GRASS, yet it is essential to take account of direction in LOS calculations when assumptions or evidence for specific bearings drive the investigation. The way around this is to use r.cva for single LOS analysis as above and use the binary viewshed output as the input for r.stats. The operation of r.stats allows you to output an ascii file with the x and y co-ordinates(x3,y3) of all the 'seen' cells (non-zero data values) for each site being tested (Group1 in this case). With these data you can use trigonometrical calculations to locate the cells' positions (x3,y3) in relation to the orientation line being accounted for (in this instance it is the orientation line of the alignment produced by a Group1 site (with co-ordinates (x1,y1) and the indicated 'point' on the horizon (with co-ordinates (x2,y2)). Mark Lake suggested this method to the author. Alternatively, the co-ordinates of (x2,y2) and (x3,y3) can be converted, in relation to (x1,y1), to azimuths. Remembering also, that I already have the azimuth or orientation of the line (x1y1, x2y2) for the Group1 sites.

If the co-ordinates are used, trigonometry can be used to calculate the distance and position of the seen cells from the nominated azimuths or orientations of each Group1 one site. These will enable a picture of the spatial patterning of those areas which were visible to be obtained. This information can be compared with the co-ordinates of the Group2 sites and their distances from the bearing. This will allow viewing or calculation of the number of co-incidences that have occurred between the 'seen cells' and the Group2 sites. That is, how many Group2 sites can be seen. The advantage of doing this trigonometrically is that you can actually calculate the number of sites that might have occurred within the same cell. Remembering that the Ordnance Survey data gives elevation information every fifty metres, it means my raster map is composed of 50 by 50 metre cells. The site data, however, is more detailed and it is possible to have a number of sites located within a 50-by-50 metre cell. Using something like 'r.coin' in GRASS 4.3, therefore, only allows you to readily calculate the number of cells that have coincidences (or the number of cells that have coincided with a site(s)) not the number of times there are site coincidences for the same cell(s). 'r.coin' requires that you have a raster sitemap perhaps converted by 's.to.rast', as a result, your raster sitemap only records absence or presence of sites.

The main reason for obtaining the x and y co-ordinates of all the seen cells is, however, that they provide data for statistical analysis. So, although getting a picture of the spatial patterning can be useful, be it via histogram or mapping, to discover whether this pattern is significant or not a more rigorous method is required to "obtain objective measures of its (existence and) strength".[3] Regardless of the method, an *a priori* decision must be made that allows one to choose how much of the area on either side of the indicated orientation is included in the assessment. It requires a limited decision to be made about the idea or concept of boundaries and where they are to be drawn. The reasoning behind the a priori decision can be found in the section below.

Creating the inclusive area for the directional viewshed

Once the 360 degree viewshed has been created, a 'cut' can be taken from this to create a directional viewshed. The idea is to create a viewshed given the observer's location and the direction in which they are looking. Taking into account all the known variables that affect visibility and vision according to the situation being investigated makes this possible. The creation of the 360 degree viewshed using CVA takes care of some of the general visibility issues, based on the assumption of a clear day, apart from the curvature of the earth[4]. What is needed now, is an estimation of the horizontal visual range (areas to the

[3] Kvamme, 1995, *Op cit.* 7

[4] The script written by Jo Wood from the University of Leicester was used to take into consideration the curvature of the earth when using Grass4.3. The module is r.xy.

left and right) a person might have when purposely directing their gaze, or looking at, a particular phenomenon on the horizon. Things to take into account include horizontal visual range when focusing upon a single direction, size of the phenomenon, head movement to make the edges of the phenomenon the centre of vision and distance of the horizon. For a first foray into the design of a directional viewshed the range of 30 degrees was chosen, that is ± 15 degrees either side of the line. Remembering that what one can see overall is not being investigated, but what else can be seen when looking along the indicated alignment towards the astronomical object of interest.

Obtaining the expected data

The creation of expected distributions for viewsheds

Remembering that the influence of landscape can not really be understood from a single model I need to create a number of models or expected distributions for each separate geographical region. This will allow the determination of the influence of landscape shape upon visibility, as well as the location of a site within that landscape. Determination of influence is considered by comparing the viewshed model, which represents a pattern that occurs when chance factors are dominantly responsible, with a viewshed based upon real archaeological site data, location and landscape. To derive significant results, or arrive at significant conclusions that have archaeological relevance, the latter viewsheds must be "sufficiently different from the background visibility properties (background values or expected distributions) of the study area".[5]

Model creation and random samples

One needs to compare the observed pattern of sites within viewsheds with four different sets of randomly generated site data for each geographical region. Three of the four sets are made using the r.random site generator option. This makes a list of locations. Here, a minimum of 2760 sets for the 360 degree, or non-directional, viewsheds for comparison with the observed sites (hypothesis 3) and at least 560 to a 1000 randomly generated sets of data for the directional viewsheds (hypothesis 4). This is in order to determine a statistical confidence level for any apparent extreme result found in the real data set. Replacement with random sampling will be allowed.

The four sets of generated data to create the expected distributions are for

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[5] van Leusen, 1999, *Op cit.*, §3.2.

Hypothesis 3

Non-directional (1): a new randomly generated set of sites (locations), where n of sites=125. The created viewsheds will be 360 degrees. This is done a minimum of 1250 times. The number of sites within and with out the viewsheds will be recorded.

Hypothesis 4

Directional sites (2): (i) use one of the randomly generated site sets from Non-directional (1).

(ii) Create 56 randomly generated orientations (equalling the number of randomly generated sites) and randomly assign them to one set of the previously listed random sites. (iii) Create directional viewsheds in the manner described above (or calculate the same trigonometrically) for each of the randomly generated sites and its accompanying orientation. Do steps (i) -(iiii) 560 -1000 times. The number of sites within and without the viewsheds will be recorded.

Directional sites (3): use randomly generated set of sites from Non-directional (1) above, and assign these new sites with the orientations from the original Ruggles' one-way data set (Group1 sites). The number of sites within and without the viewsheds will be recorded.

Directional sites (4): - use the original one-way Ruggles' site locations (Group1, n = 56) and randomly assign them one of the randomly generated directional orientations from Directional sites(2), 560 – 1000 times. The number of sites within and without the viewsheds will be recorded.

Note that the fourth set uses the locations of the Group1 sites but is given random orientations for their directional viewshed. Along with the first three sets, this ensures that all possible combinations of the location and orientation variables have been accounted for, further testing the hypotheses that either the location or the direction are statistically significant in the positioning of the Group2 sites in relation to the Group1 sites.

Comparing the observed and expected distributions

The general question I ask of each of my four expected distributions is 'how many of the 560 random choices have more sites in view than that of my observed distribution"? So, if I discover that 30 expected sites have more Group2 sites in view than the observed then it is said to be significant at the 30/560 level or .048 % level. That is, I have discovered that the number of sites in the randomly generated expected distribution are significantly less than that found in the observed distribution. Naturally I can express this in another way: the observed distribution has a significantly greater number of sites. Such a form of probability statistic is not distribution bound and is therefore suitable where one has no prior knowledge of how the expected distribution should display itself.

In Conclusion

So, I have, above, the basis or beginnings for an "ultimate design" of an investigation as explored in the introduction. Here the connection between visualisation and statistical analyses is made. This connection is not only made in the final section of the analyses, where viewsheds are constructed, but from the very start of the project where the importance of vision itself is tested using other methodologies and paradigms. In this way, the reasons for using viewsheds themselves are tested for soundness and applicability. So, too, is the complimentary creation of maps of site location, ground elevation and viewsheds to be found in the results. Naturally these will not be created until after the statistical analyses are done. Other visual aids include histograms for understanding observed orientation patterns of sites.

The results of the further cluster and viewshed analyses will provide information about the cosmological systems and monuments of western Scotland. These results are presented in this thesis.

Chapter 11

Phase III Pilot Results

Orientation and visibility analysis

Up to this point the monuments have been treated as a group, but with the methodology applied from Phase3, the monuments will also be considered individually. Each site is tested for the pattern of sites surrounding it, with the random background value of no pattern being tested for each. Similarly, for the viewshed analysis, each site in the case study area will be compared with the random background landscape values of the area.

Modified Methodology

It should be reiterated that this project is a pilot study and, whilst the methodology laid out in the previous chapter is considered the most appropriate, the application of this methodology was limited by the time available for its finalisation. For this reason the pilot project is restricted only to sections of the "Hypotheses and the appropriate tests" from "Chapter 9" that could be researched within that given time frame. Firstly Hypothesis 1, along with its statistical significance, was tested. Here the question was: are there any clusterings of Group2 sites about the Group1 sites, (where the Group2 sites are all Neolithic or Bronze Age monuments extracted from the NMRS database and the Group1 sites are the free-standing stone monuments)?

Lead-in hypotheses for Hypotheses 3 and 4 were then addressed as it was considered more sound to address these first before specifically asking those questions of Hypotheses 3 and 4. Remembering that Hypotheses 3 and 4, which were outlined in Chapter 8, are:
(iii) what is the percentage or proportion of Group2 sites that exist within the Group1 sites' 360 degree viewsheds? Or what is the number of Group2 sites "seen" within the hit cells versus the non-hit cells? Are they likely to be due to chance factors?
(iv) what is the percentage or proportion of Group2 sites that exist within the Group1's directional viewshed, as indicated by the Group1 sites' orientations? Are they likely to be due to chance factors?

The outcomes of the assessments of the lead in hypotheses will tell us what the likely patterns are and whether they were due to chance factors or not. The specific questions attached to the lead-in hypotheses are:

(i) Is the total area of the viewshed, in square kilometres, for each Group1 site likely to be due to chance factors?

(ii) Are the numbers of group2 sites found in the viewsheds of the Group1 sites likely to be due to chance factors?

(iii) Is the fraction of area of the directional viewshed, within each Group1 viewshed likely to be due to chance factors?[1]

Finally,

(iv) Are the number of Group2 sites in the directional viewshed due to chance factors?

The current pilot study was limited to answering these lead-in hypotheses only.

The next limitation was the restriction of the geographical area to Mull, Coll, Tiree and North Argyll. This area was chosen as it was one of the areas that received a statistically significant score for interest in the horizon itself, as well as significant evidence for interest in astronomical phenomena. Confirmation of these points supported the idea that visibility was of significance for the placement of the Group1 monuments in this region. Also, the results could be compared to some extent with those of Ruggles[2] who continued to study Mull but used either different techniques or a different archaeological focus.

For the creation of the background, it should be noted that 607 random viewsheds were created. The exact number is not important, the minimum number required was roughly the number of alignments times ten for statistical reasons, remembering that more is always better. The program generating the random viewsheds was to be stopped manually in accordance with the minimum number of viewsheds required but was to be run as long as possible thereafter if time allowed.

Orientation – intersite connections across time and type

Results of original hypothesis 1

The analysis shows significant clustering of the Group2 sites around 71 out of 125 Group1 sites (See Table 10.1). It might be remembered that these statistical tests only reveal that certain points or directions around the Group1 sites were preferred, but not which were preferred. Looking at the orientations plotted on a histogram for all regions in the study area, a very definite peak at 117.5-122.5

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[1] Remembering that the central lines of the directional viewsheds are indicated by the orientation of each Group1 site's alignment, be it intersite or intrasite.

[2] Ruggles, in collaboration with Appleton, Burch, Cooke, Few, Morgan and Norris, (1984), Ruggles with Martlew and Hinge (1991) and later, Gruffydd and Medyckyj-Scott (1993), and with Medyckyj-Scott (1996). Also, Martlew with Ruggles in 1993 and 1996, Fisher, Farley, Maddocks and Ruggles (1997) and so forth. See Chapters 3 and 4 for other works.

degrees from north occurs with a second dominating peak at 122.5 - 127.5 degrees for all areas considered together (see Appendix 2, A2.1 for results and Appendix 3 for maps of each area with the Group1 and Group 2 sites overplotted).

Region	n of Group1 sites	n of sites, where 0.05 > p < 0.1	n of sites, where p < 0.05	% of marginally significant sites, where p < 0.1	% of significant sites, where p < 0.05	Total % of sites displaying some significance
Lewis / Harris	12	3	**3**	25%	**25%**	**50%**
Uist	19	2	**2**	10.5%	**10.5%**	**21%**
Mull	28	2	**16**	7%	**57.1%**	**64.1%**
Argyll	21	3	**14**	14.3%	**66.7%**	**81.0%**
Islay	24	1	**19**	4.1%	**79.2%**	**83.3%**
Kintyre	21	0	**17**	—	**81%**	**81%**
Totals	125	11	71			

Table 11.1: Number and percentage of Group1 sites displaying significant clusterings of Group2 sites by region. *Probabilities in bold are where* $p < 0.05$.

Regionally, Islay, Argyll, Kintyre and Mull have the greatest percentage of significant Group2 site clusters around the Group1 sites, namely 20/24 (83.33%), 17/21 (80.95%), 17/21 (80.95%), and 22/32 (68.75%), respectively. The major feature of the histograms is the apparent significant alignment of Group2 sites around 120 degrees from north: each region has a notable peak around this point. Mull and Islay display the greatest singularity about 120 degrees (See Appendix 2; A2.2). Uist, though it too displays the same predominance, has other dominating peaks. This same peak manifests itself in the patterns of Lewis/Harris and Kintyre, though not so uniquely, with Lewis/Harris having it embedded within one of two larger ranges of clusters at opposite ends of the spectrum, and Kintyre having a more evenly spread distribution of dominant peaks. It should be noted that there is also a strong aversion for those areas between 60 degrees west and fifty degrees east of the Group1 sites, that is in a northerly direction.

It has been shown that a spatial relationship, in the form of clustering, exists between the Ruggles sites and other Neolithic or Bronze Age objects or places, we must, therefore, accept hypothesis 1 for Phase3 of the project. For a detailed site by site breakdown see Table 10.2 below.

A Detailed look at the orientations of Group2 sites about Group1

It is obvious that the most prominent form of site to site alignment runs out from the Group1 sites towards the SE for 3 regions. However, whilst Argyll and Kintyre have 20/24 (81%) and 17/21 (80.95%) significant clusters, we can see that other ranges of azimuths are also of significance. The histograms can give us some indication of this by examining these other clusters of dominant peaks.

Argyll's predominant peaks are displayed in the SSE, SW – WSW, a very narrow band within NW - WNW and the penultimate band between SE-ESE.

Group1 site id	Region	Number of Group2 sites around Group1	Prob
LH7	Lewis / Harris	23	0.7659
LH8	Lewis / Harris	22	*0.0792*
LH10	Lewis / Harris	28	0.4229
LH16	Lewis / Harris	20	**0.0094**
LH18	Lewis / Harris	20	**0.0036**
LH19	Lewis / Harris	20	*0.0774*
LH21	Lewis / Harris	14	0.1017
LH22	Lewis / Harris	13	0.1021
LH24	Lewis / Harris	12	*0.0666*
LH29	Lewis / Harris	4	0.6449
LH36	Lewis / Harris	5	0.9257
LH37	Lewis / Harris	12	**0.0043**
UI6	Uist	20	0.8131
UI9	Uist	18	0.2266
UI15	Uist	29	0.3741
UI19	Uist	33	**0.0140**
UI22	Uist	27	0.5199
UI23	Uist	23	0.4449
UI26	Uist	25	0.7163
UI28	Uist	18	*0.0860*
UI31	Uist	17	0.9659
UI33	Uist	24	0.5678
UI35	Uist	19	*0.0611*
UI37	Uist	16	0.5138
UI40	Uist	8	0.2442
UI46	Uist	4	0.9894
UI48	Uist	2	0.1655
UI49	Uist	2	0.1920
UI50	Uist	2	0.1353
UI57	Uist	26	0.9040
UI59	Uist	24	**0.0308**
NA1	Mull	8	0.2619
NA3	Mull	11	0.3973
CT1	Mull	5	**0.0490**
CT2	Mull	20	**< 0.0001**
CT3	Mull	21	**< 0.0001**
CT7	Mull	27	**< 0.0001**
CT8	Mull	8	0.2903
CT9	Mull	7	**0.0024**

Group1 site id	Region	Number of Group2 sites around Group1	Prob
ML1	Mull	14	**0.0111**
ML2	Mull	15	0.3118
ML4	Mull	14	0.1631
ML7	Mull	18	0.8683
ML9	Mull	22	0.4899
ML10	Mull	18	0.1215
ML11	Mull	15	0.3532
ML12	Mull	24	*0.0518*
ML15	Mull	19	**0.0001**
ML16	Mull	15	0.5870
ML16	Mull	12	**0.0358**
ML16	Mull	13	*0.0937*
ML18	Mull	24	**0.0002**
ML25	Mull	22	**< 0.0001**
ML25	Mull	18	**0.0005**
ML25	Mull	17	**0.0005**
ML27	Mull	25	**0.0010**
ML30	Mull	29	**< 0.0001**
ML31	Mull	34	**< 0.0001**
ML33	Mull	30	**< 0.0001**
LN7	Argyll	14	0.2836
LN18	Argyll	21	*0.0727*
LN22	Argyll	33	**< 0.0001**
AR2	Argyll	28	0.2242
AR3	Argyll	67	**< 0.0001**
AR6	Argyll	84	0.1050
AR7	Argyll	63	**0.0215**
AR8	Argyll	96	*0.0615*
AR9	Argyll	93	**0.0043**
AR10	Argyll	95	**0.0026**
AR13	Argyll	93	**0.0103**
AR15	Argyll	90	**0.0002**
AR16	Argyll	68	**0.0072**
AR17	Argyll	64	**< 0.0001**
AR18	Argyll	46	**0.0023**
AR27	Argyll	69	**< 0.0001**
AR28	Argyll	80	**< 0.0001**
AR29	Argyll	74	**< 0.0001**
AR30	Argyll	75	**0.0031**
AR32	Argyll	31	0.2360
AR33	Argyll	42	**0.0005**
JU1	Islay	11	**0.0001**
JU2	Islay	15	*0.0975*
JU3	Islay	8	0.7801

JU4	Islay	7	0.2202
JU4	Islay	6	0.2657
JU5	Islay	14	**0.0001**
JU7	Islay	14	**0.0346**
JU9	Islay	35	**< 0.0001**
IS3	Islay	27	**< 0.0001**
IS4	Islay	38	**< 0.0001**
IS5	Islay	38	**0.0003**
IS6	Islay	32	**< 0.0001**
IS7	Islay	45	**< 0.0001**
IS11	Islay	34	**< 0.0001**
IS12	Islay	27	**0.0003**
IS19	Islay	38	**< 0.0001**
IS23	Islay	35	**< 0.0001**
IS28	Islay	11	**0.0163**
IS31	Islay	12	**< 0.0001**
IS35	Islay	24	**0.0001**
IS36	Islay	23	**0.0012**
IS38	Islay	19	**< 0.0001**
IS39	Islay	28	*0.6483*
IS41	Islay	19	**0.0419**
KT2	Kintyre	20	**0.0018**
KT2	Kintyre	21	**0.0040**
KT3	Kintyre	39	**0.0413**
KT4	Kintyre	27	**0.0006**
KT5	Kintyre	40	**< 0.0001**

KT8	Kintyre	40	**< 0.0001**
KT10	Kintyre	34	**0.0016**
KT12	Kintyre	61	**< 0.0001**
KT19	Kintyre	30	**0.0116**
KT23	Kintyre	56	**0.0001**
KT27	Kintyre	22	0.1095
KT28	Kintyre	36	**0.0021**
KT29	Kintyre	27	**0.0039**
KT31	Kintyre	10	**0.0488**
KT32	Kintyre	12	**0.0053**
KT35	Kintyre	36	**0.0002**
KT36	Kintyre	15	**0.0145**
KT37	Kintyre	3	0.1382
KT39	Kintyre	10	0.9677
KT41	Kintyre	6	**0.0442**
KT44	Kintyre	2	0.4563

Table 11.2: This table reveals the probability for each clustering pattern about each Group1 site, where Prob= chance probability. Remember that the number of Group2 sites is that which appears between a Group1 site and its own horizon. Probabilities that are less than 0.1 but above 0.05 are marginally significant (italicised), those below 0.05 are significant (emboldened). The identity code for Group1 sites (Group1 site id) is taken from Ruggles et al., 1984).

It is obvious that the preferred orientations generally run across the NE - SW and the NW - SE quadrants, avoiding north almost completely (only 2 sites within the NW-ENE region) and only appear partially in the south. A similar phenomenon can be seen in Kintyre where dominant peaks straddle east as well as the SE and the SSE quadrant. In the SSW there is displayed a predominant narrow peak and a smaller, but distinctive peak between the SW and WSW. Falling opposite the southeastern peaks are those peaks between NW and NWN, and roughly the opposite with westerly to NW. Unlike Argyll, though, there is a distinct flanking either side of south with the tallest peak west of south, as well as the noted SSE peak. There is maintained the complete avoidance of the more northern sectors. We find with Kintrye then, that there is very little interest shown in the south or the west, and, once more, the north is avoided.

Uist has a *complete avoidance of almost the entire northeastern sector until ENE* (from due north), along with an almost complete avoidance from the north moving to the NW. Apart, from 170°-200°, which coincides with a tight band around the south, there is little other interest shown. Overall for Uist there is *definite interest in the eastern quadrant*, after ENE (moving in a clockwise direction), until 170°. After this point interest wanes towards the *south* until 200° west. From thereon interest is generally maintained in the western quadrants until just before the point of NW. An almost equal interest can be found in the NW and SE regions with opposing clusters found at 100° - 140° and 270° - 310°, reflecting, perhaps, the nature of the intersite alignments found in Ruggles' database of Uist. None of the other sectors with strong clustering have an equally strong interest in the opposite direction. For example, the cluster running roughly from 200° - 255°, has only 10 orientations in it is opposing quadrant of 20° - 75°, all of which fall between 65 ° and 75°. The interest found in the remaining southeastern quadrant, 140° - 160°, is almost devoid of orientation partners in the opposing northwestern quadrant (n=2).

Interestingly, looking at the alignments for the Group1 sites of Uist alone, we find that there are a total of 16 two-way alignments making up 38 alignments out of a possible 63, which makes 60.32% of Uists Group1 orientations being intersite. Further, Uist's Group1 orientation peaks match well those of the peaks of the Group2 sites locations around the Group1 sites in Uist. Perhaps this should not be such a surprise. We may just be observing the consistency of an orientation trend across intersite and intrasite alignments within the region. In the Uist case, this is most certainly so, for the Group1's intrasite points only add their weight to these strong orientation clusters of the W - NW zones (288° - 314°), the NW - NNW (324° - 334°) and the SSE to just beyond ESE (108° - 156°) and the SSW towards WSW band (from 200° - 232°). The Group1's orientations also reveal similar areas of avoidance, namely, the most northern quadrants, and much of the northeastern (NNW - NNE, and NNE - E: 334° - 109 °), the SSE to SSW (156° - 200°), and much of the more strictly western band (232° - 288°). It is possible in Uist then, we have an example of a strong continuity of the laying out and location of sites.

Discussion of Hypothesis 1

The major trends that we have seen in phase III are consistent with previous results. Mull, Argyll, Uist and Islay, regions displaying the most significant Group1 site orientation (Phase 1), also display a greater directional focus in the arrangement of Group2 monuments about Group1 monuments. In addition, those regions with the most uniformly displayed Group1 site orientations exhibit the most evenly spread Group2 site clusterings (Lewis/Harris and Kintyre). It is interesting to note, that for Lewis/Harris a good deal of the Group1 sites occur southerly of the Group2 sites but along the same line northwest- southeast line sites. This might be accounted for by the local placement of sites either side of the NW/SE running loch of East Loach Roag.

Mull, Argyll and Islay, having the greatest statistical interest in the horizon (Phase 2 – Group 1 sites), are likewise 3 of the 4 regions displaying the greatest number of statistically significant clusters of Group2 sites about the Group1 sites. Kintyre is the fourth. Considering the orientation results above for Uist, it is especially interesting to note the apparent lack of interest for both the horizon and for the clustering of Group2 sites about Group 1 sites for this same region. However, on visual inspection of the histograms/polar plots, Uist is the region that has the strongest corresponding prominent orientation clusters for Group1 sites with those orientation clusters of Group2 sites about the Group1 sites. This has yet to be tested statistically.

Geographical or topographical influences?

To further understand the nature and the spatial layout of the sites, Group1 and Group2 sites were mapped on digitised contour maps for each region using Arcview 3.2. These maps quite clearly allow us to see all the secondary sites (Group2) in relation to the primary ones (Group1) for separate regions. It is evident, though, that, once the local horizons of the individual Group1 sites are taken into account through spatial analysis, we can see features in the site distributions that are not evident from the maps alone. For example, it is not evident from the maps, especially of Argyll and Kintyre, that there is an exclusion zone of Group2 sites towards the north of the Group1 sites in the area between the latter and their horizons.

It is not possible to say exactly how much influence geography or topography has on these patterns without testing them. However, when the author investigated the digital elevation map seen in Figure 6.2 in more detail, by using the zoom feature in Arcview it was seen see that there was lack of a SE valleys, therefore it is unlikely that topography could account for this trend overall. Kintyre and Mull have SE lying valleys in some places, but these few valleys do not necessarily lie SE of the Grp1 sites anyway. However there does seem to be a connection between both the Mainland Coastal and most of the Island sites, especially Islay and Mull, having more sites on offer in the southeast, in particular, than the north or the west. This still does not account for the lack of sites in the south, as there lay Jura, Islay and Kintyre. In addition, such an explanation does not account for the lack of sites in the north between a Group1 site and the horizon profile. It would be of interest to know exactly how distant the northern horizons are from each Group1 site to see whether or not a close northern horizon, and therefore perhaps less sites in between, might account this avoidance or not. If this was the case, it would of interest to find out why this would be important to do so.

Superficially it appears that the geography of the place may have some influence in the outcomes, but the topography appears to be appreciably less of an influence.

Anything in sight? Results of Viewshed analysis for Mull

Below, in Table 11.3, is the list of sites used in the viewshed analyses pilot study of Phase 3.

Site	Name	Location	Thom	NMRS number
NA1	Branault	Ardnamurchan	-	NM56NW02
NA3	Camas nan Geall	Ardnamurchan	-	NM56SE02
CT1	Acha	Coll	-	NM15NE17
CT2	Totronald	Coll	M3/1	NM15NE15
CT3	Breachacha	Coll	-	NM15SE15
CT7	Hough	Tiree	-	NL94NE20
CT7			-	NL94NE23
CT8	Barrapoll	Tiree	M4/3	NL94SW11
CT9	Balinoe	Tiree	M4/2	NL94SE04
ML1	Glengorm	Mull	ML/7	NM45NW02
ML2	Quinish	Mull	ML/3	NM45NW05
ML4	Balliscate	Mull	ML/8	NM45SE01
ML7	Cillchriosd	Mull	ML/2	NM35SE05
ML9	MaolMor	Mull	ML/4	NM45SW05
ML10	DervaigN	Mull	M115	NM45SW04
ML11	Dervaig S	Mutt	M1/6	NM45sWO7
ML12	Ardnacross	Mull	M1/9	NM54NW03
ML13	Tenga	Mull	M1/10	W54Nw04
ML14	Tostarie	Mull	M1/11	NM34NE03
ML15	Killichronan	Mull	M2/15	NM54SW01
ML16	Gruline	Mull	M2/16	NM53NW03
ML16			M2/1	NM53NW01
ML16				
ML18	Cragaig	Ulva		NM43NW09
ML25	UluvaltI	Mull	-	NMS3SW02
ML25			-	NM53SW02
ML25			-	W5'3NW03
ML27	Rossal	Mull	-	NM52NW06
ML28	Lochbuie	Mull	M2/14	NM62NW03
ML30	Taoslin	Mull	M2/8	NM32SE01
ML31	Uisken	Mull	M2/10	NM31NE02
ML33	Ardalanish	Mull	M2/9	NM31NE01

Table 11.3: Sites used in the viewshed analysis for Mull, Coll, Tiree and North Argyll. Site = site name given by Ruggles and contributors (1984). Thom = Thom's site identifier.

Preview hypotheses (i) –(iv)

Preview hypothesis (i)

It can be seen from Table11.4 that the amount of viewed area for most sites is not significant in nature. Six (6) sites in North Argyll and Coll, however, display a significantly large amount of viewing area, namely, NA1, NA3, CT1,CT2, CT3 and CT7. That *large* viewing areas are significant can be more easily attested by observing Figure A5.1 in Appendix 5. This figure displays the probability distribution for amount of area viewed. The probability curve (on the right) is logarithmic, this can be read by looking at amount of area viewed on the x-axis, running a line vertically to the curve and then running a line at right angles to the left until reaching the y-axis. The number on the y-axis is the likelihood that this amount of area has occurred by chance.

RugID	E N	Area	Prob
NA1	152680 769500	1056.33	**0.10**
NA3	156050 761840	1141.58	**0.08**
CT1	118600 756740	1334.31	**0.07**
CT2	116650 755940	1899.79	**0.03**
CT3	115190 753290	1698.24	**0.03**
CT7	95880 745180	1302.11	**0.07**
CT8	94680 743000	80.5707	0.61
CT9	97310 742580	159.941	0.49
ML1	143470 757150	148.259	0.50
ML2	141340 755240	44.1588	0.74
ML4	149960 754130	58.261	0.69
ML7	137730 753480	73.9851	0.64
ML9	143550 753110	64.68	0.67
ML10	143900 752020	178.649	0.48
ML11	143850 751630	100.705	0.58
ML12	154220 749150	38.7394	0.76
ML15	154010 741930	39.9987	0.75
ML16a	154560 739600	38.0877	0.76
ML16b	154370 739770	30.4976	0.82
ML16c	154460 739680	520.694	0.27
ML18	140280 739010	456.945	0.29
ML25a	154690 730040	869.583	0.16
ML25b	154680 729960	704.551	0.19
ML25c	154650 729930	66.3019	0.67
ML27	154340 728200	657.644	0.20
ML30	139730 722390	284.337	0.39
ML31	139160 719610	596.359	0.22
ML33	137840 718880	47.6378	0.73

Table 11.4: Total area in viewshed. RugID = ID for Ruggles' site, E = easting, N = northing, area = area in km^2, Prob = chance probability (lies between 0 and 1). Emboldened font = significant outcomes. Underlined scores = examples of very low significance.

Preview hypothesis (ii)

Hypothesis (ii), that the number of Group2 sites in the viewsheds of each Group1 site (Ruggles' site) is due to chance factors, has been affirmed for each site (see Table 11.5). It is noted, however, that the number of sites for CT7 and ML25a are borderline significant. These are mentioned due to the results of hypothesis 1 and the following hypotheses, the discussion of all revealed points will follow the results.

RugID	E N	N of Group2 sites	Prob
NA1	152680 769500	3	0.37
NA3	156050 761840	4	0.28
CT1	118600 756740	5	0.20
CT2	116650 755940	5	0.20
CT3	115190 753290	5	0.20
CT7	95880 745180	6	0.15
CT8	94680 743000	1	0.68
CT9	97310 742580	1	0.68
ML1	143470 757150	3	0.37
ML2	141340 755240	4	0.28
ML4	149960 754130	4	0.28
ML7	137730 753480	4	0.28
ML9	143550 753110	4	0.28
ML10	143900 752020	2	0.50
ML11	143850 751630	1	0.68
ML12	154220 749150	2	0.50
ML15	154010 741930	2	0.50
ML16a	154560 739600	2	0.50
ML16b	154370 739770	2	0.50
ML16c	154460 739680	1	0.68
ML18	140280 739010	4	0.28
ML25a	154690 730040	6	0.15
ML25b	154680 729960	5	0.20
ML25c	154650 729930	4	0.28
ML27	154340 728200	1	0.68
ML30	139730 722390	1	0.68
ML31	139160 719610	1	0.68
ML33	137840 718880	3	0.37

Table 11.5: Group 2 sites in viewshed. RugID = ID for Ruggles' site, E = easting of Ruggle's site, N = northing of Ruggles' site, Prob = chance probability (lies between 0 and 1).

Preview hypothesis (iii)

Hypothesis three states that when comparing the amount of area (square kilometres) within the directional viewshed with the equivalent random background distribution, the area seen within the directional viewshed is likely to be due to chance factors. This hypothesis was rejected and the alternative hypothesis was accepted for the site alignments of ML1-ML9, ML7SE, ML7-ML2 and ML11abcSSE (see Table 10.6). It should be noted that 14 others were very borderline cases (that is 0.1>p<0.2). These alignments include NA1baSSE, NA3NNW, CT2baSSW, CT7-CT8, ML2SSE, ML4abcN, ML9NNW, ML9-ML1, ML25abcNW, ML25cbaSE, ML25-ML27, ML27-ML25, ML31SW, and ML33baWNW. These are mentioned for use in the discussion.

RugAlign	RugAlignID	Azi	Frac	Prob
110	NA1abNNW	328.8	0.000887	0.74
111	NA1baSSE	148.8	0.230227	<u>0.11</u>
112	NA3NNW	329.5	0.000514	<u>0.15</u>
113	CT1S	179.7	0.000009	0.71
114	CT2abNNE	18.4	0.001069	0.88
115	CT2baSSW	198.4	0.194531	<u>0.11</u>
116	CT2-CT3	204.8	0.121691	0.21
117	CT3-CT2	24.8	0.005949	0.92
118	CT7-CT8	204.6	0.196496	0.12
119	CT8-CT7	24.6	0.002946	0.28
120	CT9SSW	195.8	0.000214	0.37
121	ML1-ML9	175.3	0.913293	**0.0**
122	ML2SSE	168	0.165748	<u>0.17</u>
123	ML2-ML7	240.5	0.009919	0.24
124	ML4abcN	5.3	0.182618	<u>0.16</u>
125	ML4cbaS	185.3	0.010864	0.42
126	ML7SE	133	0.143749	**0.07**
127	ML7-ML2	60.5	0.078316	**0.09**
128	ML9NNW	342	0.011581	<u>0.12</u>
129	ML9-ML1	355.3	0.006738	<u>0.16</u>
130	ML10NNW	329.8	0.001156	0.43
131	ML11abcSSE	157.1	0.495297	**0.05**
132	ML12abcNNE	27.6	0.073570	0.36
133	ML12cbaSSW	207.6	0.004660	0.39
134	ML15-ML16	165.3	0.001221	0.39
135	ML16baNW	308.1	0.055004	0.25
136	ML16abSE	128.1	0.042917	0.33
137	ML16-ML15	345.3	0.024470	0.27
138	ML18baENE	67.1	0.000055	0.63
139	ML25abcNW	317	0.069188	<u>0.17</u>
140	ML25cbaSE	137	0.035404	<u>0.19</u>
141	ML25-ML27	191.8	0.064968	<u>0.17</u>
142	ML27-ML25	11.8	0.045148	<u>0.19</u>
143	ML30NNW	329.3	0.001126	0.34
144	ML31NE	49.8	0.005449	0.61
145	ML31SW	229.8	0.302109	<u>0.11</u>
146	ML33baWNW	282.4	0.306163	<u>0.14</u>

Table11.6 -Fraction of area in 30 degree band centred around surveyed, azimuth. RugAlignID = ID number for Ruggles alignment, Ruggles iRugAlign = Ruggles description of the alignment, Azi = surveyed orientation (azimuth), Frac = fraction of total viewshed able to be viewed, Prob = chance probability.

Preview hypothesis (iv)

The outcomes for hypothesis four, that the number of Group2 sites in the directional viewshed are due to chance factors, are very interesting.

RugAlignID	**RugAlign**	**Azi**	**nsites**	**Prob**
110	NA1abNNW	328.8	0	1.0
111	NA1baSSE	148.8	0	1.0
112	NA3NNW	329.5	0	1.0
113	CT1S	179.7	1	0.27
114	CT2abNNE	18.4	1	0.35
115	CT2baSSW	198.4	0	1.0
116	CT2-CT3	204.8	1	0.21
117	CT3-CT2	24.8	1	0.23
118	**CT7-CT8**	**204.6**	**5**	**0.06**
119	CT8-CT7	24.6	0	1.0
120	CT9SSW	195.8	0	1.0
121	ML1-ML9	175.3	0	1.0
122	ML2SSE	168	0	1.0
123	ML2-ML7	240.5	0	1.0
124	ML4abcN	5.3	0	1.0
125	ML4cbaS	185.3	0	1.0
126	ML7SE	133	0	1.0
127	**ML7-ML2**	**60.5**	**1**	**0.07**
128	**ML9NNW**	**342**	**1**	**0.05**
129	ML9-ML1	355.3	0	1.0
130	ML10NNW	329.8	0	1.0
131	ML11abcSSE	157.1	0	1.0
132	ML12abcNNE	27.6	0	1.0
133	ML12cbaSSW	207.6	1	0.19
134	ML15-ML16	165.3	0	1.0
135	ML16baNW	308.1	1	0.15
136	ML16abSE	128.1	1	0.15
137	ML16-ML15	345.3	0	1.0
138	ML18baENE	67.1	1	0.18
139	ML25abcNW	317	0	1.0
140	ML25cbaSE	137	0	1.0
141	ML25-ML27	191.8	0	1.0
142	ML27-ML25	11.8	0	1.0
143	ML30NNW	329.3	0	1.0
144	ML31NE	49.8	0	1.0
145	ML31SW	229.8	0	1.0
146	**ML33baWNW**	**282.4**	**4**	**0.08**

Table 11.7 - number of Group 2 sites in directional viewshed. RugID = Ruggles ID for monument, Azi = surveyed orientation (azimuth), nsites = Group 2 sites able to be viewed, Prob = chance probability.

There are, in effect, only 3 shades of probabilities, with 2 being predominant, if one can be so expressive in statistics. The probability outcomes cluster exclusively upon p=1.0 or within the range .05>p<0.35, primarily about p=0.05 or p=0.15. Thus they either showed complete insignificance (=1), or fell under the significant probability score of 0.1 or very close to this range within p=0.05. Twenty four out of thirty seven (24/37) alignments were shown to have no sites within their viewshed at all but this lack of sites has no support. This outcome is entirely due to chance factors!! Whilst the remainder of the alignments, having one or more sites, never received this particular score. Four of these alignments were considered significant for the number of sites found within their directional viewshed: CT8-CT7 (5; p=0.06), ML7-ML2 (1; p=0.07), ML9NNW (1; p=0.05) and ML33baWNW(4; p=0.08). Four sites that fell outside of the significant band, but within 0.05 were ML12cbaSSW (1, p=1; 0.19), ML16baNW (1, p=0.15), ML16abSE (1, p=0.15), ML18baENE (1, p=0.18). Having said all this though, one has to be very careful drawing any conclusions from such an outcome. The results have showed us that there is very little variation in the parameter of the variable we are testing, that is the number (parameter) of sites (variable) within the directional viewshed are limited to only 0, 1,4 or 5. This is due, in part, to its connection to the number of sites in the entire viewshed. This is, basically, a choice of numbers from one to six. Such little variability in the parameter, or low resolution, means that there is obviously a limited amount of probability scores that can exist. This being the case, it is unwise to attempt to make firm conclusions regarding the hypothesis being tested here. What can be said, however, is that the observation of zero sites when standing at any point around Mull should be the expected outcome. This is revealed by the fact that when we have zero sites the probability equals 1.0, as determined by the random distribution, or background landscape values, analysis. What has been found is that when the variable, location, is altered at random, the variable, site number, is likely to be zero. Anything more than that, however, cannot be said.

Discussion regarding preview hypothesis 4

Its seems the parameter chosen was not a good one to test the idea of the importance of line of site within this landscape. This is not imply that what was done was incorrect, for without being tested this may not have been soundly confirmed in the first place. The result might be linked to the outcome of preview hypothesis (i), which shows that on the island of Mull itself, the amount of area in view from sites is itself insignificant, compared to the area viewed at random. Secondly, for Coll, Tiree and North Argyll, though the viewing areas were significant for 6/8 sites (75%) there was a great amount of sea in these viewsheds, reducing the likelihood of sites appearing in viewshed at all. It would be preferential, however, to find out if the **actual** areas, or "locations", viewed were of significance or not. For the area, or something in the landscape, might be of some significance rather than the secondary sites. When thinking along these lines, we get back to the hypotheses of astronomical bodies, and indeed, we find an untested correlation between those sites with a large amount of area viewed and a significant astronomical declination (9/11 orientations - 81.2%; 7/9 for significant orientations matched with a statistically significantly amount of area viewed - 77.8%; see Table 11.8). Locations with views of the sea may indeed be deliberately chosen for their clear view of astronomical phenomena. Might there be other directions or forms of astronomical interest other than those indicated by the orientations of the site or intersite alignments. Similarly, might the viewsheds indicate areas of interest within the landscape itself? There were no such correlations with the data in Mull, however, but there were 3 sites with a significant amount of viewing area within the directional viewsheds, namely Glengorm, ML7 (both on-site (SE) and intersite (ENE) and Dervaig Sth - on-site (SSE).

RugAlign	RugAlignID	Site no	Area m	Prob	Azi	Dec
110	NA1abNNW	NA1	**1056.33**	**0.10**	328.8	**28.25**
111	NA1baSSE	NA1		**0.10**	148.8	**-25.75**
112	NA3NNW	NA3	**1141.58**	**0.08**	329.5	34.1
113	CT1S	CT1	**1334.31**	**0.07**	179.7	**-34.05**
114	CT2abNNE	CT2	**1899.79**	**0.03**	18.4	31.35
115	CT2baSSW	CT2		**0.03**	198.4	**-32.55**
116	CT2-CT3	CT2		**0.03**	204.8	**-30.8**
117	CT3-CT2	CT3	**1698.24**	**0.03**	24.8	**29.85**
118	CT7-CT8	CT7	**1302.11**	**0.07**	204.6	**-29.85**
119	CT8-CT7	CT8	80.5707	0.61	24.6	**29.8**
120	CT9SSW	CT9	159.941	0.49	195.8	**-31**

Table 11.8: RugAlignID = ID number for Ruggles alignment, Ruggles iRugAlign = Ruggles description of the alignment, Area (km) = Amount of area in 360^0 viewshed; Prob = chance probability for obtaining this amount of area in viewshed; Azi = orientation of alignment of site (azimuth), Dec = declination of orientation. Bold indicates statistically significant outcomes.

Fitting together the Phase 3 hypotheses - orientation and visibility

It now appears that choosing a site location might be much more complex than looking for a single special astronomical phenomenon, which can be difficult enough in itself! This has already been implied by the results of the position of Group2 sites about Group1 sites. For as well as sites being aligned within themselves[1] or with another site as astronomical indicators, it seems that sites *must* align themselves with another set of sites or monuments *across* the landscape. The results have shown, though, that these other sites are generally not located within the viewsheds and are thus not visually accessible. For aligning sites across the landscape non-visually, Mull (Coll, Tiree, North Argyll) and Islay (Jura) were found to have almost exclusive SE alignments of all regions in relation to

[1] For example, two monuments aligned within a site as defined by Ruggles or stones aligned within a monument, such as in the case of a stone row.

the Group1 sites, other regions included this SE preference but also had other significant alignment directions. Argyll does have, though, the majority of sites within peaks preferring the SE direction generally. A number of variables are now seen to come into play for locating individual monuments at one location rather than another. For the case study area of Mull Coll, Tiree, and North Argyll it is noted that there are preferential views in the southern quarters of the individual sites VSs, and an avoidance in the northerly directions generally and the northwest in particular. Site NA1 does not display this trend. Overall, this confirms the visual assessment of the topographical 2D horizon profiles of each site that indicates the horizon distances. Areas in the north tended to have close horizons whilst those in the south were the more distant. Now, as these sites are located on islands, the sites could have been chosen to look over the sea into the north. However, the majority did not. Even those sites on the northwestern side of Coll and the southwestern area of Tiree still have preferential views to the southern seas rather than the north (see Appendix 4-viewsheds of Coll and Tiree).

Having said this, it is well to remember Ruggles and Martlew's works, along with Ruggles, Martlew and Hinge, (Hinge's PhD research), in Northern Mull. Here the latter three researchers, as part of a detailed analysis of seven stone rows, investigated the variation of horizon distance with azimuth.[2] They compared the distribution of visibility from real sites and compared it with data from control points.[3] Using the Kolmogorov-Smirnoff one sampled test they determined that the population of real data was drawn from a different population to that of the random data for 3 out of 4 types of horizon distances. It was shown that for the categories 1-3 km and over 5km, p=0.1% and for horizons closer than 1 km, p=0.5. The real data then, was significantly different from random and thus were unlikely to have occurred by chance. These horizons, it seems, were chosen deliberately. Added to this, there is a marked difference between the topography of the area and the positions of the sites in relation to the horizon distance in north Mull. The local topography has a preponderance of distant horizons to the NW and the NNW, along the line of the ridges and valleys, but an adjacent ridge restricts most of the horizons to the SW and WSW. The NE and ENE and especially around azimuth 60°, there are virtually no horizons further than 3km.[4]

In contrast to this, the sites avoid nearby horizons in the S and SSW and distant horizons in the NW and the NNW. They concluded that "there was a conscious effort on the part of the builders of north Mull stone rows to locate monuments according to horizon visibility criteria that were not easy to

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[2]These sites coincided with ML1, ML 2, ML4, ML 9, ML10, ML11, ML 12.

[3]Ruggles, Martlew and Hinge, 1991, *Op cit.,* S67.

[4]*Ibid.,* S68.

achieve given the general topographical constraints in the area".[5] These statistical outcomes supporting horizon preference in North Mull reflect the overall correlation between horizon distance and direction indicated by the current project's viewsheds of Coll, Tiree, North Argyll and Mull. Further, it was found by the 1991 project that 5 of the 7 north Mull rows were also oriented onto the SSE, which falls within the directional preference for the most distant horizon.

Ruggles' and Martlew's next step was to investigate the likelihood that significant peaks existed in these preferred or indicated directions. The analysis of prominent horizon features in all directions as viewed from both the stone rows and alternative points around them, revealed a preference for a hill summit to be located to the east of south, near to the southerly limit of the major standstill rise; a preferred declination for Mull's orientations. Further to this, they wished to discover "whether sites were preferentially placed so as to associate prominent peaks with particular astronomical phenomena, regardless of their orientation".[6] Evidence was found that at some sites use was made of a second peak or groups of peaks, associating them with the southerly limit of the minor standstill rising or setting of the solstitial sun.[7] Given the results of the 1991 and 1993 studies showing evidence for particular forms of behaviour in this area, it would be of interest to investigate neighbouring areas of North Mull in detail. This would allow for the determination of how the visual landscape and astronomy were woven together nearby.

Due to time restrictions statistical analyses could not be applied at this late stage of the project. This meant investigations into areas that had many potential alternative peaks was not possible. Using such areas without the application of statistical testing would be leaving too much to guesswork and introducing a number of errors to the assessment. As Ruggles and Martlew state, identifying the most prominent hill summits at each site is subjective up to a point.[8] This means that Mull itself and North Argyll are ruled out as subjects. Coll and Tiree, on the other hand, are prime candidates for the further investigation of this trend, because the areas around the sites, and on the islands generally, are quite low in profile and any summit is generally extremely obvious, with large low-lying areas either side. For Tiree, in particular, the geography is more akin to Lewis in that is it quite flat. Thus, there is little difficulty in labelling a summit as prominent in relation to the site's position (see Figure 11.1 for a bird's eye view). Coll and Tiree, then, were the subject of detailed investigations looking at the possible relationships between site location, the landscape and celestial phenomena. The difference

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[5] *Ibid.*, S68.

[6] Ruggles and Martlew, 1992, *Op cit.*, S4.

[7] *Ibid.*, S6-S8, S12.

[8] *Ibid.*, S6.

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[1] *Ibid.*, S68.

[2] Ruggles and Martlew, 1992, *Op cit.*, S4.

[3] *Ibid.*, S6-S8, S12.

[4] *Ibid.*, S6.

Figure 11.1: A 2-D map with a z-co-ordinate, demonstrating the especially flat nature of Tiree. Coll is flatter in the southern areas where the sites are to be found. Based upon the Ordnance Survey 1:50 000 Landform PANORAMA map with permission of the Controller of her Majesty's Stationery Office © Crown Copyright

3D sky-landscape panoramas. Further, the panorama contains the paths of the sun and moon at pre-designated times in their cycles. In this way it has been made possible to view the sky and the geological landscape (such as mountains) as it might have been seen in pre-historic times, with the celestial bodies coursing across the heavens. To accomplish this a new software product, designed especially for this purpose by A.G.K. Smith, was used.

Coll and Tiree – viewing the landscape and celestial phenomena

The creation of fully rendered landscapes

The rendering of the 360 degree, 3D landscapes include the same techniques as for the production of the 2D horizon profiles explained in Chapter 6 in the section *The creation of the 2D Horizon Profiles by A.G.K. Smith.* The difference being that it was necessary to "flesh out the wireframe with colour and shading".[5] The description below follows Smith's outline for the rendering of this software.

[5] Smith, *Op cit.* forthcoming.

Creation of the paths of the sun and the moon on the landscapes

Basically the paths of the ecliptic, the Sun at the solstices, and the Moon at the major and minor standstills are plotted onto the rendered landscapes. All of which have been shown to have been of interest to peoples of western Scotland to date. The chronological parameter chosen, labelled "Epoch", was the same as that used for the rest of the project, namely 2000 BCE. This was considered a possible approximate mid-point for the erection of Neolithic and Bronze Age free-standing stone monuments.[16] The value of 100km was taken for the variable "Visibility" for the 3D landscapes viewed in this paper. Importantly, though, this value is used so that the more very distant mountains would actually be faintly visible rather than totally invisible, to clarify what was actually happening near the horizon regarding the phenomena. Observer height was taken at 2m. Elevation Range: -10.0 to +30.0 degrees. Note that the existence of any description contained herein, regarding the possible interrelationship between peaks and astronomical phenomena, was checked against 3D horizon panoramas visibility set to 10km. This is a more realistic distant for viewing in western Scotland.[17]

The paths are depicted as lines, which are drawn 0.5 degrees wide to represent the apparent width of the Sun and the Moon. All paths have been corrected for atmospheric refraction.

How to read them
Yellow lines denote the declinations of the Sun at the equinoxes and solstices. The shorter yellow lines are the winter solstice, and the longer, the summer solstice. Alternatively, these can be considered the path of the Sun on those dates. Green lines are the extreme declinations of the Moon at minor standstill. Red lines are the extreme declinations of the Moon at major standstill.

The vertical red band is the orientation of the site alignment determined by Ruggles survey. The lighter part is the outer azimuth range (AAR1 to AAR2) and darker part is the inner azimuth range (IAR1 to IAR2).[18]

It is not necessary to list all the landscape features in all directions for these can be observed by looking at the landscapes of the areas surrounding each site (See Figures 11.2 –11.8). Below, however, are the details of the relationships found between landscape, the rising, setting and paths of the sun and the moon and the location of each of the sites considered in Coll and Tiree. It will be noticed that there are more than one DTM for some sites, this is because some sites have more than

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[16] The magnitude of difference of the sun's movement along the horizon is quite small, especially if you are investigating orientation as a viewing range rather than a point on the horizon. For instance, at latitude $55^0 30'$, the sun's position would be 44.11 degrees in azimuth at its rising in the year 2,500 BCE and 43.96, in the year 2000 BCE. The equinox position is even slower to change.

[17] See. Smith, *Ibid.*

[18] See footnote 10.

one alignment and these preferred orientations are uniquely placed on each 3D landscape, as indicated by the red vertical line. . These pictures are usually intended for viewing in "Irfanview" which allows for correct ratio viewing and clear observations

Coll

CT1

Looking at CT1 first, in the NE, the Summer Solstice sun (yellow line) rises out of a distant peak, flanked by the Northerly extremes of the minor and major standstills. Though the latter rise out of low hills, they are mentioned as all three are then seen to set on the plateau of the highest horizon point, less than 100 metres away in the NW. The rising equinox sun also rises out of low hills in the east and sets in the west on the upper western flanks of the same extremely prominent mountain. At the base of the same peak the southerly limits of the standstills set, having just been seen to traverse the entire sky over the southern bay area and to have arisen out of a set of very distant mountains on the other side of the bay. Naturally as both standstills could be observed, so too the entire path over the bay of the sun at winter solstice. What we seem to have here is a mirroring effect: what is found in the eastern quarters is found in the western quarters also. Here too, we find that the site is not oriented upon a prominent peak but the opposite. The site is oriented south towards the centre of the bay and the arching of the sun's and moon's paths are indicated by the alignment of CT1.

CT2

CT2 has three 3D models. Thus, the landscape and the astronomical information are the same, but the indicated orientations from the alignments to the horizon will be different. Firstly, let us make a list of the significant declinations for CT2, namely CT2baSSW (θ=198.4, δ=-32.55), CT2-CT3 (θ=204.8, δ=-30.8). The insignificant one was CT2abNNE (θ=18.4, δ=+31.35). As one looks around the horizon of any of the three models for CT2, there can be seen some very distinctive peaks. In a similar fashion to the CT1 location, the setting minor and major northerly standstills look to flank the summer the solstice setting *upon the highest peak* along the horizon. Also, in the same way as CT1, there is the mirroring effect, whereby the pattern found in the NW is found about a peak in the NE. The summer solstice sun rises out of a peak, either side of this highest eastern point are found the rising northerly lunar standstills. To the south, the entire path of the southerly limit of the minor standstill, straddles a bay, as was found in CT1. In addition, the minor standstill and the winter solstice pathways are in full view across the same bay. The significant indicated declinations, $\delta = -{}^{-}32.55$, $\theta = 198.4$ and $\delta = {}^{-}30.1$, $\theta = 204.8$, were both in a southwesterly direction. Again, like CT1, indicating the traversing of the sun and moon across the bay, this time within 7° and 3° of the southerly major lunar standstill (red line).

CT3

Note that the NW peaks for CT3 (between 15° towards north from NW and 10° south from NW) are the SW peaks for CT2. Once more the entire rising and setting of the southern limits of the major and minor lunar standstills and the winter solstices and are placed over the sea in the south. At $\theta = 312.5$ (NW), the same pattern of the summer solstice setting flanked by the northern limits of the minor and major lunar standstills occurs upon the highest peaks along the horizon. The significant alignment was $\delta =-^{+}29.85$, $\theta = 24.8$ (rising northern limit major standstill).

Tiree

CT7

CT7-CT8: Even though we are now on a different island, striking similarities in landscape choice appear. Once more to the NW we have the summer solstice setting flanked by the northern limits of the minor and major lunar standstills occurring upon the highest peaks along the horizon. In addition, the major standstill moon slips over SSW mountains on its most western flank having just skimmed over a notch (Az = 204.6°). Even more fascinating though, is that the alignment of CT7-CT8 actually indicates the point of where the moon skims over this flank, with the outer indicating ranges (lighter red colour) indicating the notch. This moon has travelled over this mountain range from the south east over the view of the sea and prior to that, another mountain range flanking the bay area to the south east. This rising over a bay area and setting on the other side, with flanking mountains, is remarkably similar to the sites discussed in Coll. The rising point of this phenomenon is not a prominent peak this time, nonetheless the effect is striking, as are the correspondences: a continuation of distant sea views in the south along with the entire paths of the southerly limits of the moon and the winter solstice sun, further support this observation. In this case, the site is aligned with the setting major standstill ($\delta =-^{-}29.85$, $\theta = 204.6$). Also to be noted is the setting of the equinox sun into the foot of most prominent peaks.

CT8

In the northerly directions, NNW, only the major lunar standstill can be seen to set behind a distant prominent hill. In fact, it sets in the SAME notch as that seen from CT7. The indicated orientation (CT8-CT7) is 24.6° NE. The accompanying horizon declination for this alignment is $^{+}29.84°$, the rising northerly limit of the major standstill. So here, via site orientation and prominent peak, both the rising and setting of a limit of the major lunar standstill may be accounted for. As usual, the two mountain chains are seen to flank the bay, with the southerly limit of the major standstill rising out of mountains east of the bay, climbing and travelling over the southern bay and setting in the mountains west of the bay, as for CT7. Most fascinating is that the moon sets in a notch here and then reappears at the foot of the chain. Furthermore, this very notch may indicated by the alignments of "CT7 to

CT8", adding further weight to the idea that these two sites, CT7 and CT8, are indeed connected. Added to this the winter solstice sun is seen to rise out of the eastern chain of mountains and setting in the southwest, slightly west of the western mountain range. The same setting occurs, naturally, at CT7. The southerly limit of the minor standstill sets slightly west of SW, having risen east of the eastern chain and travelled across the bay first and then over the western range of mountains. Notice in the northerly direction that at exact north a foreshortened horizon is chosen, being blocked out by a chain of mountains between 354° and 10° in azimuth.

CT9

Southerly Major moon travels from the edge of the bay southeast of site CT9 over the same mountain chain in the now SSW that the southerly major moon at site CT7 rose over and CT8 rose out of. At CT9 it virtually skims over the majority of this entire chain just before setting at its western foot. The southerly minor moon is seen to rise out this same bay, and possibly winter solstice sun is seen to rise out of this bay too. They both travel over the same mountain chain as the major moon with the minor moon setting in the same obvious chain that the major moon sets in and reappears as seen from CT8, and that the moon at CT7 skims across the western tip of prior to setting. The winter sun and the minor moon thus traverse the bay in southwest of the site, though the bay does not appear to be seen. In addition, the summer solstice sun sets in the distant but prominent peak in the NW, as it did at the site CT7. Very interestingly, the site orientation clearly indicates the notch in the mountain chain in the SSW that the major moon skims above. Also to be noted is that like CT7 the summer solstice sun sets behind the prominent chain in the NW.

Preferred horizons and their distances

As can be seen with from the 2Dhorizon profiles the closest horizons usually include north and the most distant usually include east, and south of east. Table 11.9, below, details this more specifically.

Site name	Closest horizon ranges	Furthest horizon ranges
CT1	SW → N	ESE → SW
CT2	N to 15° west of N	ESE →SW; W
CT3	W → NNE	NE →SSE
CT7	WNW → ENE	EN → SE
CT8	Slightly west of N (5°west); Overall NW → NNE (small gap dead on north, but still a close horizon here with mountain)	ENE →ESE
CT9	NWN → ENE	NE → SE

Table 11.9: Exposition of relationship between direction and distance in choice of horizon type by builders of the Coll and Tiree monuments.

Comparing Mull with Coll and Tiree - intricate vistas

Though there have been definite patterns found in Coll and Tiree they are not as simple as those found by Ruggles *et al.* in Mull, but there are some similarities. There is a preference for close or restricted northern horizons for all sites and distant easterly, NE to SE for four of the sites (CT1, CT2, CT3, CT7) and ESE to SW for the remaining two (CT8, CT9). For Mull, there was a distinct avoidance of distant northern horizons and nearby S and SSW restricted horizons. Whilst all the significant preferred orientations appear to fall into those sections of the viewsheds with distant horizons, as do those for Mull, five of the preferred declinations are located at the setting of the southerly minor standstill (SSW), and the other two, the rising of the northerly major standstill (NNE). Mull has locational preferences for a hill in view in the SSE and a second group of peaks in the SW. Coll and Tiree also appear to have peaks at these horizon points, but the SE/SSE peaks are not always prominent, and may indeed be very distant. Two other groups of peaks, or a peak, always appear in the NW, and with 5/6 sites having a peak in the NE, of these 3/6 appear very distantly and 2/6 very prominently. These peaks in the SE and NE are mentioned despite their distance because of their consistent associations with the same rising solar and lunar for each site.

What can be said for Coll and Tiree, though not actually statistically tested, is that the overall preferred direction of the distant views, as indicated by the viewsheds and horizon profiles is southerly. This is reinforced by the preferred direction of the astronomical views, as supported by the statistical analyses. The other similarity between these sites across the islands is that the azimuths on Coll and Tiree are within 10 degrees of each other for all seven sites, six within 5 degrees. For six of these sites the builders have managed to get similar declinations also, thus deliberately choosing a horizon that would give them not only the same direction in general, but the correct altitude in the direction required to indicate an astronomical body.

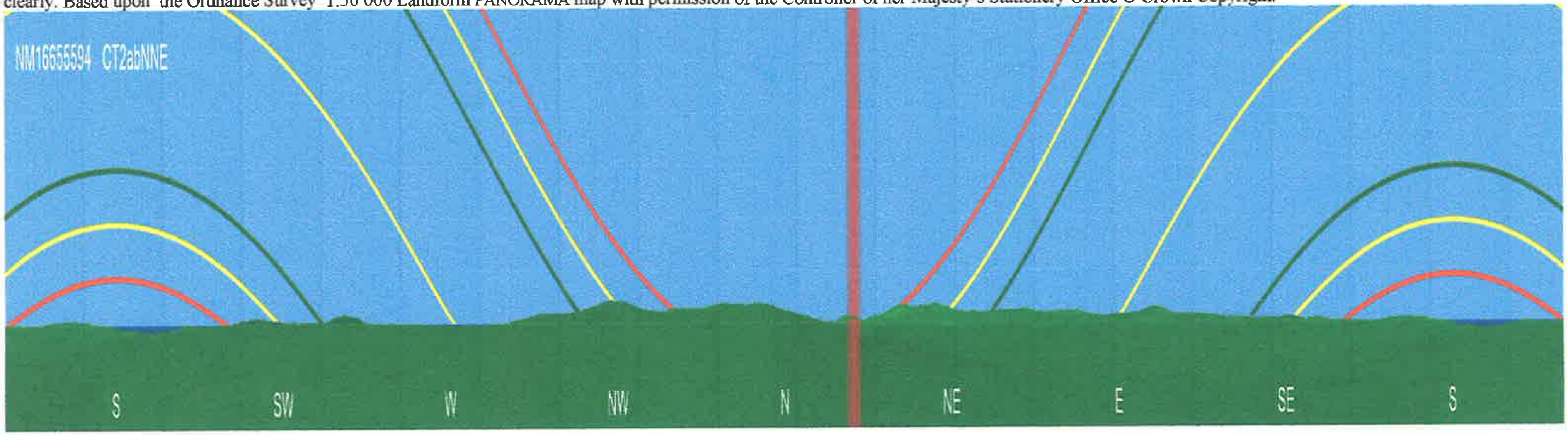
Fisher *et al's* work has also shown that there are directions other than those indicated by the orientation of the site that might be of interest to those who erected stone monuments in northern Mull. Fisher et al's work has tested the broader idea of the amount and kind of landscape areas around sites that might be of visual importance using GIS viewshed analyses. Fourteen Bronze Age cairns' visible areas were compared with areas visible from random, stratified and proximal sites within the general landscape. Their research demonstrated that the areas visible from the Bronze Age cairns are distinctive among the population of the possible sites in the area, being both larger and a greater area of the sea visible.[19] This result, too, is consistent with those found on Coll and Tiree. The difference being that, Coll and Tiree have southern views of the sea, whilst those of the northern Mull cairn sites have an interest in the north. The CVS, though, found more widespread interest including towards the southwest, down, and across the Sound of Mull.

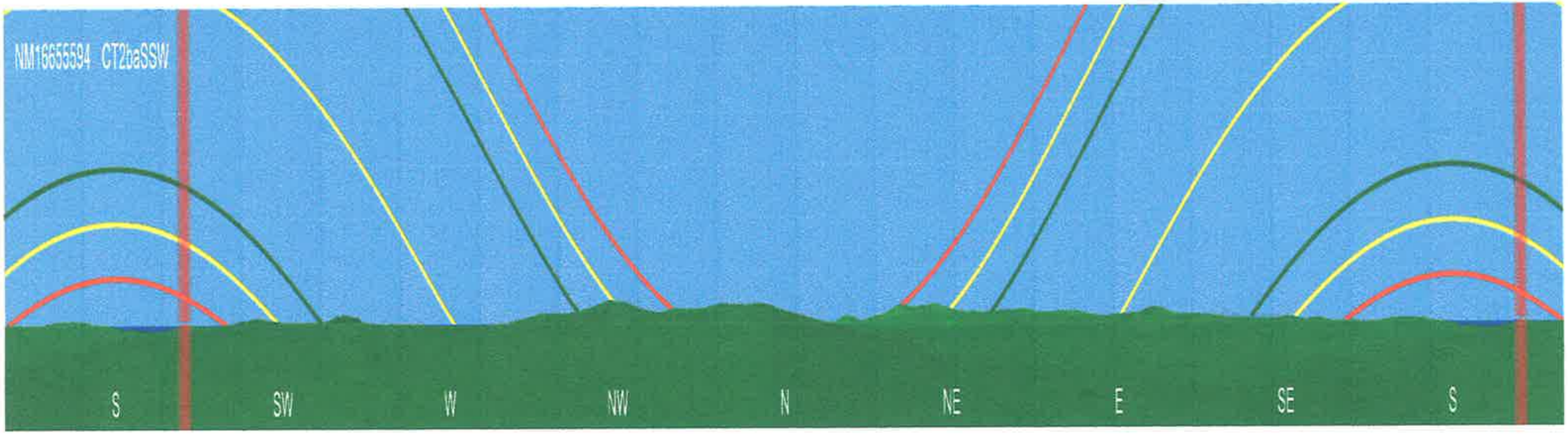
[19] *Op cit.*, 588.

Alignments Phase 3a and Phase 3b

In Phase3 it was of interest to know exactly how distant the northern horizons were from each Group1 site, in order to discover whether or not a close northern horizon might account for the lack of Group2 sites in this direction. In addition, in Phase3, Mull was one of two regions displaying the greatest singularity of Group2 sites about 120 degrees in relation to the Group1 sites (See Appendices 2 and 3: figures A2.2 and A3.2). The viewsheds and the 2D horizon profiles of Phase 3B have revealed that for the regions of Mull, Coll and Tiree the northerly direction is avoided, that is, a close northerly horizon is favoured, whilst Ruggles *et al.* (1997) also discovered that distant northern horizons were avoided. This preference for close northern horizons, and the evidence for favoured distant southern horizons, may indeed account for the lack of Group2 sites north of the sites in the greater region designated as Mull in Ruggles 1984 study. It may also account for the large number of sites found in the southeast in relation to the Group1 sites. This greater region included Coll, Tiree and North Argyll. Thus, we now have firmer evidence that the pattern regarding the placement of the Neolithic and Bronze Age sites in relation to each other is unlikely to be caused by topographical effects in Mull, but by human action.

Figures 11.2-11.8: These are the 3-D 360 degree landscape profiles for CT1, CT2, CT3, CT7, CT8, CT9. The scales are: 1:0.70 for height and 1:0.24 for width. This enables the viewer observe the patterns more clearly. Based upon the Ordnance Survey 1:50 000 Landform PANORAMA map with permission of the Controller of her Majesty's Stationery Office © Crown Copyright.





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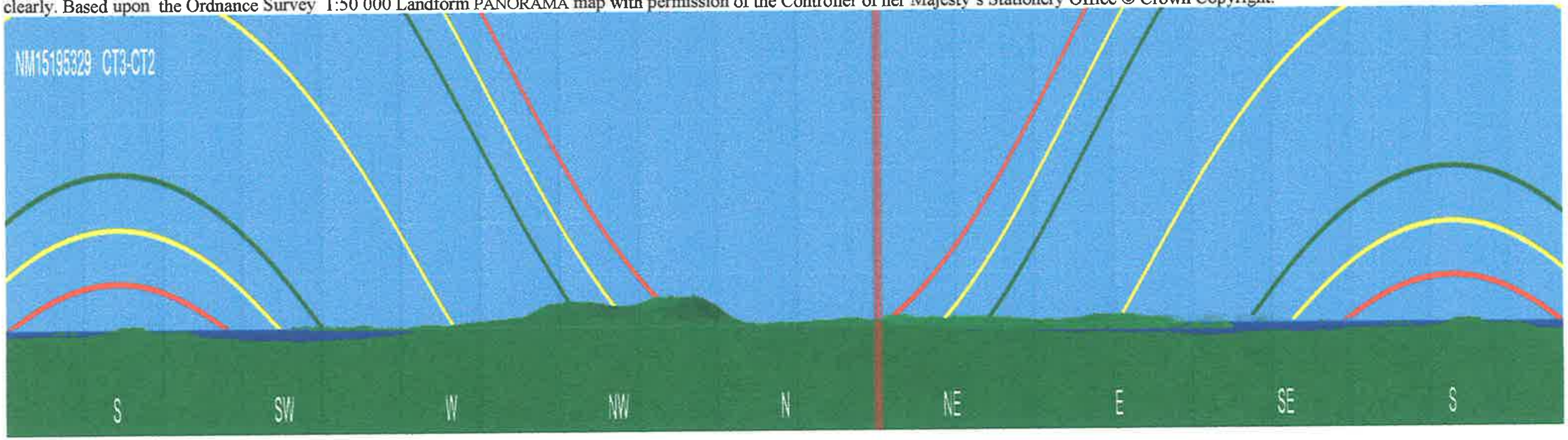

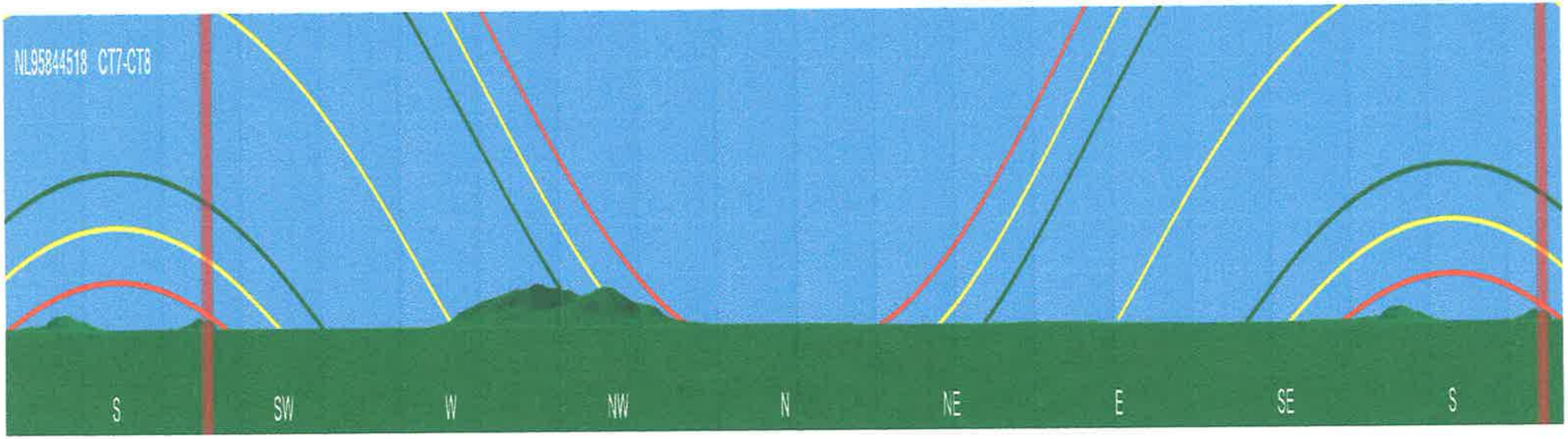

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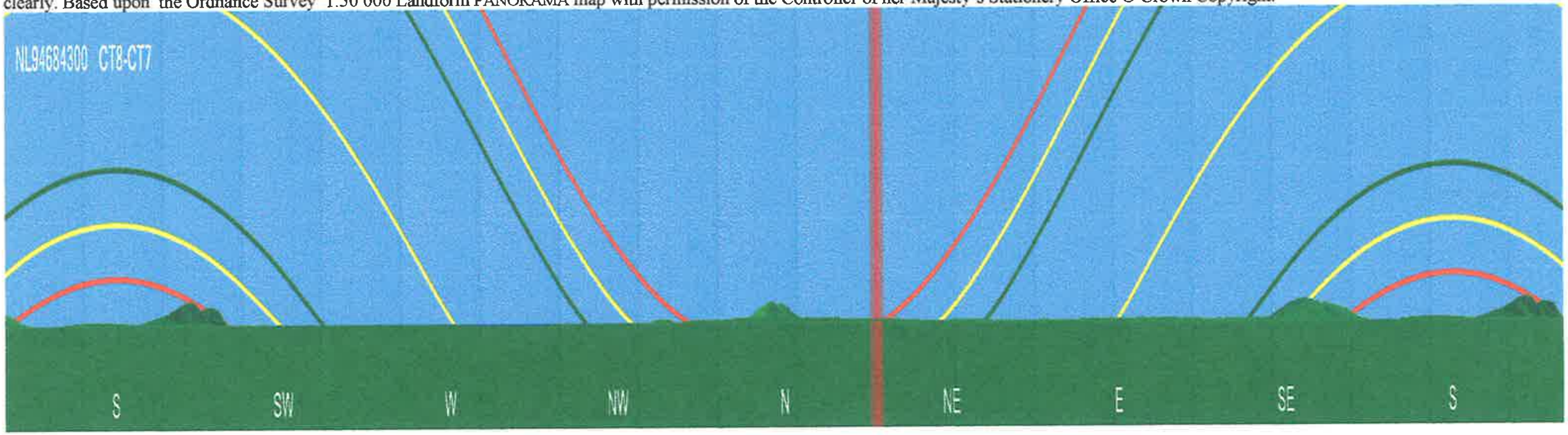

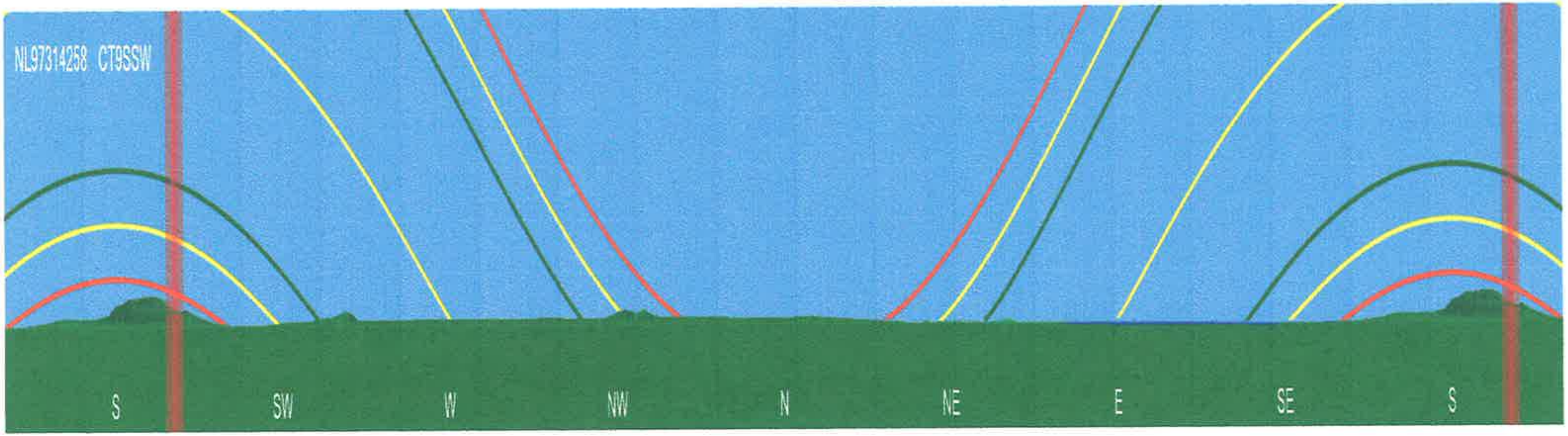

Chapter 12

Orientation and Visibility Analysis

Elaborate landscapes - further interpretive assessment of possible complex cosmological systems

The results for Phase3a revealed that it was important to place sites along a SE line, in relation to the Group1 sites location, for all regions. These sites included barrows, Bronze Age cairns with cists, cinerary urns or cremations, standing stones (rows, circles, individual, other), chambered cairns, and cup and ring markings. The SE line (120-130, where SE is actually 135°) for Mull and Islay was an almost exclusive.[1] Argyll, though, had preferences for NW/SE, NNW/ SSE and two smaller peaks, namely SW-WSW. The dominant peaks for Lewis/Harris were in the regions from E to SE and W to NW, whilst Kintyre had a number of discrete significant orientations (E, SE, SSE, SSW, SW-WSW, WNW-NW) again perhaps reflecting the differences between the interests of the cultures in the north and south. Interestingly, the predominant peak SSW had no distinct peak in the opposite direction. Uist's predominant peak runs ESE. There is also a distinct interest in the SE, SSW and WSW. That all regions paid little attention to, or avoided, south, north and west, was consistent throughout.

Consistencies of orientations across scales of alignment

It is interesting to observe that these larger, general alignment trends across vast spaces are reflected at differing scales of site arrangements found *within* the free-standing stone database of Scotland; namely, intersite visual alignments (where separate sites are in view, one direction is acceptable), intrasite, inter-monument alignments (between two monuments which are considered part of the same site) and within monuments (via intra-monument orientation). Examples of the first and second are known and defined by Ruggles' 1984 study. Here two monuments can see each other but are not considered as part of the same site (for example, as a stone circle and stone row). The second consists of monuments clearly defined as separate entities but within 300 metres of each other (such as parallel stone rows). The third form uses the linear axes of monuments to measure the orientation. This could be, for instance, the axis of a stone row or a tomb. For Ruggles' database, only stone row axes were measured, as stone circles were considered to

[1] Remembering that the term SE is used, NW must be considered for even though the peaks are placed at the SE, it has not yet been determined which sites were placed first and so the sites alignment may be thought of in terms relating to NW also, or any direction opposite that peaking on the histograms.

have too many options to test easily and well. Tombs, too, were not measured as this was a study of free standing monuments only.

Intersite alignments

Site to site in Uist

North Uist has many intersite alignments as discussed in Chapter 5, for instance, sites UI6 to UI59, with a particular concentration from sites UI22 to UI37 in North Uist. Despite the variety of site types, including slabs (UI6, UI31), single standing stones (UI15), pairs of stones (UI9, UI23), stone row (UI19), ring of menhirs (UI33), and ring of stones (UI37, UI40), Uist is the region with the strongest alignment clustering within the NW - SE quadrants, with lesser clustering about the line NE-SW for the Group1 sites. This strong interest in the middle zones of these quadrants, and an almost complete lack of interest in the northern, southern and western cardinal points mirrors well that larger scale alignment pattern found in the Phase3a results. It must be mentioned too, that many of these alignments are two-way and we do not know which is their preferred direction, much in the same way as it is not clear as yet whether the Group1 sites (mainly circles and rows and standing stones) were at the beginning of the large scale landscape alignments, or towards the end. Not until there is a correlation between site type, chronology and position in this alignment will this be made more definite.

Intra-site alignments

If we look at the RCAHMS's *Argyll. An Inventory of the Monuments* there are some interesting trends to be noted now, that could be tested in more detail at a later date. In Lochbuie, Mull, there is a group of prehistoric monuments comprising a stone circle, several standing stones and a kerb cairn[2]. Here the open stone circle lies SE of the Cairn, with a standing stones, lying both SE and SW. In Hough, Tiree, there are two open circles and a cairn (inventory no. 107).[3] The two circles are aligned SW-NE, but the seven metre turfed covered circular Cairn is situated on a knoll to the SE of the southernmost of these circles.

Intra-monument alignments

Stone rows

For regions with significant intersite and intrasite clustering (Phase1), the majority of the orientations ran in some form of NE/SW or NW/SE line, as opposed to N/S. Uist's orientations therefore run principally

[2]RCAHMS, 1980, *Argyll. An Inventory of the Monuments:* ***Volume 3*** *Mull, Tiree, Coll and Northern Argyll*, inventory no 110, 69. The kerb-cairn is inventoried at number 49.
[3]*Ibid.*, 68.

about the mean of NW/SE, which is indeed also the mode. Moving south easterly, the mean of Islay's run E, ENE/WSW and ESE/WNW, for Argyll NNW and SSE. The number of orientations within 11.5 degrees of north and south are very few.[4] This finding is further supported by the orientations of the 3-5 stone rows in this region. Looking at these we find the following:

Region and site(s)	**direction**	**number of orientations**
Lewis/Harris LH24		
	NNW-SSE	1
Total		**1**
Uist UI19		
	WNW -ESE	1
Total		**1**
Mull ML1, ML2, ML4, ML9, ML10, ML11, ML12, ML25		
	NNW_SSE	5
	NNE-SSW	1
	NW_SE	2
	N-S	1
Total		**9**

Region and site(s)	**direction**	**number of orientations**
Islay/Jura JU7, IS41		
	NNE-SSW	1
	N-S	1
Total		2
Argyll (incl Lorn) LN22, AR6, AR13 (2 rows), AR15, AR28		
	NNW_SSE	1 (Lorn)
	NW_SE	2
	NNE-SSW	2
	N-S	1
Total		6
Kintyre KT10, KT27		
	NNE_SSW	1
	NE-SW	2
Total		3

Table 11.1 The directional totals for the orientation of the 3-5 stone rows in the study area of western Scotland. The azimuths come from Ruggles' and Burl's 1996 paper, "Astronomical influences on prehistoric ritual architecture in north-west Europe: the case of stone rows", Table 3, 523. Two orientations were not included in the 1984 study, and therefore are not to be found elsewhere in this pilot study. These were: (i) ML1, Glengorm, NM 4347 5715. Though used as a foresight for an intersite indication it was not considered for intrasite assessment until archaeological work revealed more accurate data as to the nature of the row (Ruggles, 1988, Table9.1); (ii) ML12 (Ardnacross SE row). From Martlew and Ruggles, 1993, § 7.1 and § 7.5. Not considered previously due to lack of archaeological field work to determine original positions of rows.

[4] 11.5 degrees is the dividing line between N and NNW or NNE and S and SSE or SSW. Those that fall below that line and considered as northern or southern orientations and those above that line are categorised as NNE, NNW etc.

Interestingly, Ruggles and Burl concluded from the orientation data (Table 3 of their 1995 paper) that the directions for western Scottish stone row alignments were primarily northerly and southerly. The outcome of this present study upholds that this labelling veils the real pattern. It conceals the NNW, SSE orientations and similar forms, by placing them under the broad description of "generally N-S orientation".[5] This N-S label may well have been used to highlight the orientation difference with the Irish short stone rows, which are thought to run NE/SW. Whilst looking at the two tables of Ruggles and Burl (1995), a difference is obvious, but that difference is not a separation between N/S alignments and NE/SW alignments as they point out. Rather, it is a more subtle variation. What distinguishes the Scottish sites is that they have more sites lying in their NW– SE direction (n=11) than their NE - SW direction (n=6), but they sit in the NNW, NNE, and SSW SSE sectors. For the Irish sites the directions lie within the SE - NW bands (n=32) and NNW/SSE bands (n=33), within the same 2 quadrants, ratio 1:1. The difference between the two data sets is that the Scottish sites can be found over all 4 quadrants and fall generally further north or south from east and west along the horizon, whilst the Irish ones stay in a relatively narrow band within two quadrants and have a greater ratio of sites closer to the east and west points on the horizon, than do the Scottish (2:1). The difference between them, then, is not that one favours north and south and one favours NE and SW.

The apparent interest in north and south sectors of the horizon in Scotland cannot be determined or supported by the indications of the Scottish row alignments. In regard to astronomy, to place an orientation even symbolically and loosely towards a particular direction is not difficult, to within 20 degrees. This is a large amount of sky to 'play with'. If the cardinal point north or south were of interest more orientations would have fallen within the 22.5 degree band about north or south, but very few do. Rather, the above has shown us that these indications of the Scottish 3-5 stone rows mimic the large scale orientation preferences of the large scale alignments made up of varying site-types found across the landscape of western Scotland (Group1 / Group2 alignments).

Abundant evidence has been seen that the north and south cardinal points are generally avoided by alignments, either for the 3-5 stone row intrasite alignments above, or the alignments found between the free-standing stone monuments and other Neolithic, Bronze Age sites. The avoidance of Group2 sites north of Group1 sites runs from 5° south of NW to 5° south of NE, a band of 100 degrees. This coincides with the preference for shorter horizons in a northerly direction. The south is less consistent across a wide band, but for all regions, 10° either side of south is avoided consistently by the Group2 sites. Distant horizons in the north were also shunned by the Group1 sites' horizons in Mull, and in Coll and Tiree close northern horizons were preferred. Added to this, those close northern horizons that were chosen were devoid of solar or lunar activity at the solstices, equinoxes and standstills.

[5] Ruggles and Burl, 1995, 522.

Indicating alignments were not usually used, it seems, to refer to cardinal points. However, in Islay there appears to be quite a different story. The azimuthal plots show an interest in lying close to, and onto east, whilst specifically avoiding west, but flanking close to it. Declinations also exhibit some correlation with the equinox points. This island, along with Jura, seems to possess significant cultural differences in cosmological focus whilst maintaining and participating in the more general trend of monument location in relation to one another across the landscape. In fact, Islay has the greatest significant number of Neolithic and Bronze Age sites placed along the SE - NW alignment. This area is certainly one where it would be of great interest to investigate the possible diversities of these islands and see if other archaeological evidence might support this conclusion.

Single standing stones

By looking at the alignment of single standing stones only, it can be seen whether or not they have a similar orientation pattern to the other alignment forms seen above.

Site	description
LH29	NW
LH36	WNW
UI16	WNW
UI16	ESE
UI28 (nth uist)	SSE
UI46 (sth uist)	NW
UI49	NE
NA3	NNW
CT1	S
CT9	SSW
ML2	SSE
ML7	SE
ML9	NNW
ML10	NNW
ML30	NNW
ML31	NE
ML31	SW
LN7	N
AR2	N
AR9	ENE
AR16	NW
AR16	SE

Site	description
AR32	WNW
AR32	ESE
AR33	WNW
AR33	ESE
IS39	E
IS41	S
KT4	S
KT5	NNE
KT5	SSW
KT12	N
KT23	SW
KT28	ENE
KT29	ENE
KT31	WNW
KT35	WNW
KT35	ESE
KT39	NW
KT39	SE
KT41	NW
KT41	SE
KT44	N
KT44	S

Table 11.2 Table of single standing stone orientations. They were calculated in the same manner for designating all sub-quadrant labels. Each section, about an 1/8 of a circle, has assigned to it 22°. So to be labelled SE, it has to be an orientation at 135°, ± 11.5°.

The above table reveals the same patterns as we have seen above, a preponderance of alignments that avoid the north, south, and west cardinal points: north=4/38, south =4/38, and west = 0/38 orientations. Here there is also an avoidance of the cardinal point of east.

Location, location, location

As indicated by the discussion at the end of Chapter 9, the reason for locating sites in one place rather than another is now recognised as being more involved than a single object nominated by a preferred alignment. It is acknowledged that *other visual points of interest* are also of interest. The south in Coll and Tiree, for instance, though NOT indicated by the orientations of the alignments, was always associated with the southerly, major standstill's entire path across the sky, often rising or setting out of a mountain chain, if not both, and seen to be coursing its way across an open body of water. Added to this were the appearance of the rising and setting of the southerly limiting minor standstill and winter sun at the solstice, when topographically possible. That is, these also rose or set out of the same mountain chains as the southern standstill moon when the mountain chain was wide enough across the horizon. Again, closely examining the case study area of Coll and Tiree has revealed, through the associations of peaks with specific astronomical rising and settings, the possible preferred directions are running from NNW-WNW, WSW-SSW, SSE-ESE and ENE-NNE. North and any association with astronomical phenomena is not a preference.

Cosmological Conclusions

Both for our methodology and our interpretations we have assumed that belief systems guide, or influence, human action and thought, and that these are expressed by material culture. In our attempt to link material cultural to human action, and, finally, beliefs, we offer the following as a possible interpretation to date.

Overview

Primarily, this project has found that it was important for Neolithic and Bronze age peoples of western Scotland purposely to locate their structures to enable these sites to participate in a design of inter-relationship between themselves and the natural environment, this raises the question whether any other recognisable entities might also be included. This suggests that it was of relevance to their belief systems to order their world in a very specific way. The patterns that we have found evidence for are 'simple' alignments and alignment clusters. Alignments are where one or more arranged objects, or sites, are aligned with either another arranged object or site and/or a natural 'object'. What connects all these monuments is the possibility of a shared belief system across geographical space and time.

Simple alignments and alignment clusters

Direction and final destination are fundamental for many simple alignments. The assembling of the alignments (human action) produced distinct orientations or indicated directions to be viewed from a specific place within the landscape. Such appropriation may mark a stage in a process by which particular people become more closely associated, or identified, with particular locations in the landscape, not only those that the sites are located upon but also those they indicate.[6] For the free standing stone monuments, in Mull, Argyll, Islay and Uist, these significant directions have been shown to be regionally linked. The directions appear to be connected to celestial phenomena for the 3 regions of Argyll, Mull and Islay. To reiterate, these region titles include the areas of Coll, Tiree and North Argyll for Mull, Jura for Islay, and Lorn for Argyll. The geographical and chronological extent of these relationships shows that the associated symbolic concepts held some weight.

The concept of alignment clusters is connected to the idea of incorporating a variety of site types into one, or many, significant alignments running across land and water. Using sites varying in type and age implies that regardless of WHEN a site was built, it was *still relevant* to place it along some form of interconnecting linear pattern. It was not shown, for this particular form of alignment, that the majority of sites should be to be visually interconnected from the viewpoint of the free-standing stone monuments, at least within the region of Mull. The most common direction moving out from a free standing stone monument appears to be southeast. These appear to be placed, then, to the northwest of the Group2 sites in Islay, Argyll, Kintrye and Mull, especially. The latter having the least number of Group1 sites significantly arranged with Group2 sites about them (68.75%). By the fact that barrows, stone circles of varying type, stone rows and both Neolithic and Bronze Age cairns were involved, as well as cup and ring markings, the possible span of involvement in this system could be at least 2,500 years. The complexity of the relationship is revealed by these chronologically broad site types and the large number of landscape variables that seem to have come into play in the final decision for monument location.

The human action that is presented to us for each of these regions is that of forming configurations between and within structures, and particular points within landscape as well as objects. These places may well represent or be the manifestations of the phenomena that appear so important to capture via indication, location and visibility.

From the evidence to date, then, Mull, Argyll, Islay, and Uist appear to be linked to the same coherent, fundamental system. The spatial design and visual focus that they all share may well be associated with, or represent, the same or similar elementary concept(s). There is some evidence to suggest that northern Kintyre shares the same orientation and system and visual focus as Argyll, with the south designating itself as separate from this, thus revealing, perhaps, another regional area. Overall, however, it is still part of the broader cosmology based upon the arranging and aligning of monuments, for Kintyre featured seventeen out of a possible twenty-one Group1 sites having significant clusters of other Neolithic and Bronze Age sites about them (81%), in a manner similar to that of Argyll and Uist.

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[6] Bradley, 1996, *Op cit.* chapter9.

Possible associated belief systems

We have seen that both the moon and the sun were important entities to the builders of many of the sites researched to date in western Scotland. The material culture has revealed this to us via the purposely-created alignment indications. The strength of these indications and the geographical extent of these also emphasise the weaving and integration of an important belief system that extends through out much of western Scotland.

The consistent pointing to or indication of these bodies means that they were meant to be noticed, looked at or considered in a manner that was not associated with the every day or rather *the ordinary.* The interpretation of the evidence for this is twofold: (i) these bodies were already in themselves noticeable features of the sky and do not need any deliberate indication to inform people either of their existence or appearance in general; (ii) these bodies are primarily indicated when they appear at specific points on the horizon only. It is our job to try to find the likely associations between these objects in the sky and what they represent to the builders of the time. We have, then, a series of built-in representations within the landscape/site/phenomena relationship. It seems that the actual monuments are the material expression or material representation of the event that occurs on the horizon, as is the indication they make through their alignments.

The objects that the alignments point to may in effect be representations of symbolic concepts which themselves are representative constructs of their belief system, and not only significant within themselves. What then, are their beliefs?

What can we know about their belief system from the evidence we have so far? The lunar phenomena that were of primary focus were the major and minor standstills, and of these two, the former was predominant for Mull and Argyll and the latter for Islay. This lunar position is when the moon reaches its maximum distance north or south of the equator during its 18.6 lunar period, before it then begins its march back in the other direction. The minor standstill is when the moon's path is maintained inside that of the sun's and reaches its maximum possible distance north or south of the equator whilst staying within this boundary. Argyll also has an interest in the sun at the winter solstice and Islay has an interest around the equinox. It is possible then, that the people of these monuments had a keen understanding of the cycles of the moon and sun. It is very likely that such changeable phenomena marked out, or mirrored, the equivalent changes in their immediate worldly landscape, such as tides and fishing, bird and other migration, parallel human movements and plant life. The sun and the moon for such peoples, then, were likely symbols of life-giving forces. Naturally, the great phenomena of light and warmth, regardless of whether they were associated with life-giving forces or not, would be worthy of appreciation and, perhaps, adoration. The major events in these bodies' movements, such the major standstills and solstices, may have represented times of great cosmological importance and may have implied 'magical' or 'powerful' moments in time. Perhaps part of the monuments' roles, then, was to bear witness to such events and not merely to record or register them. The monuments themselves are participating in the events.

If enclosures may have symbolised the ideal community of the past, and long mounds may have produced the form of long houses that were no longer being built, the orientations within and between the Group1 freestanding stone monuments seem to partake in events and ideas that were current at the time. The sun and moon were still rising and setting in a particular place along the horizon and the places that were chosen to be marked were those points that change as dramatically in the short-term or *longue duree*. The orientation clusters between monuments of all periods and types, however, may be more representative of traditions that could have possibly lost contact with the initial ideas and forms of reasoning that first created them, whilst still somehow partaking in them. The very fact that the free-standing stone monuments appear clearly northwest of the majority of the other sites in Mull, Uist and Islay, and the majority equally WNW-NW and NNW for Argyll, may well indicate that these sites 'look back' or connect in some way to the traditional long-line placement of sites in relation to each other. It could well be as Bradley states, "the fact of the (Group2 sites) survival meant that they had to be incorporated in any understanding of the world; ideas about their origin and significance may have changed quite radically, but it would have been very difficult to remain innocent of their very existence".[7] It may well, therefore, have been important to consider both the indicated astronomical phenomena as well as the previously placed monuments and weave these together in a very particular order or arrangement upon the land. Perhaps too, "the building of the monuments prevented ritual and mythological significance of particular places being lost and forgotten".[8] These points certainly seem supported by the examination of the Neolithic and Bronze Age sites of western Scotland.
Similarly the rebuilding or reuse of sites discussed in Chapter 2, may have served an equivalent purpose. Referring further to Chapter 2, it may be remembered that the reuse of monuments in the Bronze Age often entailed the closing off of previously open monuments such as stone circles or recumbent stone circles. There were, it seems, possible internal public forums reverting to closed, unapproachable spaces. The questions asked in chapter 2 were: "what has happened to the notions of open space, public forum and circularity? Did they disappear?" It is felt that the results of the current research project on megalithic monuments in western Scotland have demonstrated, significantly and effectively, that these notions, rather than disappearing, actually expanded, encompassing not just the area designated to symbolise previous cosmic notions but came to include the largest circular property that one could envisage or experience, that of the horizon. In effect the sacred space has been enclosed by the horizon. Where and when stone rows came to be used, or to dominate and make a new landscape, it seems there are no longer designated boundaries upon the ground to stand within. It appears that shift in interests has

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[7] Bradley, 1996, *Op cit.* 72. Adopting and reversing sentence order of Bradley's words in relation to earthwork monuments.
[8]Tilley, C., 1994, 204.

come about in the Bronze Age in particular. Though the author fully agrees that it is not necessary to point to an outside influence as the reason for a change in behaviour or a shift in mental focus, external factors should still be considered. For instance, the evidence points to stressful times in Bronze age due to climate change (See Tipping's work in Chapter 2 herein). Is it possible with both the move towards farming and the inclement weather that people felt a stronger need for reassurance and control over the entire cycle of life and death to assist them and that this need drove people to build the stone rows in western Scotland with the idea of the focus upon all that surrounds one. This may be further supported by the connections of the sites with the sun and the moon, which were likely symbols of the life-giving forces. As a result of this need it is possible that they built monuments that would either represent or actually participate in the cycles of the heavens as they cross the edges of the earth.

Interpretation Summary

The knowledge or appearance of the monuments we have investigated may have induced the appropriate cosmological connections to the celestial phenomena or the horizon. The monuments could have been then, a representation of the sacredness of these things, as well as possibly being sacred within themselves. Further, these monuments and the associated phenomena were likely mnemonics for the symbolic concepts that were associated with their beliefs.

The apparent objectives of monument building (not necessarily mutually incompatible) were likely to be to:

- represent, create, or participate in organising, an ordered universe
- represent, create or induce powerful cosmological entities
- represent, create, enhance or induce powerful cosmological connections (thus enhancing the power of the created places)
- steer people's mental/spiritual focus

With the enormous investment of time and space, and the consistent patterns over the same, the monuments, the horizons and the associated phenomena appear to be parts of the same fundamental cosmological system. This system seems to be connected to astronomical phenomena and their cycles. Added to this, regions appear to have some cultural independence, for there are variations in the astronomical system they focus upon. It is also possible that all the differing orientations of the freestanding stone monuments with and without astronomical associations are differing versions or expressions of the long-standing and widespread SE alignment.

Unanswered Questions - methodological commentary

The are very many unanswered questions about the monuments from this region. However, those questions regarding specific areas and the relationships between sites and their locations will be understood more fully when the full viewshed analyses are finalised, as outlined in Chapter 9, during post-doctoral work.

For other questions relating to the SE/NW and related cluster alignments, a study of the probable order of appearance of the monuments might be enlightening. This might allow us to discover whether one form of site was of more prominence than another or more central to the scheme of creating an ordered world. Studying the likely order of appearance of sites, at least generally, may help with more definitive hypothesis or theory development in relation to this NW/SE line and other prominent directions. Also, testing viewsheds in relation to the variable of site type, and possible chronological age, might assist in the determination of which site type significantly sees which site type along this long alignment, if any. However, with fewer monuments in western Scotland being fully or even partially excavated "the complications and dangers of attempting to categorise monuments on the surface evidence" alone are quite high.[9] Naturally, then, these queries can be addressed more easily as more sites are excavated. Naturally, excavation can also tell us something of the order of monuments where they are in close association with one another, such as tombs in circles and cairns between stone rows. Order of occurrence issues, then, will help uncover information relating to sites that have more than one monument, which in turn may assist in discovering whether monuments were aligned along different azimuths according to the period or the style of monument.

A more general study on monument type and placement within the large scale landscape alignments and local intra-site alignments could begin early during post-doctoral work. By investigating morphological variables, it might help answer some questions of the relative age of monuments by testing for a correlation between type and position relative to other monuments, remembering that all Group1 sites on Islay and Mull were placed NW of all the other Neolithic and Bronze Age monuments that could be easily, and unequivocally as possible, recognised as such. More specifically, it would be helpful to know how many, or which, stone rows were built within a close time frame. This might help us to know how many of these sites were in use at the same time and excavation may tell us whether any of them were even used after they were built. Remembering that Argyll is one of the areas in the British Isles with the greatest number of standing stones, these answers might help us to know why so many built in the same geographical region

[9] Bradley, 1996, *Op cit.* chapter9.

Unanswered social and cosmological issues

There are other issues too, that need to be addressed regarding the connection between monument and cosmological beliefs. For instance, did each local area, of those astronomically significant regions, need an indicating stone row or other form of astronomical alignment? If so, what does this tell us? Such sites may not have been boundary markers of the local peoples who 'used' the surrounding area, but rather these alignments may well have been something the area had to have to be considered a viable functioning *locale.* Perhaps they were there to make sure each area is given the connection to the phenomenon or perhaps to make sure each area paid the honour due to the phenomenon (astronomical body).

The connection between north-east Ireland and the southern islands of western Scotland also needs to be addressed. Even though site lists were gathered for Neolithic and Bronze Age sites within the 100 km horizon of all Group1 sites, these secondary sites only came from Scotland. Those from north -eastern Ireland were not included. Nor was the relationship considered between any possible free-standing stone monuments in Arran, Bute, Cunningham, Carrick, and Galloway with the other monuments. Arran and Bute were only considered as secondary areas having Group2 monuments. This was an artefact of using the 1984 Ruggles data. By adding these new data to the database, a clearer picture of the connections between these two regions would be possible, and one that investigates possible similarities and differences between these two cosmological orders would be extremely advantageous in terms of understanding the content of belief systems and the way they are applied in differing areas or the way they may translate as they travel. Naturally, this is true of any systems that may be divided by water or distance. Taking a closer look at Lewis/Harris, and Uist, as well as the inner Hebrides, and comparing them more closely with the mainland areas, would therefore be very wise.

Methodological summary

We have in this project's original methodological plan the basis for the "ultimate design" of an investigation, as explored in the introduction. Here the connection between visualization and statistical analyses is made. This connection is not only made in the final section of the analyses, where viewsheds are constructed, but from the very start of the project where the importance of vision itself is tested using other methodologies and paradigms. In this way, the reasons for using viewsheds themselves are tested for soundness and applicability. So, too, is the complimentary creation of maps of site location, ground elevation and viewsheds, once the statistical analyses are done. Other visual aids include histograms and polar plots for understanding observed orientation patterns of sites.

The results of the viewshed analyses, when complete, will provide this investigation with additional information into the cosmological systems and monuments of western Scotland.

Regional work, its wider implications and significance

Connections

> ...this society might have been wide-spread throughout Britain, instead of being split into various tribes in scattered localities[10]

The traditions of monument building are recognised as extensive, with similar forms used in differing geographical locations. Added to this is the recognition that distributions of monuments can, in some cases be grouped into regional traditions,[11] such as the short stone rows of western Scotland and south-west Ireland and recumbent stone circles of northeast Scotland. In addition, monument *development* is sometimes seen as being broadly similar in several parts of the British Isles, but with different rates of change *within regional traditions,* such as those suggested by the construction dates of large enclosures.[12] This in itself suggests that the ideas or beliefs associated with monument building in one area may well be shared by those in another. Naturally, this is not a hard and fast rule, and the copying of architectural designs for their own sake cannot be completely ruled out. However, if the same type of monuments in differing locations share variables relating to location or archaeological small finds or the relative position to other monuments, it might well be said of them that an underlying philosophy or cosmological belief system is also shared by the same peoples that constructed them. The degree of similarity would surely vary according to the distance of time and place, and the number of variables that they shared.

From our earlier look at the stone rows in Counties Cork and Kerry south-west Ireland, for instance, it was noted, that despite the fact these stone rows could be up to one stone longer in length, the orientation preference about NE/SW and the avoidance of the cardinal points, especially west, was prevalent. There is some consistency too with a statistically significant interest in an alignment with the major lunar standstills, emphasising a possible fundamental connection between these two regions cosmological systems and those regions of Mull, Coll, Tiree, North Argyll, and Argyll in western Scotland. It seems too, that there is some dating evidence that supports chronological overlap between the stone rows of southwestern Ireland and western Scotland. The calibrated dates for the Irish sites are c.1600 BC (Maughanasilly, Co. Cork) and 1675 BC (Dromatouk, Co. Cork), and for the Scottish, 1640±70 BC and 1580±100 BC (Ballychroy, Argyll).[13] Interestingly, there is a very late date for stone row erection at Ardnacross in Mull, c.1140 - 820 BC, exhibiting a continued interest in this style of monumental form and possibly an ongoing connection to the cosmological belief system that prevailed 500 years previously in

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[10]Mackie, in Douglas Heggie, 1981, *Megalithic Science,* 230.
[11]Bradley, R., 1984, "Regional Systems in Neolithic Britian", *Neolithic Studies: a review of some current research*, BAR **133**, 6.
[12] Bradley, R., 1984, Ibid, 9.
[13]Ruggles and Burl, 1995, *Op cit.* 522-523.

the area. Close regional work, then, can be seen as a reliable way of investigating and comparing the wider social and philosophical connections that may have made their way across the landscape and time.

Regional Significance

This regionally based study has uncovered shared belief systems in action that continued to some extent across time and across monumental style to some extent. Importantly it has also shown us that there are distinctive differences within areas of this geographical region, such as the orientation interest about or near the equinox for Islay and Jura, a trend not accredited elsewhere. Too there is the very significant orientation interest in Uist, but as to what that directional focus is, has not been discovered at this stage of the investigation. All that can be said is that specific orientations of the monuments do not appear to be astronomically linked. A possible future investigation would be to apply a similar form of study as applied to Coll and Tiree, to see if anything else in the landscape, like horizon features, in directions other than those suggested by the alignments, might be of possible interest. Uists, like Coll and Tiree, have relatively demure landscapes so any particularly high peaks will be evident. Also, of course, Uist is a set of islands, and water may be shown to be of importance in their cosmological system, whether through its seaways or the masses of inland water, such as in North Uist. This in itself maybe of import, then, for

> throughout the region the marine element is clearly pronounced, and both sea-bourne contact and marine resources appear central to the megalithic tradition of westerly chambered tomb construction.[14]

This then, brings us back to the results of Fisher *et al* in Mull, where sea water was a central element in the viewsheds of Bronze Age Cairns, almost two millennia later. Here "the sea across the Island of Ulva, the sea to the north, and the view down and across the sound of Mull" are deemed as "important" to the builders of these monuments.[15] Their interpretations fit, to some extent, the work of Hunt. Namely that "these show the direction of the primary water bound trading in this part of the Western Isles", as well as a possible social explanation of the sea being the focus for people of this area,[16] being as it is, important to the very existence and maintenance of groups living here. There is then, a necessary cultural link to the sea itself.

Archaeoastronomical implications

Interestingly, we have almost come full circle back to Archie Thom's idea, that a single monument might act as a calendrical indicator for several specific **times** of the year, for reasons of symbolism or otherwise, and might indicate a number of relevant astronomical phenomena that occur along the horizon. Here we have a similar idea developing, but rather than *the site* indicating all evenly divided calendrical dates, it

[14] Hunt, D. 1987, *Op cit.* 117.
[15] Fisher *et al.*, 1997, *Op cit.* 591.

seems that such a site, such as a stone row, could *represent* by ***its presence*** just a few of these dates whilst actually *indicating only one* (or possibly two for a 2-way alignment). It may be the job of a specific *landscape* feature, such as a range of hills or water, to indicate the other dates expressed as astronomical phenomena. The coincidence of the landscape feature and the astronomical phenomena can only be seen from a particular angle and position, giving extra weight to the theory of *purposely* located monuments. It might be these very landscape features, then, that not only provide the indication necessary to mark out the phenomena visually, but to indicate their cosmological status amongst the builders of the monuments as being culturally significant.

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[16]Fisher *et al.*, 1997, *Ibid.* 591.

Appendices

Appendix AA – Full description of all Ruggles sites.

Appendix AB – List of all alignment details.

Appendix 1 – 2D Horizon Profiles.

Appendix 2 – Results of Phase3a – testing for patterns of Group2 sites within the horizon of each Group1 site.

Appendix 3 – Maps showing Group 1 and Group 2 sites.

Appendix 4 – Viewsheds Of Mull, Nth Argyll, Coll and Tiree

Appendix 5 – Results of Phase3b - viewshed analysis results.

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations'	Other points	Ruggles' Site Type	Place
Kirkibost	Airigh Mhaoldonuich, Callanish XV	11775	93459	LH7	Recumbent menhir	All	3.5 m long; appears to have stood at its SW end.	8	Gt Bernera
Bernera Bridge	Cleiter, Callanish VIII	11642	93424	LH8	Semi-circle of Slabs	Unclear	2 large standing slabs, heights 2 m and 3 m high, a small erect slab less than 1 m tall, and a large prostrate stone 2.5 m long (Ruggles, 1984, 77). Stones arranged in a semi-circle on cliff edge (Ponting and Ponting 1993, 33).	3	Gt Bernera
Beinn Bheaq	Airigh na Beinne Bige, Callanish XI	12223	93568	LH10	A standing menhir, fallen menhir	All	Standing menhir: 1.5 tall by 0.5 by 0.5; fallen menhir: 1.9 m tall by 0.8 by 0.2 m. 50 metres apart Other fragments unlikely to be pre-historic. Possible ruined cairns approximately east of area.	4	Lewis
Callanish		12130	93300	LH16	Stone circle with cairn, stone rows, stone avenue	Centre of circle used for alignment with centre of other monuments in sight; 5 radial lines of menhirs, 2 of these form an avenue	A 13 m circle of menhirs 3-4 m in height; surrounding a cairn and great menhir; radial lines begin outside of the circle	1	Lewis
Cnoc Fillibhir Bheag	Callanish III	12250	93269	LH18	Stone circle with inner standing stones	Centre of circle used for alignment with centre of other monuments in sight	A 17m ring of menhirs up to 2.5 m in height; surrounding 4 menhirs are positioned at approximately 153°, 215°, 223°, 334° from due north (from Ponting and Ponting, 1993, fig ***)	7	Lewis
Cnoc Ceann alGharaidh	Callanish II	12220	93260	LH19	Stone circle with cairn	Centre of circle used for alignment with centre of other monuments in sight	A 21 m circle of 5 menhirs 2-3 m in height; surrounding a cairn	7	Lewis
Ceann Hulavig	Callanish IV	12297	93042	LH21	Stone circle with cairn	Centre of circle used for alignment with centre of other monuments in sight	A 13 m circle of 5 menhirs 2-3.5 m in height; surrounding a cairn	7	Lewis
Cut a' Chleit	Callanish VI	12465	93034	LH22	Standing stones	All	2 standing stones, 1.5 and 0.8 m tall, 10 m apart. Various interpretations of site's previous incarnation.	3	Lewis
Airigh nam Bidearan	Callanish V	12342	92989	LH24	Standing slabs	3 slabs all within 10m and in a line	5 small upright slabs, 0.5 m in height 3 of which appear to make a row (or part thereof); In most plans only 5 stones exist but in Sharbau (1860) shows more. Ponting & Ponting indicate 12 of the 'more prominent' stones they discovered (1993).	3	Lewis
Dursainean NE		15281	93340	LH29	Standing stone	All	An erect block 1.7 m high by 1.8 m by 0.5 m. Maybe standing stone	6	Lewis
Horgabost	Clach Mhic Leoid	10408	89727	LH36	Standing slab	All	Slab 3.5m high by 1.4 m by 0.4 m. Some small stones nearby which maybe remains of cairn (OSAR:NG09.nw, 4)	5	Harris
Scarista	Borvemore	10202	89392	LH37	Standing slab, 2 prostrate stones	Standing slab and 1 prostrate stone	Slab 2 m high by 0.8 m by 0.3 m. One of the two stones is 2.5 long which appears it could have stood in alignment with the slab (according to Ruggles 1984). RCAHMS (1928, 136) reports other features.	3	Harris
Borve	Cladh Maolrithe	9122	88068	UI6	Standing slab	All	Slab 2.5m high by 2 m by 0.3 m. Stands adjacent to a rectangular enclosure	5	Berneray
Newtonferry	Crois Mhic Jamain	8937	87818	UI9	Standing slab, standing stone	All	Slab (0.9-1.5 m) high above present ground level by 0.5 m by 0.2 m. Stone 0.5m high by 0.4 m by 0.3 m. Both set into the summits of a mound 6 m apart.	3	N Uist

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[1]	Other points	Ruggles' Site Type	Place
Maari		8645	87292	UI15	Standing stone	All	2.2 m in height (leaning approx. 45o) by 0.5 by 0.4	7	N Uist
Blashaval	Na Fir Bhreige	8875	87176	UI19	Stone row	All	All 0.5 m above present peat level (Ruggles 1984), spaced 15 m and 35 m apart in almost a straight line.	1	N Uist
South Clettraval		7501	87118	UI22	Standing stone, Hebridean Chambered Cairn, Clyde long cairn	Standing stone	Stone is 1.5 m by 1.0 m by 0.8 m; 220 m to the SE is Tigh Cloiche (W) the chambered cairn and 150 m in the NW is the long cairn.	7	N Uist
Toroghas	Fir Bhreige	7700	87029	UI23	Standing stones	All	Two stones about 1.0 m above present peat level, approximately 35 m apart.	3	N Uist
Beinn alCharra		7863	86909	UI26	Standing stone	All	A menhir 2.8 m by 1.5 m by 0.6 m. Triangular in cross-section, leans to south.	7	N Uist
Unival	Leacach an Tigh Clioche	8003	86685	UI28	Standing slab, Hebridean chambered tomb	All	2.5 m by 1.5 m by 0.3 m, SW of the Hebridean chambered tomb.	5	N Uist
Claddach Kyles	Clach Mhor a Che	7700	86619	UI31	Standing slab, ruined chambered tomb	All	2.5 m by 1.5 m by 0.3 m, 20 m north of the ruined chambered tomb (Dun na Carnaich).	5	N Uist
Ben Langass	Pobull Fhinn, Sornach Coir Fhinn	8427	86502	UI33	Stone circle	Centre of circle used for alignment with centre of other monuments in sight; 5 radial lines of menhirs	A 35 m ring of menhirs up to 2.1 m in height	7	N Uist
Cringraval W		8116	86447	UI35	Stone ring	Assumed centre of ring used for alignment with centre of other monuments in sight	What appears to be a 35 m ring made up of prostrate menhirs (up to 1.5 m) and a standing slab (0.75 m high) (Ruggles, 1984). Ruined chambered cairn to ENE (Barnatt, 1989, 241).	8	N Uist
Loch a'Phobuill	Sornach a'Phobuill (locals), Sornach Coir' Fhinn (O.S)	8289	86302	UI37	Stone ring	Centre of circle used for alignment with centre of other monuments in sight	A c.40 m ring of stones up to 1 metre in height. Craonaval chambered tomb can be seen on the skyline to the east(Thom and Burl, 313) 14 stones remaining out of a possible 28-50 (Barnatt, 1989, 241).	7	N Uist
Carinish		8321	86021	UI40	Stone circle	Centre of circle used for alignment with centre of other monuments in sight	Ruined by road construction	7	N Uist
Stiaraval	Rueval (looks to be Ruval stone as called by RCAHMS)	8142	85315	UI46	Standing slab	All	Stated by Ruggles to be possibly a standing stone (1984, 106). 1.2 m high by 1.2 m by 0.3 m.	6	Benbecula
Stoneybridge	Crios Chnoca Breaca	7340	83366	UI48	Standing menhir	All	Rectangular menhir, 2.5 m by 0.5 m by 0.3 m, on the summit of a one metre mound. Incorrectly described as a chambered cairn on OS 1"map, (sheet No. 23), but recognised by NMRs (RCAHMS) as a standing stone. The stone is as described; the grass-covered	7	S Uist

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[1]	Other points	Ruggles' Site Type	Place
							mound of stones on which it stands is probably packing material.		
Beinn a'Charra	An Carra, Loch an Athain, (RCAHMS)	7703	83211	UI49	Standing slab	All	5m high by 1.5 m by 0.6 m. Its width is regular for more than half its height, after which it tapers towards the top (RCHAMS, NUMLINK 9978). Not to be confused in name with standing stone: An Carra, Beinn A'Charra, Nth Uist (786408, 869090)	5	S Uist
Ru Arclvule	Kildonan	7273	82860	UI50	Standing stone, fallen stones	Standing stone	By the time of Ruggles visit in 1979 the standing stone was below the sand and found by a wooden marker placed next to it (1984, 106). Originally this site was described as follows by RCHAMS, 1928: A standing stone, 7ft high, 2ft 11 ins wide at the base and 12 ins thick, is situated on the machair 400 yards west of the northern end of Loch Kildonan in South Uist. About 100 yards to the NNW, there are two prostrate stones, one lying across the other. One is 6 1/2ft long and the other 6ft. Some 18ft ENE is a third prostrate stone 7 1/2ft long (RCAHMS database NUMLINK:9843).	7	S Uist
Borve		6527	80144	UI57	Standing stone, fallen slab	All	Two 'standing stones', 8 metres apart. The standing one is 1.5 m above ground level by 0.6 m by 0.2 m (NE). Only the tip of the fallen one (SW) shows.	3	Barra
Brevig	DRUIM A' CHARRA, BREVIG, BARRA (RCAHMS, NUMLINK:21388)	6890	79903	UI59	Standing menhirs	All	Two menhirs standing 5 metres apart, one triangular in cross section and 2.5 m high, the other prostrate and broken in two (Ruggles, 1984, 120). Situated on the summit of the ridge Druim a Charra "on the spur running down eastwards from Heaval to Breivig, about 250 yards north of Cruchain", about 250 ft above sea level, RCAHMS 1928. There is a further earthfast piece of stone, 0.8m long, nearby which may also have been part of the broken stone-visited by OS (N K B) 16 May 1965 (see RCAHMS, NUMLINK: 21388).	4	Barra
Branault	Cladh Chatain	15268	76950	NA1	Standing stones	All	A standing stone (SSE), 2.2 m high by 0.9 m, and one standing stone (NNW) 0.4 m. The latter may be a stump. Ruggles, 1984, 121 and Burl, 1993, 265.	4	Ardnamur chan
Camas nan Geall	Ardnamurchan	15605	76184	NA3	Standing slab	All	A standing slab, 2.3 m high by 0.9 m by 0.2 m.	5	Ardnamur chan
Acha	Loch nan Cinneachan	11860	75674	CT1	Standing slab	All	A standing slab, 1.0 m high by 0.9 m by 0.3 m. Approximately 20 metres from two grassy-covered mounds which may (RCHAMS 1980: no 50) or may not (OSAR: NM15NE, 17) be cairns (Ruggles, 1984,121).	5	Coll
Totronald	Na Sgialaichean	11665	75594	CT2	Standing slabs	All	Two 'standing stones', approximately 14 metres apart. 1.4 m by 1.2 m by 0.3 m (NNE), 1.5 m by 1.3 by 0.4 m (SSW) Ruggles 1984, 121). Stones aligned WNW and ESE RCAHMS 1980, 71, no.121.	3	Coll
Breachacha		11519	75329	CT3	Standing slab	All	This stone is aligned approximately N and S and stands to a height of 1.5m. About 1.1m in breadth and 0.6m in thickness, it rises with straightish sides to a rounded top and now leans to the W at an angle of 12 degrees. A large recumbent slab, a little to the W, is not considered to have been a standing stone. RCAHMS 1980, 66,	6	Coll

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[1]	Other points	Ruggles' Site Type	Place
							94.		
Hough	Moss	9588	74518	CT7	Stone rings, cairn	Central point between the two circles used as observing position for alignment with centre of other monuments in sight (see Ruggles, 1984, 140)	The NE stone circle(95900 745200) is oval on plan, measuring 33m from NE to SW by at least 40m transversely. It consists of ten stones, only one of which is intact and upright; five others have been reduced to stumps, while the rest have fallen. In the centre of the circle there is a low, roughly circular, mound measuring about 14m in diameter(NL94NE23).Ninety metres to the SW a stone circle(95800 74505) is situated on gently sloping ground probably measured about 40 m in diameter. It now consists of eleven fallen stones together with the stump of another, but originally there were probably additional stones in the gaps. A turf bank and the remains of a turf-walled building flank the circle on the N (NL94NE20). 95830 745050 Cairn, Hough: Situated on a slight knoll about 6m SE of the SW stone circle there is a roughly circular turf-covered cairn measuring 7m in diameter and 0.7m high. RCAHMS 1980, 68, 107, PLATE 9A and RCAHMS database NUMLINKS: 21429, 21432, 21433.	7	Tiree
Barrapoll		9468	74300	CT8	Standing stone	All	A standing stone of trapezoidal construction, 1.5 m high, by 0.8 m by 0.6 m.	7	Tiree
Balinoe	Balemartin	9731	74258	CT9	Standing stone	All	A large standing stone 3.5 m high by 2.0 m by 1.0 m. Irregular in shape.	5	Tiree
Glengorm		14347	75715	ML1	Standing stones	All	Three standing stones occupy a commanding position on the end of a ridge of broken ground. All the stones upright, but two had been re-erected by 1942 (information from V G Childe MS notebook, held in NMRS)(RCAHMS, 1980, 68, no 105). Ruggles 1984, 123, states that these probably aren't in their original position (later work showed this to be so Martlew and Ruggles, 1987). Stone A measures 2.05m in height, 0.78m in breadth, and 0.36m in thickness at the base; it leans slightly to the SE, with flattish sides and a rounded top. Stone B, aligned N and S, is 2.1m high and 2.3m in girth at the base. Stone C measures 2.15m in height by 0.5m at the base; the sides are flat and the top sloping. (Ruggles, 1984, says, C = slab, 0.3m thick)	7	Mull
Quinish	Mingary	14134	75524	ML2	Standing stone, fallen stones	All	The site is a level terrace. At the present time only a single stone, measuring 2.7m high and 0.7m by 0.6m at the base, is still erect; aligned N and S and leaning slightly it rises with straightish sides to a rounded top. Some 3m to the NE is a fallen stone 3.6m long, 1.1m broad and 0.5m thick. Both these stones are of basalt. At a distance of 8m to the NE there is the stump of another stone, while various fragments of stones, doubtless from the same group, are visible round about (see RCHAMS, 1980, no.111, 70). Ruggles concluded that 4 appear probably to have formed an alignment some 10 m long. The 5th stone may have been part of	2	Mull

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[i]	Other points	Ruggles' Site Type	Place
							this originally (Ruggles, 1984,123).[ii]		
Balliscate		14996	75413	ML4	Stone row	All	Three standing stones of basalt have been erected in an approximately straight line running N and S, 5 m. long. The northern stone (A on plan of RCAHMS, 1980, fig. 39), 1.8m in height (Ruggles, 1984, 123) and 0.65m by 0.6m at the base, is a straight-sided monolith with a flattish top. Stone B is prone, half-embedded in peat, and is 2.8m long by 0.7m broad and 0.4m thick. The tallest of the stones (C) stands within a ruined turf-and-stone bank and measures 2.5m in height (Ruggles, 1984) 1.1m in breadth and 0.8m in thickness; it is an irregular slab, which expands above the base before narrowing to a pointed top (RCAHMS, 1980, no 90).	2	Mull
Cillchriosd		13773	75348	ML7	Standing stone	All	This stone is situated in an arable field 230m E of Cillchriosd. Measuring 2.6m in height and 1.4m by 0.65m at the base, it is aligned NW and SE; the sides are vertical and the top level (RCAHMS, 1980, no.98, 66 plate 7F).	5	Mull
MaolMor	Dervaig 1, Kilmore/Dervaig A	14355	75311	ML9	Stone row	All	A 10 m long four stone alignment. Three stones stand, and are about 2 m tall, the fourth is prone and 2.4 m long.	1	Mull
DervaigN	Cnoc Fada, Dervaig 2, Kilmore/Dervaig B	14390	75202	ML10	Stone row	Stone row	A linear setting of five basalt blocks extending over a distance of 18.3m. Only two of the stones remain upright, but it seems likely that originally they all stood in a line running approximately NNW and SSE. Stone A on plan is prostrate and measures 2.4m in length, 0.75m in breadth, and 0.5m in thickness. Stone B stands to a height of 2.5m, measures 0.8m by 0.55m at the base, and rises with straight sides to a sloping top. Stone C, which is also prone, measures 2.4m in length by 0.9 in breadth and at least 0.5m in thickness. Stone D is a rectangular block standing to a height of 2.4m and measuring 1m by 0.7 at the base. Stone E lies partly embedded in the turf and measures 2.4m in length, 1.75m in breadth, and 0.6m in thickness (RCAHMS, 1980, no. 101(2), fig 42). Some 250 m to the SE and also in alignment is an erect stone 1.0 m tall by 0.6 m by 0.6 m, which is possibly a standing stone (Ruggles, 1984, 127).	2	Mull
Dervaig S	Glac Mhor , Dervaig 3, Kilmore/Dervaig C	14385	75163	ML11	Stone row, Standing stone	Stone row	There are four stones, three of which (A - C on plan, RCAHMS, 1980, fig 43) are approximately on a line running NNW and SSE. Stone A, which is now embedded in a dyke, is 1.07m high and 0.8m by 0.5m at ground-level. Although it was originally taller, stone B is now 1.3m high and measures 0.65m in breadth by 0.6m in thickness. Stone C is a shattered block 1m high and 1.15m by 1.1m at the base. The fourth stone (D) forms one side of a gate-way through the wall and is probably not in its original position; it measures 1.1m in height and 0.8m by 0.8m at the foot. (RCAHMS,	1	Mutt

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[i]	Other points	Ruggles' Site Type	Place
							1980, no. 101(3)). The row is 15 m long (Ruggles, 1984, 127)		
Ardnacross		15422	74915	ML12	Stone rows, cairns	Stone rows	Two groups of standing stones appear to have been aligned NNE and SSW but only one stone is still upright. The SE group comprises one prostrate slab (at least 2.3 m long and 1.1 m broad), a standing stone of rectangular section, now leaning slightly to the S (2.4 m high and 1.05 m by 0.5 m at the base), and a third slab, half of which is covered by turf, but which is at least 1.9 m long and 1.25 m broad. The three stones of the NW group have all fallen and are partly obscured by turf, but the largest is at least 2.8 m long, 1.4 m broad and 0.35 m thick (RCAHMS, 1980, no.10, 50). The rows are about 10 metres in length (Ruggles, 1984, 127). In immediate association with 3 cairns.	2	Mull
Killichronan	Torr nam Fiann	15401	74193	ML15	Standing stone	All	2.4 high by 0.5 by 0.3 m, leaning 70° from the vertical	7	Mull
Gruline				ML16	Standing stones	All	Two Standing stones, approximately 250 m apart. One is a slab 2.3 m tall by 0.8 m by 0.3 m. oriented across the line joining the two stones. The other is a lozenged-shape stone, 2.4 m high.	3	Mull
		15437	73977	ML16	Stone b				
		15456	73960	ML16	Stone a				
Cragaig		14028	73901	ML18	Standing stones	All	Two Standing stones, approximately 4 m apart. One is a 1.3 m tall by 1.2 m by 0.6 m. The other is 1.6 m high by 0.6 by 0.6 m. Both stones appear to have been broken off.	3	Ulva
Uluvaltl	Barr Leathan	15469	73004	ML25	Arc of earthfast stones	none	This was described as the remains of a chambered cairn by Betts (1959), probing failed to reveal and cairn material within the arc, the rectangular building is of recent date, RCAHMS database, NUMLINK 22255, see also RCAHMS, 1980, no. 121(3).	3	Mull
		15468	72996	ML25	Stone row	Unclear	There was formerly a linear setting of four standing stones, but only one boulder (B on plan, RCAHMS, no.2, 72, fig 49) remains upright; it measures 0.7m by 0.5m at the base. The measurements of the three fallen stones are as follows: 'A': 1.95m long, 0.7m broad and 0.35m thick. 'C: 2.35m long, 0.45m broad and 0.4m thick (RCAHMS, database, NUMLINK 22255). (note: there seems to be no measurements for Stone D). NOte too, "a basalt slab lying about 55m of 'A' may also be a fallen standing stone; it is 2.1m long, 0.5m broad and 0.35m thick. (This is doubtless the stone at NM 5463 3002, dismissed by OS field investigator as a natural erratic)"(NUMLINK 22255). Ruggles alignments (ML25abc/cba) seems to be made up of all 4, with RCAHMS' stone D = Ruggles ML25and the RCHAMS' stone A = ML25c. This is indicated by the orientation of the alignments abc=NW and cba=SE.	3	Mull
		15465	72993	ML25	Standing stone	none	A standing stone 1.9m high by 0.9m wide by 0.6m thick. RCAHMS, 1980, call this a standing stone, but the notes from the	3	Mull

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[1]	Other points	Ruggles' Site Type	Place
							RCAHMS database NUMLINK 22255, state the following: this does not seem to be prehistoric and is possibly one of a series of marker stones along the pilgrim route from Green Point to Iona. Now leaning a little to the S, it has slightly tapering sides and an uneven top.		
Rossal	Breac Achadh	15434	72820	ML27	Standing stone	All	It is 2.1m in height and now leans slightly to the NE. Its long axis is NW and SE and its lozenge-shaped base measures 0.8m by 0.45m (RCAHMS, NUMLINK, 22222).The OS say that it does not appear to be a prehistoric standing stone and is possibly one of a series of marker stones along the pilgrim route from Green Point to Iona (1972).	8	Mull
Taoslin	Bunessan	13973	72239	ML30	Standing stone	All	A rectangular standing stone 2.1 high by 0.8 m by 0.4 m. Possibly one of a series of marker stones along the pilgrim route from Green Point to Iona.	6	Mull
Uisken	Druim Fan; Am Fan	13916	71961	ML31	Standing slab	All	2.2 m high by 1.3 m by 0.3 m.	5	Mull
Ardalanish		13784	71888	ML33	Standing stone	All	1.9 m high by 0.9 m by 0.3 m.	3	Mull
Benderloch N		19062	73865	LN7	Standing slab	All	1.5 high by 1.0 m by 0.2 m	7	Benderloc h
Glenamacrie		19250	72854	LN18	Standing stone	All	1.5 high by 0.7 m by 0.6 m	4	Lorn
Duachy		18014	72052	LN22	Stone row	All	Three are disposed in a straight line running NNW-SSE while the fourth, now reduced to a stump, stands apart 38 metres to the east. The most northerly of the line of three measures 0.7 by 0.5 metres at the base and 2.8 metres in height, rising with a slight taper to an almost level top. The centre stone, 2.7 and 2.1 metres from the north and south stones respectively, is now leaning towards the east at an angle of about 30. It measures 0.6 by 0.5m in girth and 1.9m in length, though a portion appears to have broken off the tip. The south stone measures 0.7 by 0.6 metres at ground level and 2.2 metres in height. Like the north stone, its sides are smooth and its top is level.	1	Lorn
Sluggan		18405 18403	70762 70757	AR2 AR2	Standing slab, fallen slab	Southern Slab(?)	A slab within a field clearance, which may be the remains of the northernmost of two standing stones marked on the 1:10000 Ordnance survey map. The southernmost is a slab 2.5 m high by 0.8 m by 0.2 m standing in situ. (See RCAHMS, 1980, no.77, 74 for fuller description of general area).	5	Argyll
Barbreck		18315	70641	AR3	Standing slabs	2 aligned slabs A and B	Standing slabs which comprises: a pair of large monoliths (A, B), about 23m to the E, a large upright (C), with earthfast stones (D, E) to E and S of it respectively, and a massive block (F), now leaning towards the E, to the W of it; a displaced boulder (G), a little to the SW of stone C (Campbell and Sandeman 1964). Letters in brackets refer to plan in RCAHMS (1988, no.200). Ruggles dimensions are: A = 1.3 m high by 1.0 m by 0.2 m; B = 2.5 m high by 2.0 m 0.2 m.	1	Argyll

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[1]	Other points	Ruggles' Site Type	Place
							A and B are approximately 3 m apart and are aligned.		
Salachary		18405	70403	AR6	Standing menhirs, fallen menhir	All	Three menhirs appear to have formed an alignment about 4 m long (Ruggles, 1984, 148). The north stone 2.75 m tall by 0.7 m by 0.72 m. The middle stone is similar, but leans NE. The southern stone, fallen, 3.4 m by 0.65 m.	2	Argyll
Torran		18788	70488	AR7	Standing menhir	All	3 m high by 0.9 m by 0.5 m. Photograph: RCAHMS, 1988, no 230,143.	7	Argyll
Ford		18668	70333	AR8	Standing menhir	All	3 m high by 0.5 m by 0.4 m. OSNB states there were two stones here (no. 56, 14) according to RCAHMS, 1988, 215,134). Photograph: RCAHMS, 1988, no 215,134.	7	Argyll
GlennanN	Creagantairbh	18595	70157	AR9	Standing slab (stump)	All	2 m high by 1.4 m by 0.6 stump, broken top lying adjacent was about 4 m. Two cairns , some 150 E and 300 m to the ENE	5	Argyll
Glennan S		18573	70113	AR10	Standing slab	All	2 m high by 1.0 m by 0.4 m. 2 cairns some 100 metres to WNW. (Campbell & Sandeman, 1961, 106, 106a)	5	Argyll
Kilmartin		18263	69783	AR13	Stone circles	None	The major feature of the site is a ring of standing stones now partly masked by cairn material called the south-west circle; the stones are laid out not in a true circle, but in an ovoid measuring about 13m by 12m. There were originally twenty-two uprights, standing to heights of 1.6m above ground level, but the stones of the SE quadrant have now been removed (Ruggles, 1988, no. 228, 139. There is a circle some 20 m NE of this circle, and named the North-east circle.		
		18279	69774		Standing stone	None	Known as Thoms S_6 see 18282 69760 and 18283 69761.		
		18282	69760		Standing slabs	All	300 m to the SE of the circles are 5 standing stones (see Burl, 1993, 195, fig. 42). At 18282 69760 are a pair of aligned slabs, both about 2.5 m high by 0.8 m by 0.3 m.	1	Argyll
		18283	69761		Standing slabs	All	300 m to the SE of the circles are 5 standing stones (see Burl, 1993, 195, fig. 42). At 18283 69761 are a pair of aligned slabs, both about 2.5 m high by 1.1 m by 0.3 m. In between these pairs of slabs is a centrally placed slab (Thom's S_1). It is flanked by 4 small erect slabs. Between the SW pair and this central slab are a similar group of stones. Ruggles 1984, 148, states there are 3 slabs however, Burl's figure shows 4 stones.	1	Argyll
		18252	69761		Standing stone (stump)	None			
Duncracaig	Ballymeanoch	18337	69641	AR15	Aligned slabs	All	A 15 m long alignment of 4 slabs up to 4 m high. About 40 m SW of this lies an adjacent and roughly parallel alignment of 2 slabs 4 m apart (see RCAHMS, 1988, no. 199 (fig), 128). Roughly WNW of this lies a further stone (G). There are two cairns nearby, one 29 m NE of the stones. Ballymeanoch henge is 130 m to the SSW *(RCAHMS, Ibid.)*	1	Argyll
Rowanfield	Poltalloch	18205	69585	AR16	Standing slab	All	2.5 m high by 1.0 m 0.4 m.	5	Argyll
Duntroon		18034	69561	AR17	Standing stone	All	A small rectangular standing stone, 1.3 m high by 0.5 m 0.3 m.	7	Argyll

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[i]	Other points	Ruggles' Site Type	Place
CrinanMoss		18083	69410	AR18	Standing stones	All	A setting of four tiny erect stones, largets being about 1 m tall. About 20 m in the SE is another erect stone 0.5 m tall, and a second listed by Campbell and Sandeman (1961:no. 173) appears to be recumbant.	8	Argyll
Dunadd		18386	69362	AR27	Fallen slab, standing stone	All	A fallen slab 4.2 m long (erect in 1872 and faced ENE). Some 250 m NW is a standing stone 1.4 m tall by 0.5 m by 0.3 m (18397, 69343). According the RCAHMS this is aligned NNWW to SSE 1988, no. 212).	4	Argyll
Dunamuck I		18471	69290	AR28	Stone row	All	A 5 m long alignment. End stones are some 2.5 m tall and the central one, which has fallen, is some 350 m.	2	Argyll
DunamuckII		18484	69248	AR29	Aligned slabs	All	3.5 m tall and 2.5 m tall, approximately 6 m apart.	1	Argyll
DunamuckIII		18484	69233	AR30	Prostrate slabs	All	Two prostrate slabs some 4m and 3 m long.	5	Argyll
Oakfield	Auchendarroch	18572	68852	AR32	Standing slab	All	1.7 m tall by 1.1 m by 0.3 m. Two smaller erect stones nearby are probably not prehistoric.	5	Argyll
Kilmory		18674	68652	AR33	Standing slab	All	2.5 m tall by 1.0 m by 0.2 m.	5	Argyll
Tarbert		16089	68221	JU1	Standing slabs	All	(16089 68221)This standing stone stands 1.8m high by 0.5m broad and 0.2m thick. It is orientated N-S. Both faces have an incised cross 1.0m long and 0.5m across, extending to the limits of the stone. RCAHMS, 1984, state that "it (no. 328) may be of prehistoric origin, like that at 16062 68231(no 122). Ruggles seems to agree but states that RCAHMS, 1984, suggests that "it is probably not prehistoric" (1984, 163). no. 122 stands 2.5 m high by 0.6 m by 0.3 m, 290 m WNW.	4	Jura
KnockromeN		15505	67192	JU2	Standing stone	All	A small erect boulder 0.9 m by about 0.8 m by 0.6 m.	8	Jura
Ardfernal		15601	67171	JU3	Standing stone	All	A squat standing stone 1.2 m high and triangular is cross-section with sides 1.3 m, 1.3 m and 0.6 m.	7	Jura
Knockrome		15484 15503	67144 67148	JU4(b) JU4(a)	Standing slab Standing slab	All All	A slab 1.4 m high by 0.7 m by 0.2 m. 200 m westish of 15503 67148 A slab 1.5 m high by 1.2 m by 0.3 m.	3	Jura
Leargybreck		15387	67128	JU5	Standing stone	All	Irregular block of stone 1.3 m tall by 1.5 m by 0.9 m	8	Jura
Sannaig		15184	66480	JU7	Stone row, other possible remains	Stone row	The stone row is made up of a standing stone, slab stump and prostrate stone. The standing stone is 2.2 m tall by 0.5 m by 0.4 m. This stands between the stump (1.2 m by 0.7 m) and the prostrate some 2.5 m long. The alignment seems to be about 5 m long.[iii]	2	Jura
Camas an Staca		14641	66477	JU9	Standing slab	All	3.5 m tall by 1.4 m by 0.3 m.	5	Jura
Beinn alChuirn		13475	66978	IS3	Standing slab	All	1.2 m high by 0.9 m 0.3 m	5	Islay
Finlaggan		13927	66856	IS4	Standing stone	All	2.0 m tall 1.3 m by 0.6 m	5	Islay
Scanistle		14108	66724	IS5	Erect boulder	All	Irregular boulder 1.2 m tall by 1.0 m by 0.4 m	5	Islay
Beinn Cham		13492	66793	IS6	Standing stone	All	1.1 m tall by 0.9 m by 0.5 m. Adjacent to it lies a loose block of stone about 1.0 m tall by 0.6 m by 0.3 m which might have originally stood, but has presumably been moved to its present position.	7	Islay

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[i]	Other points	Ruggles' Site Type	Place
Ballachlavin	Baile Tharbach	13636	66762	IS7	Standing stone	All	Irregularly-shaped stone 1.2 m tall by 1.2 m by 0.5 m	5	Islay
Knocklearoch		13989	66483	IS11	Standing stones	All	1.7 and 1.5 m tall but both leaning to the south, some 2.5 m apart.	3	Islay
Mullach Dubh		14037	66410	IS12	Standing stone	All	1.2 m tall by 0.8 m by 0.5 m	7	Islay
Uisgeantsuidhe		12938	66335	IS19	Standing slab	All	2.5 m tall by 1.4 m by 0.5 m	5	Islay
Gartacharra		12527	66137	IS23	Standing stone	All	2.7 m tall by 0.8 m by 0.4 m	5	Islay
Cultoon		11956	65697	IS28	Stone ring	All	40 m diameter stone ring excavated by Mackie (1981, 116-228). Stone circle was unfinished.	7	Islay
Kelsay		11901	65561	IS31	Erect boulder	All	1.2 m tall by 1.0 m by 0.8 m, but stands on the edge of an old lazy-bed enclosure, and may have been set in its present position as a result of the clearance for the adjacent cultivation.	8	Islay
Claggain Bay		14618	65372	IS35	Boulder	All	Massive boulder may have been erected in antiquity or may be an glacial erractic. 1.7 m tall by 1.8 m by 0.8 m	6	Islay
Trudernish		14630	65290	IS36	Standing stone	All	1.8 m tall by 0.6 m by 0.35 m	7	Islay
Cnoc Rhaonastil	Clachan Ceann Ile	14369	64832	IS38	Stone ring	All	Four poster type: stones no higher than 0.5 m	7	Islay
Lagavulin N		13954	64621	IS39	Standing slab, fallen slab	All	3.5 m tall by 1.2 m by 0.4 m. Two metres away lies one end , presumably the base, of a fallen slab some 3.5 m long and up to 1.0 m wide. The two slabs apparently formed an alignemnt when this stood.	3	Islay
Laphroaig	Archnancarranan	13895	64607	IS41	Stone row	All	A 6 m long 3 stone alignment. Two end stones stand between 2.5 and 3 m tall. The central one is fallen and about 3 m long.	2	Islay
Carse	Loch Stornaway	17425 17414	66163 66166	KT2 KT2	Stone pair Standing stone	All All	Two standing stones, a pair (A, B) (Campbell and Sandeman 1964, from (RCAHMS, NUMLINK 38987). Stone A, which is aligned N and S, is 2.4m high, 1.25m broad and 0.4m thick; it rises to a rounded top on the N and to an angled top on the S. Stone B situated 2.5m to the S and is also aligned N and S, measures 0.65m by 0.45m at the base and 3.2m in height; it rises with straight sides for 1.5m, then its sides converge, finally outcurving to a point on the N. The surface has distinct veins of white quartz (RCAHMS, NUMLINK 38987). The third stone (C) 110m to the WNW of A and B above has been surrounded by field-gathered boulders, but some of the original packing-stones of the stone-hole are also visible. Aligned approximately NE and SW, and now leaning a little to the NE, it is lozenge-shaped at the base, measuring 1.85m in girth and rising to a height of 2.3m (RCAHMS, NUMLINK 38987).	3	Knapdale
Ardpatrick	Achadh-Chaorun	17573	66014	KT3	Standing slab	All	A slab 2.2 m tall by 1.4 m by 0.3 m.	5	Knapdale
Avinagillan		18391	66746	KT4	Standing slab	All	A slab 1.9 m tall by 1.0 m by 0.2 m.	5	Knapdale
Escart		18464	66678	KT5	Stone row	All	An alignment of 5 standing stones. Stone A measures 1.0m x 0.3m at base and rises to a height of 2.85m. Stone B is 3.3m high, and 1.3m x 0.4m at base. Stone C, which has been tilted NE by a tree, is 2.44m high and 0.7 x 0.4m at base. Stone D measures 1.0m x 0.5m	1	Kintyre

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[1]	Other points	Ruggles' Site Type	Place
							at its foot, and 2.06m high. Only part of stone E survives, the top having been broken off when the tree beside C was felled. It now measures 0.8m x 0.25m at base by 1.12m high; originally, it would have been at least 1.5m. There is some evidence to suggest that there were formerly more stones in the group (RCAHMS, NUMLINK 39335). Both Ruggles (1984, 183) and RCAHMS (1971, 143; see also fig. 34) refer to the alignment as sinous, Ruggles adds that the alignment is 15 m in length.		
Dunskeig		17624	65704	KT8	Stone pair	All	Not recorded on any ancient monument lists at time of Ruggles' work. The site consists of 2 stones some 6 metres apart, the SE of which is 1.o m high and leans about 30° or so from the vertical, while the NW stone is rounded, 0.4m high, and earthfast. May not be prehistoric.	5	Kintyre
Balloychroy 1		17309	65241	KT10	Stone row, cist	Unclear	A 5 metre long 3 stone alignment (Ruggles, 1984, 185). The most southerly of these three standing stones is situated 36.5m NE of cist NR75SW 2 (173050 652390). It measures 0.6m x 0.6m at the base, and rises fairly evenly to a height of 2.4m, before tapering to a pointed top, 3.4m high. The centre stone, 3.0m high, is 3.0m to the E. It is a thin slab, 1.5m x 0.3m at base, oriented NW-SE. The third stone, 2.0m NE appears to have been broken off at the top. It measures 0.9m x 0.3m at base, and rises with a slight taper to a height of 2.0m. (RCAHMS, 1971, 47, no. 57 and Database, NUMLINK 38960). "It is hardly fortuitous that this cist is in close proximity to standing stone NR75SW 3, and on the same alignment; possibly all four monuments are contmporary" (RCAHMS, 1971, 47, no. 57). Ruggles further notes that a sketch by Lhuyd (c.1700), copied by Stukeley (1776) also shows a further cairn and standing stone in this same alignment.	1	Kintyre
Tarbert		16555	65227	KT12	Standing slab	All	2.3 m high by 0.9 m by 0.4 m, leaning 20^{0} to the E.	5	Gigha
South Muasdale	Carragh Muasdale	16792	63914	KT19	Standing slab, stump	All	3.0 m high by 1.1 m by 0.5 m, oriented roughly N-S. Posssible stump of second stone 12 m WSW of the slab, 1.1 m high by 1.8 m by 0.6 m, now built into field wall.	4	Kintyre
Beinn an Tuirc	Arnicle; Crois Mhic-Aoida	17349	63506	KT23	Standing slab	All	A slab 1.8 m tall by 1.4 m by 0.3 m.	5	Kintyre
Clochkeil		16577	62445	KT27	Standing stone	All	0.8 m tall by 0.8 m by 0.5 m. "Listed by Ordnance Survey as a possible standing stone ... may ...have been set up as a cattle rub" Ruggles, 1984, 189.	8	Kintyre
Skeroblingarry	Skeroblin Cruach	17094	62701	KT28	Standing slab	All	1.5 m tall by 0.9 m by 0.2 m	5	Kintyre
High Park		16950	62572	KT29	Standing stone	All	3.0 m tall by 1.3 m by 0.6 m	5	Kintyre
Craigs		16902	62362	KT31	Standing slab	All	2.5 m tall by 1.7 m by 0.3 m	5	Kintyre
Glencraigs S		16932	62354	KT32	Standing slab	All	2.0 m tall by 1.1 m by 0.4 m	5	Kintyre
Glenlussa Lodge		17614	62541	KT35	Standing slab	All	2.3 m tall by 1.2 m by 0.5 m	5	Kintyre

Appendix AA – Full description of all Ruggles' sites

Name	Alternative name	Easting	Northing	Ruggles Site no.	Main descriptor of site	Remains used by Ruggles for his initial orientation considerations[i]	Other points	Ruggles' Site Type	Place
Campbeltown		17238	62123	KT36	Standing slab	All	4.0 m tall by 1.4 m by 0.5 m	5	Kintyre
Stewarton		16995	61982	KT37	Fallen stone	All	1.8 m tall	8	Kintyre
Mingary		16533	61940	KT39	Standing stone and cairn	Standing stone	1.4 m tall by 1.0 m by 0.4 m. This stands at the foot of the remains of the outer two banks surrounding a cairn.	5	Kintyre
Knockstapple		17026	61240	KT41	Standing slab	All	3.2 m tall by 1.8 m by 0.6 m	5	Kintyre
Southend		16976	60787	KT44	Standing slab	All	2.7 m tall by 1.5 m by 0.3 m	5	Kintyre

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[i] These remains are of those mentioned in the previous column marked *Main descriptors of sites*

ii Te RCAHMS database explains that The RCAHMS, quoting ONB, erroneously state that the ONB records that in the mid-19th century there was a group of five standing stones, three of which were erect and the other two recumbent (see RCHAMS, 1980, no 111). The ONB actually state: 'These three large stones, one standing, the other two lying, are the remains of a Druidical Circle (OS Name Book 1878), no.69,14).' The RCAHMS final statement from the 1972 visit is that there is no evidence that they formed a circle (RCAHMS, Database NUMLINK, 22081).

[iii] I suspect that as the stone row is so compact that the individual stones are not labelled as they are in JU4. Thus the orientation description from Table 11.2 (JU7NNE, JU7SSW) which reflects the rows actual alignment must refer to the whole row and not to the alignment of the single standing stone, which itself is oriented SSE/NNW according the RCAHMS (1984, no 116, 71). This 'abc' style of labelling, however, might indicate if row has all stones standing. For instance, IS11 has indeed ab and is only 2.5 apart!

Align No.	Alignment	Align No.	NGR	Site	Align No.	Lat	Lat	Lat	Alt	Inter/Intra	Matching Pair	Correct Pairs	Location	AAR1	IAR1	IAR2	AAR2	DECS	DECS	DECS	DECS	Intra Class	Inter Class	Horizon
1	LH7-LH8	1	11775 93459	LH7	1	58	12	35	0.6	2	3	1	LH	250.6	251.6	251.8	253	-10.1	-9.5	-9.3	-8.9		B1	8
2	LH8baSW	2	11642 93424	LH8	2	58	12	21	1.2	1	0	0	LH	217.4	219.4	223.6	226	-23.8	-23	-21.6	-20.6	3a		15
3	LH8-LH7	3	11642 93424	LH8	3	58	12	21	1	2	1	1	LH	70.6	71.6	71.8	72.8	9.5	10	10.1	10.7		B1	1.5
4	LH10abSE	4	12223 93568	LH10	4	58	13	21	0	1	0	0	LH	145	146	147	148	-27.1	-27	-26.5	-26.1	4a		10
5	LH10-LH16	5	12223 93568	LH10	5	58	13	21	0.5	2	18	1	LH	193.8	194.8	195	196	-30.9	-31	-30.5	-29.7		A2	29
6	LH10-LH18	6	12223 93568	LH10	6	58	13	21	0.7	2	24	2	LH	169.4	170.4	170.6	172	-31.2	-31	-31	-30.6		A1	27
7	LH10-LH19	7	12223 93568	LH10	7	58	13	21	0.3	2	29	1	LH	175	176	176.2	177	-32.1	-32	-31.9	-31.9		A1	16
8	LH10-LH21	8	12223 93568	LH10	8	58	13	21	0.7	2	32	1	LH	166.6	167.6	167.8	169	-30.8	-31	-30.7	-30.6		A3	27
9	LH10-LH22	9	12223 93568	LH10	9	58	13	21	0.2	2	39	1	LH	150.4	151.4	151.6	153	-28.2	-28	-27.9	-27.6		A3	23
10	LH10-LH24	10	12223 93568	LH10	10	58	13	21	0.7	2	46	1	LH	163.2	164.2	164.4	165	-30.4	-30	-30.2	-30		B3	22
11	LH16avW-N	11	12130 93300	LH16	11	58	11	52	1.4	1	0	0	LH	5.6	7.6	10.8	12.8	32.1	32.1	32.5	32.5	1a		3.5
12	LH16avE-N	12	12130 93300	LH16	12	58	11	52	1.6	1	0	0	LH	7.8	9.8	12	14	31.9	32.3	32.5	32.5	1a		3.5
13	LH16sR-N	13	12130 93300	LH16	13	58	11	52	1	1	0	0	LH	358.4	359.4	0	1	32.3	32.4	32.4	32.5	1a		3
14	LH16Wr-W	14	12130 93300	LH16	14	58	11	52	0.7	2	15	1	LH	264	266	268.6	271	-2.8	-1.8	-0.6	0.3	1a		1.5
15	LH16Wr-E	15	12130 93300	LH16	15	58	11	52	0.6	1	14	1	LH	84	86	88.6	90.6	-0.1	0.9	2.3	3.3	1a		6
16	LH16Er-W	16	12130 93300	LH16	16	58	11	52	1.1	2	17	1	LH	257.8	258.8	259.6	261	-5.5	-5.2	-5	-4.6	1a		1.5
17	LH16Er-E	17	12130 93300	LH16	17	58	11	52	0.9	1	16	1	LH	77.8	78.8	79.6	80.6	5.3	5.9	6.3	6.7	1a		9
18	LH16-LH10	18	12130 93300	LH16	18	58	11	52	1.4	2	5	1	LH	13.8	14.8	15	16	31.3	31.6	31.7	31.9		A2	3
19	LH16-LH18	19	12130 93300	LH16	19	58	11	52	1	2	25	2	LH	98.8	99.8	100.8	102	-5.6	-5.1	-4.6	-4.1		A1	11
20	LH16-LH19	20	12130 93300	LH16	20	58	11	52	0.4	2	0	0	LH	107.8	109.6	111.4	113	-12.1	-11	-10.2	-9.3		A1	2.5
21	LH16-LH21	21	12130 93300	LH16	21	58	11	52	0.5	2	33	2	LH	142	143	143.2	144	-25.3	-25	-24.8	-24.6		A3	6.5
22	LH16-LH22	22	12130 93300	LH16	22	58	11	52	0.2	2	40	2	LH	123	124	124.6	126	-18.1	-18	-17.4	-16.9		A1	4.5
23	LH16-LH24	23	12130 93300	LH16	23	58	11	52	0.4	2	47	2	LH	140.6	141.6	141.8	143	-24.8	-25	-24.5	-24		B3	6.5
24	LH18-LH10	24	12250 93269	LH18	24	58	11	45	1.5	2	6	2	LH	349.2	350.2	350.4	351	32.3	32.5	32.5	32.5		A2	3.5
25	LH18-LH16	25	12250 93269	LH18	25	58	11	45	0.3	2	19	2	LH	276.8	278.8	283.6	286	3.6	4.5	7	8		A1	12
26	LH18-LH19	26	12250 93269	LH18	26	58	11	45	1.3	2	0	0	LH	245.2	247.2	251	253	-11.9	-11	-9.1	-8		A1	6
27	LH18-LH21	27	12250 93269	LH18	27	58	11	45	1	2	34	2	LH	163.2	164.2	164.4	165	-30.1	-30	-29.9	-29.8		A1	20
28	LH18-LH24	28	12250 93269	LH18	28	58	11	45	0.4	2	48	1	LH	156.8	157.8	158.2	159	-29.3	-29	-29.2	-28.9		B2	21
29	LH19-LH10	29	12220 93260	LH19	29	58	11	41	1.5	2	7	1	LH	355	356	356.2	357	32.8	32.9	33	33		A3	3.5
30	LH19-LH22	30	12220 93260	LH19	30	58	11	41	0.4	2	41	1	LH	127.8	128.8	129.2	130	-20	-20	-19.4	-18.9		A1	8.5
31	LH19-LH24	31	12220 93260	LH19	31	58	11	41	0.8	2	49	1	LH	151	152	152.2	153	-27.8	-27	-27.4	-27.2		B2	20
32	LH21-LH10	32	12297 93042	LH21	32	58	10	33	0.8	2	8	1	LH	346.6	347.6	347.8	349	31.1	31.3	31.4	31.5		A3	5.5
33	LH21-LH16	33	12297 93042	LH21	33	58	10	33	0.1	2	21	2	LH	321.2	322.6	324	325	23.8	24.4	24.8	25.4		A1	4
34	LH21-LH18	34	12297 93042	LH21	34	58	10	33	0.6	2	27	2	LH	343	344	344.4	345	30.2	30.5	30.6	30.8		A2	3.5
35	LH21-LH22	35	12297 93042	LH21	35	58	10	33	1	2	42	2	LH	87.6	88.6	89	90	0.3	1	1.3	2		A2	7.5
36	LH21-LH24	36	12297 93042	LH21	36	58	10	33	1.3	2	50	2	LH	133.8	134.8	135.4	136	-21.7	-21	-21	-20.5		B2	3
37	LH22baNNE	37	12465 93034	LH22	37	58	10	34	0.8	1	38	1	LH	31	33	35.8	37.8	25.3	25.8	26.5	27.3	3a		9.5
38	LH22abSSW	38	12465 93034	LH22	38	58	10	34	1.2	2	37	1	LH	211	213	215.8	218	-26.6	-26	-24.5	-24	3a		14
39	LH22-LH10	39	12465 93034	LH22	39	58	10	34	0.6	2	9	1	LH	330.4	331.4	331.6	333	27.2	27.7	27.8	28.2		A3	6
40	LH22-LH16	40	12465 93034	LH22	40	58	10	34	0.1	2	22	2	LH	303.2	304.2	304.8	306	16.4	16.8	17.1	17.5		A1	8
41	LH22-LH19	41	12465 93034	LH22	41	58	10	34	0	2	30	1	LH	307.8	308.8	309.2	310	18.4	18.8	19	19.5		A3	14
42	LH22-LH21	42	12465 93034	LH22	42	58	10	34	1.2	2	35	2	LH	267	268	268.4	269	-1	-0.3	-0.2	0.1		A2	17
43	LH22-LH24	43	12465 93034	LH22	43	58	10	34	0.8	2	51	2	LH	241.8	243.8	247.8	250	-13.9	-13	-11	-10		B2	25
44	H24bcdNNW	44	12342 92989	LH24	44	58	10	17	0.4	2	45	1	LH	340	342	344	346	29.5	29.9	30.5	30.9	3c		8
45	LH24dcbSSE	45	12342 92989	LH24	45	58	10	17	1.4	1	44	1	LH	160	162	164	166	-29.6	-30	-29.2	-29.2	3c		17
46	LH24-LH10	46	12342 92989	LH24	46	58	10	17	0.6	2	10	1	LH	343.2	344.2	344.4	345	30.3	30.5	30.6	30.8		B3	8
47	LH24-LH16	47	12342 92989	LH24	47	58	10	17	-0.1	2	23	2	LH	320.4	321.4	322	323	23.3	23.7	24	24.4		B3	4.5
48	LH24-LH18	48	12342 92989	LH24	48	58	10	17	0.3	2	28	1	LH	336.8	337.8	338.2	339	28.8	29	29.2	29.3		B2	7.5
49	LH24-LH19	49	12342 92989	LH24	49	58	10	17	0.1	2	31	1	LH	331	332	332.2	332	26.9	27.3	27.4	27.7		B2	14
50	LH24-LH21	50	12342 92989	LH24	50	58	10	17	0	2	36	2	LH	312	313.4	314.8	316	20.3	20.8	21.4	21.8		B2	8
51	LH24-LH22	51	12342 92989	LH24	51	58	10	17	0.7	2	43	2	LH	64.2	65.2	65.6	66.6	12.3	12.8	13	13.4		B2	14
52	LH29-NW	52	15281 93340	LH29	52	58	13	13	0.2	1	0	0	LH	303.6	305.4	307.2	309	16.5	17.4	18.3	19	6		13
53	LH36-WNW	53	10408 89727	LH36	53	57	52	1	0.1	1	0	0	LH	282.4	284.4	289	291	5.8	6.9	9.6	10.9	5a		5
54	LH36-LH37	54	10408 89727	LH36	54	57	52	1	1.3	2	56	1	LH	206.6	207.6	207.8	209	-27.4	-27	-27.2	-26.8		A3	8
55	LH37baWNW	55	10202 89392	LH37	55	57	50	8	-0.1	1	0	0	LH	300	302	305	307	14.8	15.8	17	18.1	3b		0
56	LH37-LH36	56	10202 89392	LH37	56	57	50	8	1.6	2	54	1	LH	26.6	27.6	27.8	28.8	29.3	29.3	29.4	29.5		A3	18
57	UI6WNW	57	09122 88068	UI6	57	57	42	35	-0.2	2	58	1	UI	292	293	294	295	10.8	11.3	11.8	12.3	5a		0

Align No.	Alignment	Align No.	NGR	Site	Align No.	Lat	Lat	Lat	Alt	Inter/Intra	Matching Pair	Correct Pairs	Location	AAR1	IAR1	IAR2	AAR2	DECS	DECS	DECS	DECS	Intra Class	Inter Class	Horizon
58	UI6-ESE	58	09122 88068	UI6	58	57	42	35	0.1	1	57	1	UI	112	113	114	115	-13.3	-13	-12.3	-11.8	5a		64
59	UI6-UI9	59	09122 88068	UI6	59	57	42	35	0.3	2	61	1	UI	211	212	212.4	213	-27.2	-27	-26.8	-26.4		A3	14
60	UI9baSW	60	08937 87818	UI9	60	57	41	10	0.5	1	0	0	UI	227	229	232.4	234	-21.1	-21	-18.9	-18	3a		8
61	UI9-UI6	61	08937 87818	UI9	61	57	41	10	1	2	59	1	UI	31	32	32.4	33.4	26.9	27.4	27.6	27.9		A3	6
62	UI15-UI19	62	08645 87292	UI15	62	58	31	53	-0.2	2	64	2	UI	110.8	111.8	112.8	114	-13.1	-13	-12.2	-11.9		A2	3
63	I19abcWNW	63	08875 87176	UI19	63	57	37	42	2.3	1	0	0	UI	287	288.8	290.6	292	10.7	11.7	12.5	12.9	1a		2.5
64	UI19-UI15	64	08875 87176	UI19	64	57	37	42	1.7	2	62	2	UI	291	292	292.6	294	12.6	12.9	13	13.3		A2	2.5
65	UI22-UI26	65	07501 87118	UI22	65	57	36	45	0.1	2	71	1	UI	114.2	115.2	115.6	117	-14.3	-14	-13.5	-13.2		A3	83
66	UI22-UI31	66	7501 87118	UI22	66	57	36	45	-0.2	2	82	1	UI	152.4	153.4	153.8	155	-30	-30	-29.3	-28.8		A3	20
67	UI23baE	67	07700 87029	UI23	67	57	36	25	1.2	1	0	0	UI	92	94	96	98	-4.1	-2.8	-1.2	0.3	3a		4
68	UI23-UI26	68	07700 87029	UI23	68	57	36	25	0.3	2	72	1	UI	119.4	120.4	120.8	122	-16.3	-16	-15.9	-15.5		A1	80
69	UI23-UI28	69	07700 87029	UI23	69	57	36	25	0	2	76	1	UI	132.6	133.6	133.8	135	-22.7	-22	-22.2	-21.5		A1	4.5
70	UI23-UI31	70	07700 87029	UI23	70	57	36	25	-0.1	2	83	1	UI	174.2	175.2	175.4	176	-33	-33	-32.9	-32.7		A3	55
71	UI26-UI22	71	07863 86909	UI26	71	57	35	50	0.2	2	65	1	UI	294.2	295.2	295.6	297	12.2	12.9	13.1	13.7		A1	4
72	UI26-UI23	72	07863 86909	UI26	72	57	35	50	0.8	2	68	1	UI	299.4	300.4	300.8	302	15.5	16	16.2	16.7		A2	4.5
73	UI26-UI28	73	07863 86909	UI26	73	57	35	50	0.2	2	77	1	UI	142.8	143.8	144.2	145	-26.6	-26	-25.9	-25.3		A1	2.5
74	UI26-UI31	74	07863 86909	UI26	74	57	35	50	-0.6	2	84	1	UI	203.8	204.8	205.2	206	-30.6	-30	-30.3	-30		A3	0
75	UI28SSE	75	08003 86685	UI28	75	57	34	42	-0.2	1	0	0	UI	153.2	154.8	156.4	158	-30.6	-30	-29.8	-29.4	5a		22
76	UI28-UI23	76	08003 86685	UI28	76	57	34	42	0.3	2	69	1	UI	312.6	313.6	313.8	315	21	21.5	21.6	22		A3	5
77	UI28-UI26	77	08003 86685	UI28	77	57	34	42	0.3	2	73	1	UI	322.8	323.8	324.2	325	25.1	25.4	25.6	25.9		A2	4.5
78	UI28-UI33	78	08003 86685	UI28	78	57	34	42	0.2	2	86	1	UI	107.8	108.8	109.2	110	-11.1	-11	-10.2	-9.9		A3	12
79	UI28-UI35	79	08003 86685	UI28	79	57	34	42	-0.3	2	88	1	UI	149	150	150.2	151	-28.9	-29	-28.5	-28.3		B2	15
80	UI28-UI37	80	08003 86685	UI28	80	57	34	42	-0.2	2	92	1	UI	137.4	138.4	138.8	140	-25.1	-25	-24.3	-24		A3	6.5
81	UI31ESE	81	07700 86619	UI31	81	57	34	13	0.8	1	0	0	UI	106	107.4	108.8	110	-9.9	-9.3	-9.1	-8.6	5a		15
82	UI31-UI22	82	07700 86619	UI31	82	57	34	13	1.2	2	66	1	UI	332.4	333.4	333.8	335	29.1	29.4	29.6	29.9		A3	6
83	UI31-UI23	83	07700 86619	UI31	83	57	34	13	1.2	2	70	1	UI	354.2	355.2	355.4	356	33	33.1	33.1	33.1		A3	4.5
84	UI31-UI26	84	07700 86619	UI31	84	57	34	13	1.3	2	74	1	UI	23.8	24.8	25.2	26.2	29.8	29.9	30	30.2		A3	5.5
85	UI31-UI35	85	07700 86619	UI31	85	57	34	13	0.8	2	89	1	UI	106.6	107.6	108.2	109	-9.3	-9.2	-9.1	-8.9		B3	14
86	UI33-UI28	86	08427 86502	UI33	86	57	33	53	0.7	2	78	1	UI	287.8	288.8	289.2	290	9.4	10.1	10.4	11.2		A1	4.5
87	UI33-UI37	87	08427 86502	UI33	87	57	33	53	-0.1	2	93	1	UI	209	210	211	212	-28.7	-28	-28	-27.7		A2	3.5
88	UI35-UI28	88	08116 86447	UI35	88	57	33	28	1	2	79	1	UI	329	330	330.2	331	27.8	28.2	28.3	28.8		B1	2.5
89	UI35-UI31	89	08116 86447	UI35	89	57	33	28	-0.2	2	85	1	UI	286.6	287.6	288.2	289	8.1	8.7	9	9.5		B3	8
90	UI35-UI37	90	08116 86447	UI35	90	57	33	28	0.2	2	94	1	UI	124	125	126	127	-19.3	-19	-18.2	-17.7		B2	2.5
91	UI35-UI40	91	08116 86447	UI35	91	57	33	28	-0.1	2	95	1	UI	148.2	149.2	149.6	151	-28.6	-28	-28.1	-27.8		B3	5
92	UI37-UI28	92	08289 86302	UI37	92	57	32	46	0.7	2	80	1	UI	317.4	318.4	318.8	320	23.3	23.9	24.1	24.7		A1	5
93	UI37-UI33	93	08289 86302	UI37	93	57	32	46	1.4	2	87	1	UI	29	30	31	32	27.9	28.3	28.7	29		A2	3
94	UI37-UI35	94	08289 86302	UI37	94	57	32	46	0.4	2	90	1	UI	304	305	306	307	17.4	17.8	18.3	18.7		B2	2.5
95	UI40-UI35	95	08321 86021	UI40	95	57	31	16	0.4	2	91	1	UI	328.2	329.2	329.6	331	27	27.4	27.5	28		B3	7.5
96	UI46NW	96	08142 85315	UI46	96	57	27	24	-0.1	2	97	1	UI	302.6	303.6	304.4	305	16.1	16.6	17	17.4	6		84
97	UI46SE	97	08142 85315	UI46	97	57	27	24	-0.1	1	96	1	UI	122.6	123.6	124.4	125	-18.8	-18	-18	-17.5	6		120
98	UI48-UI49	98	07340 83366	UI48	98	57	16	36	3	2	102	1	UI	107.4	108.4	108.6	110	-8.3	-7.5	-7.4	-6.4		A3	9
99	UI48-UI50	99	07340 83366	UI48	99	57	16	36	-0.1	2	104	1	UI	181.8	182.8	183.2	184	-33.4	-33	-33.3	-33.3		A3	0
100	UI49NE	100	07703 83211	UI49	100	57	15	55	3.3	1	101	1	UI	50.2	51.2	52	53	22.1	22.4	22.4	22.6	5a		5.5
101	UI49SW	101	07703 83211	UI49	101	57	15	55	-0.2	2	100	1	UI	230.2	231.2	232	233	-21	-21	-20.2	-19.7	5a		0
102	UI49-UI48	102	07703 83211	UI49	102	57	15	55	-0.2	2	98	1	UI	287.4	288.4	288.6	290	8.6	9.1	9.2	9.7		A1	0
103	UI49-UI50	103	07703 83211	UI49	103	57	15	55	-0.2	2	105	1	UI	225	226	226.4	227	-23.2	-23	-22.6	-22.2		A3	0
104	UI50-UI48	104	07273 82860	UI50	104	57	13	51	0.1	2	99	1	UI	1.8	2.8	3.2	4.2	32.2	32.3	32.3	32.3		A1	5
105	UI50-UI49	105	07273 82860	UI50	105	57	13	51	0.6	2	103	1	UI	45	46	46.4	47.4	21.8	22.1	22.2	22.6		A3	5.5
106	UI57abNE	106	06527 80144	UI57	106	56	58	58	4.4	1	107	1	UI	31.4	33.4	37.6	39.6	29.8	30	30.9	31.4	3b		1.5
107	UI57baSW	107	06527 80144	UI57	107	56	58	58	5.7	2	106	1	UI	211.4	213.4	217.6	220	-21.7	-21	-21	-20.8	3b		3
108	UI59abWNW	108	06890 79903	UI59	108	56	57	49	10	2	109	1	UI	296.6	298.6	300.6	303	23.3	23.8	24.7	25.9	4a		1
109	UI59baESE	109	06890 79903	UI59	109	56	57	49	-0.1	1	108	1	UI	116.6	118.6	120.6	123	-17.6	-17	-15.8	-14.8	4a		110
110	NA1abNNW	110	15268 76950	NA1	110	56	45	5	0.7	2	111	1	NA	326.4	328	329.6	331	27.2	28.1	28.4	29.1	4a		29
111	NA1baSSE	111	15268 76950	NA1	111	56	45	5	2.7	1	110	1	NA	146.4	148	149.6	151	-26.4	-26	-25.5	-25.4	4a		2.5
112	NA3NNW	112	15605 76184	NA3	112	56	41	5	6.4	1	0	0	NA	326	328	331	333	33.1	33.3	34.9	35.5	5a		1
113	CT1S	113	11860 75674	CT1	113	56	37	4	-0.2	1	0	0	CT	176	178	181.4	183	-34.1	-34	-34.1	-34	5a		0
114	CT2abNNE	114	11665 75594	CT2	114	56	36	34	0.4	1	115	1	CT	16.6	17.8	19	20.2	30.7	31.2	31.5	31.8	3a		3

Align No.	Alignment	Align No.	NGR	Site	Align No.	Lat	Lat	Lat	Alt	Inter/Intra	Matching Pair	Correct Pairs	Location	AAR1	IAR1	IAR2	AAR2	DECS	DECS	DECS	DECS	Intra Class	Inter Class	Horizon
115	CT2baSSW	115	11665 75594	CT2	115	56	36	34	0.2	1	114	1	CT	196.6	197.8	199	200	-32.6	-33	-32.1	-31.9	3a		4
116	CT2-CT3	116	11665 75594	CT2	116	56	36	34	-0.2	2	117	1	CT	203.6	204.6	205	206	-31	-31	-30.6	-30.4		A2	0
117	CT3-CT2	117	11519 75329	CT3	117	56	35	6	0.4	2	116	1	CT	23.6	24.6	25	26	29.7	29.8	29.9	30.2		A1	5.5
118	CT7-CT8	118	09584 74511	CT7	118	56	29	59	0.8	2	119	1	CT	202.8	204	205.2	206	-30.3	-30	-29.7	-29.6		A2	5
119	CT8-CT7	119	09468 74300	CT8	119	56	28	48	0.2	2	118	1	CT	22.8	24	25.2	26.4	29.3	29.7	29.9	30.3		A2	2.5
120	CT9SSW	120	09731 74258	CT9	120	56	28	40	1.4	1	0	0	CT	193.4	195	196.6	198	-31.1	-31	-31	-30.6	5a		2.5
121	ML1-ML9	121	14347 75715	ML1	121	56	38	9	1.4	2	0	0	ML	174	175	175.6	177	-32.3	-32	-32.1	-32		A3	12
122	ML2SSE	122	14134 75524	ML2	122	56	37	3	1.8	1	0	0	ML	164	166	170	172	-31.5	-32	-30.8	-30.5	2c		8
123	ML2-ML7	123	1492 7550	ML3	123	56	37	3	1	2	127	1	ML	239	240	241	242	-15.9	-15	-14.9	-14.5		A3	6
124	ML4abcN	124	14996 75413	ML4	124	56	36	44	0.7	1	125	1	ML	2.6	4.4	6.2	8	32.8	33.2	34	34.2	2a		14
125	ML4cbaS	125	14996 75413	ML4	125	56	36	44	5	1	124	1	ML	182.6	184.4	186.2	188	-28.7	-29	-28.4	-28.2	2a		1.5
126	ML7SE	126	13773 75348	ML7	126	56	35	59	2.1	1	0	0	ML	131.6	132.6	133.4	134	-20.9	-21	-20.2	-19.6	5a		5.5
127	ML7-ML2	127	13773 75348	ML7	127	56	35	59	0.8	2	123	1	ML	59	60	61	62	15.5	15.8	16.3	16.8		A3	9.5
128	ML9NNW	128	14355 75311	ML9	128	56	35	59	0.2	1	0	0	ML	339	341	343	345	30.2	30.9	31.6	31.9	1a		47
129	ML9-ML1	129	14355 75311	ML9	129	56	35	59	-0.4	2	0	0	ML	354	355	355.6	357	31.7	32	32.3	32.3		A3	11
130	ML10NNW	130	14390 75202	ML10	130	56	35	24	0.2	1	0	0	ML	326.6	328.6	331	333	26.7	27.5	28.7	29.8	2a		3
131	ML11abcSSE	131	14385 75163	ML11	131	56	35	12	1.8	1	0	0	ML	155	156.4	157.8	159	-29.3	-29	-28.9	-28.5	1a		8
132	ML12abcNNE	132	15422 74915	ML12	132	56	34	12	1.9	1	133	1	ML	24	26	29.2	31.2	29.8	30.4	31.3	31.8	2c		8
133	ML12cbaSSW	133	15422 74915	ML12	133	56	34	12	7	1	132	1	ML	204	206	209.2	211	-23.5	-23	-22.2	-21.6	2c		2
134	ML15-ML16	134	15401 74193	ML15	134	56	30	18	5.5	2	137	1	ML	161.4	163.4	167.2	169	-27	-27	-27	-26.8		A2	5
135	ML16baNW	135	15456 73960	ML16	135	56	29	6	3.3	1	136	1	ML	306.6	307.6	308.6	310	21.8	22.3	23	23.7	3a		4
136	ML16abSE	136	15437 73977	ML16	136	56	29	6	2.5	1	135	1	ML	126.6	127.6	128.6	130	-18.6	-18	-17.7	-17.1	3a		11
137	ML16-ML15	137	15446 7396	ML16	137	56	29	6	1.6	2	134	1	ML	341.4	343.4	347.2	349	34.9	35.3	35.9	36.2		A2	3
138	ML18baENE	138	14028 73901	ML18	138	56	28	18	6.4	1	0	0	ML	65.6	66.6	67.6	68.6	16.9	17.5	18	18.8	3a		9
139	ML25abcNW	139	15469 73004	ML25	139	56	23	55	15	1	140	1	ML	315.2	316.4	317.6	319	35.8	36.8	37.3	37.4	3c		3.5
140	ML25cbaSE	140	15468 72996	ML25	140	56	23	55	6.4	1	139	1	ML	135.2	136.4	137.6	139	-18.9	-19	-17.9	-17.4	3c		4
141	ML25-ML27	141	15465 72993	ML25	141	56	23	55	3.1	2	142	1	ML	190.6	191.6	192	193	-30.1	-30	-29.9	-29.8		B2	4.5
142	ML27-ML25	142	15434 72820	ML27	142	56	22	56	5.4	2	141	1	ML	10.6	11.6	12	13	37.7	38	38.1	38.3		B2	3
143	ML30NNW	143	13973 72239	ML30	143	56	19	20	0	1	0	0	ML	326.2	328.2	330.4	332	27	27.5	28.5	28.9	6		2.5
144	ML31NE	144	13916 71961	ML31	144	56	17	50	2.4	1	145	1	ML	48.4	49.4	50.2	51.2	22.2	22.6	23	23.4	5a		6.5
145	ML31SW	145	13916 71961	ML31	145	56	17	50	0.3	1	144	1	ML	228.4	229.4	230.2	231	-22	-21	-21	-20.7	5a		4
146	ML33baWNW	146	13784 71888	ML33	146	56	17	23	2.8	1	0	0	ML	280	281.6	283.2	285	7.9	8.8	9.5	10.8	3b		1
147	LN7	147	19062 73865	LN7	147	56	29	35	1.4	1	0	0	LN	358	0	4	6	33.7	34	34.5	34.8	5a		25
148	LN18abW	148	19250 72854	LN18	148	56	24	26	2.1	1	0	0	LN	268.2	270.2	273.8	276	1.2	1.7	3.1	4	4a		1
149	N22abcNNW	149	18014 72052	LN22	149	56	19	34	6.5	1	150	1	LN	324.6	326.6	329	331	31.7	32.7	34.8	35.9	1a		1
150	LN22cbaSSE	150	18014 72052	LN22	150	56	19	34	7.2	1	149	1	LN	144.6	146.6	149	151	-21.8	-22	-21.2	-20.6	1a		1
151	AR2N	151	18405 70762	AR2	151	56	12	43	7.3	1	0	0	AR	354	356	358	0	40.7	40.9	41	41.6	5a		2.5
152	AR2-AR3	152	180404 7075	AR2	152	56	12	43	0	2	155	1	AR	212.6	213.6	214.4	215	-28.7	-28	-27.7	-27.3		A2	66
153	AR3abN	153	18315 70641	AR3	153	56	12	3	5.2	1	154	1	AR	5.2	6.4	7.6	8.8	38.4	38.5	38.6	38.7	1b		3.5
154	AR3baS	154	18315 70641	AR3	154	56	12	3	3.2	1	153	1	AR	185.2	186.4	187.6	189	-30.7	-31	-30.5	-30.5	1b		4
155	AR3-AR2	155	18315 70641	AR3	155	56	12	3	2.9	2	152	1	AR	32.6	33.6	34.4	35.4	29.1	29.7	30.1	30.6		A2	5
156	AR6abcN	156	18405 70403	AR6	156	56	10	48	1.7	1	0	0	AR	355	356.4	357.8	359	34.9	35	35.3	35.3	2a		2
157	AR7-AR8	157	18788 70488	AR7	157	56	11	21	2.3	2	158	1	AR	213.6	214.6	215	216	-25.8	-25	-25.2	-24.8		A2	3
158	AR8-AR7	158	18668 70333	AR8	158	56	10	29	2.3	2	157	1	AR	33.6	34.6	35	36	28.5	29	29.2	29.5		A2	3
159	AR9ENE	159	18595 70157	AR9	159	56	9	31	2.6	2	0	0	AR	67.8	69.4	71	72.6	11.6	12.4	13.9	14.6	5a		9
160	AR9-AR10	160	18595 70157	AR9	160	56	9	31	7	2	161	1	AR	202.4	203.4	203.8	205	-24.1	-24	-24	-23.9		A2	1.5
161	AR10-AR9	161	18573 70113	AR10	161	56	9	17	2	2	160	1	AR	22.4	23.4	23.8	24.8	32.2	32.3	32.4	32.5		A2	1
162	R13S2-S3-S6	162	18282 69760	AR13	162	56	7	20	5.7	1	0	0	AR	328	329	329.8	331	33.5	33.8	34.2	34.3	1a		2.5
163	R13S5-S1-S2	163	18282 69760	AR13	163	56	7	20	2.1	1	164	1	AR	19.2	20.2	21.2	22.2	32.8	33	33.2	33.2	1a		6.5
164	R13S2-S1-S5	164	18282 69760	AR13	164	56	7	20	1.1	1	163	1	AR	199.2	200.2	201.2	202	-31.1	-31	-30.7	-30.6	1a		19
165	R13S4-S1-S3	165	18282 69760	AR13	165	56	7	20	2.8	1	166	1	AR	25	26	26.8	27.8	32.3	32.4	32.5	32.5	1a		2.5
166	R13S3-S1-S4	166	18282 69760	AR13	166	56	7	20	1.1	1	165	1	AR	205	206	206.8	208	-29.9	-30	-29.3	-29.3	1a		6.5
167	AR13S5-S4	167	18282 69760	AR13	167	56	7	20	4.6	1	0	0	AR	321.2	322.2	322.8	324	29.8	30.3	30.5	31	1b		2
168	R15abcdNW	168	18337 69641	AR15	168	56	6	41	3	1	169	1	AR	318.8	320.8	324	326	27.3	28.3	29.3	29.9	1a		4
169	AR15dcbaSE	169	18337 69641	AR15	169	56	6	41	1.8	1	168	1	AR	138.8	140.8	144	146	-26.5	-26	-23.7	-22.7	1a		3
170	AR15efNNW	170	18337 69641	AR15	170	56	6	41	3.1	1	171	1	AR	331.4	333.4	335.4	337	32.2	32.7	33.2	33.6	1b		4
171	AR15feSSE	171	18337 69641	AR15	171	56	6	41	0.7	1	170	1	AR	151.4	153.4	155.4	157	-30.8	-30	-29.6	-29	1b		5.5

Align No.	Alignment	Align No.	NGR	Site	Align No.	Lat	Lat	Lat	Alt	Inter/Intra	Matching Pair	Correct Pairs	Location	AAR1	IAR1	IAR2	AAR2	DECS	DECS	DECS	DECS	Intra Class	Inter Class	Horizon
172	AR15-AR18	172	18337 69641	AR15	172	56	6	41	1.1	2	178	1	AR	223.6	224.6	225	226	-23.3	-23	-22.6	-22		B3	6
173	AR16NW	173	18205 69585	AR16	173	56	6	20	4	1	174	1	AR	314.8	316.8	319.6	322	26.3	27.2	28.8	29.5	5a		2.5
174	AR16SE	174	18205 69585	AR16	174	56	6	20	0.9	1	173	1	AR	134.8	136.8	139.6	142	-25.5	-25	-23.5	-22.4	5a		11
175	AR16-AR17	175	18205 69585	AR16	175	56	6	20	0.9	2	176	1	AR	257.8	258.8	259.4	260	-6.5	-5.9	-5.4	-4.8		A2	18
176	AR17-AR16	176	18034 69561	AR17	176	56	6	10	1.1	2	175	1	AR	77.8	78.8	79.4	80.4	5.9	6.5	6.9	7.6		A2	4
177	AR17-AR18	177	18034 69561	AR17	177	56	6	10	2.1	2	179	1	AR	157.6	158.6	159.6	161	-29.8	-30	-29.5	-29.5		B2	5
178	AR18-AR15	178	18083 69410	AR18	178	56	5	22	2.3	2	172	1	AR	43.6	44.6	45	46	24.8	25.1	25.3	25.9		B3	4.5
179	AR18-AR17	179	18083 69410	AR18	179	56	5	22	2.3	2	177	1	AR	337.6	338.6	339.6	341	32.8	33.1	33.5	33.7		B2	3.5
180	AR27abNNW	180	18386 69362	AR27	180	56	5	8	1.6	1	0	0	AR	325.6	327.4	329.2	331	28.7	29.3	29.9	30.6	4a		7
181	R28abcNNW	181	18471 69290	AR28	181	56	4	49	3.2	1	182	1	AR	342.8	344.2	345.6	347	34.9	35.3	35.6	35.9	2a		1.5
182	AR28cbaSSE	182	18471 69290	AR28	182	56	4	49	2.1	1	181	1	AR	162.8	164.2	165.6	167	-31.5	-31	-30.6	-30.1	2a		2
183	AR28-AR29	183	18471 69290	AR28	183	56	4	49	2.6	2	187	1	AR	158.4	159.4	160	161	-29.8	-29	-29.2	-28.8		A2	2
184	AR28-AR30	184	18471 69290	AR28	184	56	4	49	2.2	2	188	1	AR	163	164	164.6	166	-31	-31	-30.5	-30.2		A2	2
185	AR29abNW	185	18484 69248	AR29	185	56	4	36	2.1	1	186	1	AR	312	314	318.4	320	23.3	24.2	26.3	26.6	1b		1
186	AR29baSE	186	18484 69248	AR29	186	56	4	36	3.7	1	185	1	AR	132	134	138.4	140	-21.9	-22	-19.5	-18.4	1b		2
187	AR29-AR28	187	18484 69248	AR29	187	56	4	36	2	2	183	1	AR	338.4	339.4	340.4	341	32.5	33.1	33.3	33.3		A2	2
188	AR30-AR28	188	18484 69233	AR30	188	56	4	31	1.9	2	184	1	AR	343	344	344.6	346	33.7	34	34.1	34.5		A2	5
189	AR32WNW	189	18572 68852	AR32	189	56	2	30	4.6	1	190	1	AR	285	287	289	291	11.9	13.1	14.3	15.4	5a		2
190	AR32ESE	190	18572 68852	AR32	190	56	2	30	3.2	1	189	1	AR	105	107	109	111	-9.2	-8.1	-6.8	-5.6	5a		3
191	AR33WNW	191	18674 68652	AR33	191	56	1	27	3	1	192	1	AR	297	299	302	304	17.2	18.2	19.3	20.3	5a		3.5
192	AR33ESE	192	18674 68652	AR33	192	56	1	27	2.1	1	191	1	AR	117	119	122	124	-16.5	-16	-14.2	-13.2	5a		1
193	JU1baWNW	193	16089 68221	JU1	193	55	58	25	2.4	1	0	0	JU	284.2	285.2	285.6	287	9.3	10.1	10.5	11.4	4b		5
194	JU2-JU3	194	15505 67192	JU2	194	55	52	41	2.4	2	195	1	JU	97.6	98.6	99	100	-3.8	-3.3	-2.9	-2.4		B2	1
195	JU3-JU2	195	15601 67171	JU3	195	55	52	36	4.8	2	194	1	JU	277.6	278.6	279	280	7.6	8.6	8.9	9.7		B2	7.5
196	JU3-JU4	196	15601 67171	JU3	196	55	52	36	4	2	200	1	JU	252.4	253.4	254	255	-6.3	-6	-5.8	-5.3		A2	6
197	JU3-JU5	197	15601 67171	JU3	197	55	52	36	3.6	2	202	1	JU	254.8	255.8	256.2	257	-5.5	-5.1	-4.8	-4.5		B2	6
198	JU4baENE	198	15484 67144	JU4	198	55	52	26	1.9	1	199	1	JU	72	73	73.2	74.2	10.2	10.6	10.8	11.3	3a		1
199	JU4abWSW	199	15503 67148	JU4	199	55	52	26	5.4	1	198	1	JU	252	253	253.2	254	-5.4	-5.1	-5	-4.7	3a		5
200	JU4-JU3	200	15503 67148	JU4	200	55	52	26	1.9	2	196	1	JU	72.4	73.4	74	75	10.2	10.2	10.5	11.1		A1	1
201	JU4-JU5	201	15503 67148	JU4	201	55	52	26	4.8	2	203	1	JU	256	257	257.4	258	-3.9	-3.3	-3.1	-2.9		B2	5
202	JU5-JU3	202	15387 67128	JU5	202	55	52	18	0.9	2	197	1	JU	74.8	75.8	76.2	77.2	8	8.2	8.3	8.7		B2	2.5
203	JU5-JU4	203	15387 67128	JU5	203	55	52	18	1.4	2	201	1	JU	76	77	77.4	78.4	7.4	7.9	8.1	8.3		B2	2.5
204	JU7NNE	204	15184 66480	JU7	204	55	48	45	0.5	1	205	1	JU	16	18	22	24	30.7	31.6	33.3	34.2	2a		17
205	JU7SSW	205	15184 66480	JU7	205	55	48	45	-0.2	1	204	1	JU	196	198	202	204	-33.5	-33	-32.2	-31.5	2a		0
206	JU9NNW	206	14641 66477	JU9	206	55	48	34	4.2	1	207	1	JU	333	334	344.8	336	33.7	34	34.5	35	5a		1.5
207	JU9SSE	207	14641 66477	JU9	207	55	48	34	0	1	206	1	JU	153	154	154.8	156	-31.3	-31	-30.8	-30.7	5a		51
208	IS3WSW	208	13475 66978	IS3	208	55	50	53	0.9	1	0	0	IS	255.8	256.8	257.4	258	-7.5	-7	-6.6	-6	5a		1.5
209	IS4WNW	209	13927 66856	IS4	209	55	50	23	4.5	1	0	0	IS	295.4	296.4	297.2	298	17.5	18.2	18.6	19	5a		4
210	IS5-IS12	210	14108 66724	IS5	210	55	49	44	1.2	2	219	1	IS	188.2	189.2	189.4	190	-33	-33	-32.9	-32.7		A3	12
211	IS6-IS7	211	13492 66793	IS6	211	55	49	54	-0.2	2	213	1	IS	97.8	98.8	99	100	-6.3	-5.7	-5.6	-4.9		A2	13
212	IS6-IS11	212	13492 66793	IS6	212	55	49	54	0.3	2	217	1	IS	117.4	118.4	118.6	120	-16.5	-16	-15.7	-15		A3	8.5
213	IS7-IS6	213	13636 66762	IS7	213	55	49	47	2.5	2	211	1	IS	277.8	278.8	279	280	6.3	6.8	6.9	7.3		A1	1.5
214	IS7-IS11	214	13636 66762	IS7	214	55	49	47	0.5	2	218	1	IS	123.6	124.6	124.8	126	-19.1	-19	-18.6	-17.8		A3	9
215	IS7-IS12	215	13636 66762	IS7	215	55	49	47	0.9	2	220	1	IS	126.6	127.6	128	129	-20.2	-20	-19.6	-19.3		A3	12
216	IS11abENE	216	13989 66483	IS11	216	55	48	24	2.1	1	0	0	IS	56.4	58.4	61.8	63.8	16	16.6	18.6	19.9	3a		12
217	IS11-IS6	217	13989 66483	IS11	217	55	48	24	0.5	2	212	1	IS	297.4	298.4	298.6	300	15	15.5	15.6	16.1		A3	6
218	IS11-IS7	218	13989 66483	IS11	218	55	48	24	0.3	2	214	1	IS	303.6	304.6	304.8	306	18.2	18.4	18.5	19		A3	5
219	IS12-IS5	219	14037 66410	IS12	219	55	48	1	-0.3	2	210	1	IS	8.2	9.2	9.4	10.4	32.7	32.7	32.8	33		A3	0
220	IS12-IS7	220	14037 66410	IS12	220	55	48	1	0.1	2	215	1	IS	306.6	307.6	308	309	19.2	19.7	19.9	20.4		A3	6
221	IS19SSE	221	12938 66335	IS19	221	55	47	15	0.3	1	0	0	IS	167.2	168.4	169.6	171	-33.8	-34	-33.6	-33.5	5a		18
222	IS19-IS23	222	12938 66335	IS19	222	55	47	15	1	2	224	1	IS	239.6	240.6	241	242	-16	-16	-15.3	-14.7		A3	6.5
223	IS23E	223	12527 66137	IS23	223	55	46	3	1.2	1	0	0	IS	90.8	92.4	94	95.6	-2.5	-1.6	-0.8	-0.3	5a		18
224	IS23-IS19	224	12527 66137	IS23	224	55	46	3	0.8	2	222	1	IS	59.6	60.6	61	62	15.5	16.2	16.3	17.3		A3	30
225	IS28-IS31	225	11956 65697	IS28	225	55	43	29	-0.2	2	226	2	IS	197	198	198.4	199	-33.4	-33	-33.1	-32.9		B2	55
226	IS31-IS28	226	11901 65561	IS31	226	55	42	44	1	2	225	2	IS	16.4	17.6	18.8	20	32.5	32.8	33	33.2		B1	1.5
227	IS35-IS36	227	14618 65372	IS35	227	55	42	37	0.6	2	228	1	IS	167.2	168.2	168.6	170	-33.5	-33	-33.3	-33.2		B2	3.5
228	IS36-IS35	228	14630 65290	IS36	228	55	42	11	2.3	2	227	1	IS	347.2	348.2	348.6	350	35.5	35.5	35.6	35.7		B2	3

Align No.	Alignment	Align No.	NGR	Site	Align No.	Lat	Lat	Lat	Alt	Inter/Intra	Matching Pair	Correct Pairs	Location	AAR1	IAR1	IAR2	AAR2	DECS	DECS	DECS	DECS	Intra Class	Inter Class	Horizon
229	IS38abENE	229	14369 64832	IS38	229	55	39	38	0.2	1	230	1	IS	56.8	58	59.2	60.4	16	16.6	17.3	17.8	4b		39
230	IS38baWSW	230	14369 64832	IS38	230	55	39	38	1.2	1	229	1	IS	236.8	238	239.2	240	-17.5	-17	-16	-15.4	4b		3
231	IS39E	231	13954 64621	IS39	231	55	38	22	0.5	1	0	0	IS	80.4	82.4	86.6	88.6	0.7	1.8	4.3	5.2	3b		36
232	IS39-IS41	232	13954 64621	IS39	232	55	38	22	0.8	2	0	0	IS	251.4	252.4	253	254	-9.8	-9.4	-9.1	-8.7		A2	6
233	IS41S	233	13895 64607	IS41	233	55	38	17	-0.3	1	0	0	IS	167	168.4	169.8	171	-34.6	-35	-34.4	-34	2a		70
234	KT2baS	234	17425 66163	KT2	234	55	47	43	1.6	1	0	0	KT	176.4	177.4	177.8	179	-32.9	-33	-32.9	-32.9	3a		1.5
235	KT2acWNW	235	17425 66163	KT2	235	55	47	43	3.5	1	236	1	KT	283	284	284.6	286	9.9	10.6	10.9	11.5	3a		2.5
236	KT2caESE	236	17414 66166	KT2	236	55	47	43	1.1	1	235	1	KT	103	104	104.6	106	-8.3	-7.5	-7.1	-6.5	3a		8
237	KT2bcWNW	237	17425 66163	KT2	237	55	47	43	3.3	1	238	1	KT	280.4	281.8	283.2	285	8.1	9	10	10.9	3a		2.5
238	KT2cbESE	238	17414 66166	KT2	238	55	47	43	1.4	1	237	1	KT	100.4	101.8	103.2	105	-7.5	-6.6	-5.7	-4.7	3a		8
239	KT3NW	239	17573 66014	KT3	239	55	46	57	2.9	1	240	1	KT	315.6	316.6	317	318	26	26.5	26.6	27	5a		8
240	KT3SE	240	17573 66014	KT3	240	55	46	57	2.2	1	239	1	KT	135.6	136.6	137	138	-23	-23	-22.3	-21.8	5a		3
241	KT3-KT8	241	17573 66014	KT3	241	55	46	57	1.8	2	246	1	KT	166.4	167.4	167.6	169	-31.9	-32	-31.8	-31.8		B1	3
242	KT4S	242	18391 66746	KT4	242	55	51	7	2.8	1	0	0	KT	169.2	170.4	171.6	173	-31.5	-31	-30.9	-30.5	5a		4.5
243	KT5NNE	243	18464 66678	KT5	243	55	50	46	2.4	1	244	1	KT	26.2	27.4	28.6	29.8	30.6	31.4	32	32.4	1a		3
244	KT5SSW	244	18464 66678	KT5	244	55	50	46	0.8	1	243	1	KT	206.2	207.4	208.6	210	-29.9	-30	-29.3	-29.1	1a		9.5
245	KT8baSE	245	17624 65704	KT8	245	55	45	20	1.7	1	0	0	KT	127.4	128.4	129.2	130	-20.5	-20	-19.3	-18.9	5b		19
246	KT8-KT3	246	17624 65704	KT8	246	55	45	20	0.8	2	241	1	KT	346.4	347.4	347.6	349	33.7	33.7	33.7	33.9		B2	9
247	KT10cbaSW	247	17309 65241	KT10	247	55	42	43	0.1	1	0	0	KT	220	222	224	226	-26.3	-26	-24.5	-23.7	1a		12
248	KT12N	248	16555 65227	KT12	248	55	42	25	0.7	1	0	0	KT	3.2	4.8	6.4	8	34.3	34.4	34.4	34.5	5a		1.3
249	KT19abWSW	249	16792 63914	KT19	249	55	35	26	-0.2	1	0	0	KT	249	250	250.6	252	-12.4	-12	-11.3	-10.7	4b		0
250	KT23SW	250	17349 63506	KT23	250	55	33	23	0.2	1	0	0	KT	219.6	221.6	225.4	227	-26.1	-25	-23.5	-22.7	5a		5
251	KT27abcNE	251	16577 62445	KT27	251	55	27	28	3	1	252	1	KT	45.4	47.4	49.4	51.4	23	24.1	25	25.9	2a		3
252	KT27cbaSW	252	16577 62445	KT27	252	55	27	28	0.2	1	251	1	KT	225.4	227.4	229.4	231	-24.1	-23	-22.2	-21.3	2a		45
253	KT27-KT39	253	16577 62445	KT27	253	55	27	28	1.6	2	269	1	KT	180.8	181.8	182	183	-33.4	-33	-33.3	-33.2		A3	7
254	KT28ENE	254	17094 62701	KT28	254	55	28	59	2.7	1	0	0	KT	65	67	72	74	10.4	11.7	15	16.4	5a		4.5
255	KT29ENE	255	16950 62572	KT29	255	55	28	15	2	1	0	0	KT	54.8	56.8	59.6	61.6	17.3	18.2	19.7	20.9	5a		5.5
256	KT31WNW	256	16902 62362	KT31	256	55	27	6	0.8	1	0	0	KT	294.8	296.4	298	300	14	14.9	15.7	16.2	5a		2.5
257	KT31-KT37	257	16902 62362	KT31	257	55	27	6	1.4	2	264	1	KT	162.2	163.2	163.4	164	-32.2	-32	-31.8	-31.5		A3	5.5
258	KT31-KT39	258	16902 62362	KT31	258	55	27	6	1.8	2	270	1	KT	217	218	218.2	219	-25.2	-25	-25.1	-24.5		A3	9
259	KT32-KT31	259	16932 62354	KT32	259	55	27	4	0.1	2	0	0	KT	282.8	283.8	284.2	285	7	7.4	7.6	8.1		A2	2.5
260	KT32-KT39	260	16932 62354	KT32	260	55	27	4	2	2	271	1	KT	219.8	220.8	221	222	-24.3	-24	-23.8	-23.4		A3	12
261	KT35WNW	261	17614 62541	KT35	261	55	28	16	2	1	262	1	KT	287	288.4	289.8	291	10.9	11.7	12.5	13.4	5a		3
262	KT35ESE	262	17614 62541	KT35	262	55	28	16	0.1	1	263	1	KT	107	108.4	109.8	111	-12.2	-11	-10.7	-10	5a		63
263	KT36-KT37	263	17238 62123	KT36	263	55	25	55	1.6	2	265	1	KT	235.6	236.6	236.8	238	-17.8	-17	-17	-16.3		A2	10
264	KT37-KT31	264	16995 61982	KT37	264	55	25	5	1.4	2	257	1	KT	342.2	343.2	343.4	344	33.8	34	34	34.3		A3	5.5
265	KT37-KT36	265	16995 61982	KT37	265	55	25	5	1.6	2	263	1	KT	55.6	56.6	56.8	57.8	18.3	19.2	19.4	20.1		A2	3.5
266	KT37-KT39	266	16995 61982	KT37	266	55	25	5	1	2	272	1	KT	260.6	261.6	261.8	263	-4.8	-4.3	-4.1	-3.5		A3	5.5
267	KT39NW	267	16533 61940	KT39	267	55	24	44	0	1	268	1	KT	311.4	313.4	315.6	318	21.3	22.4	23.5	24.4	5a		40
268	KT39SE	268	16533 61940	KT39	268	55	24	44	1.4	1	267	1	KT	131.4	133.4	135.6	138	-23.4	-23	-22.2	-21.6	5a		2.5
269	KT39-KT27	269	16533 61940	KT39	269	55	24	44	0	2	253	1	KT	0.8	1.8	2	3	33.8	34	34	34.1		A3	13
270	KT39-KT31	270	16533 61940	KT39	270	55	24	44	1.2	2	258	1	KT	37	38	38.2	39.2	26.8	27.2	27.3	27.7		A3	13
271	KT39-KT32	271	16533 61940	KT39	271	55	24	44	0.9	2	260	1	KT	39.8	40.8	41	42	25.4	25.8	25.9	26.5		A3	14
272	KT39-KT37	272	16533 61940	KT39	272	55	24	44	0.2	2	266	1	KT	80.6	81.6	81.8	82.8	3.7	4.3	4.4	5		A3	33
273	KT41NW	273	17026 61240	KT41	273	55	21	6	0.8	1	274	1	KT	318	320	324	326	25.8	26.4	27.5	28	5a		6
274	KT41SE	274	17026 61240	KT41	274	55	21	6	0.3	1	273	1	KT	138	140	144	146	-27.7	-27	-24.8	-23.9	5a		1.5
275	KT44N	275	16976 60787	KT44	275	55	18	39	1.6	1	276	1	KT	7	8.4	9.8	11.2	35.2	35.2	35.5	35.7	5a		2.5
276	KT44S	276	16976 60787	KT44	276	55	18	39	-0.1	1	275	1	KT	187	188.4	189.8	191	-35.1	-35	-34.7	-34.5	5a		70

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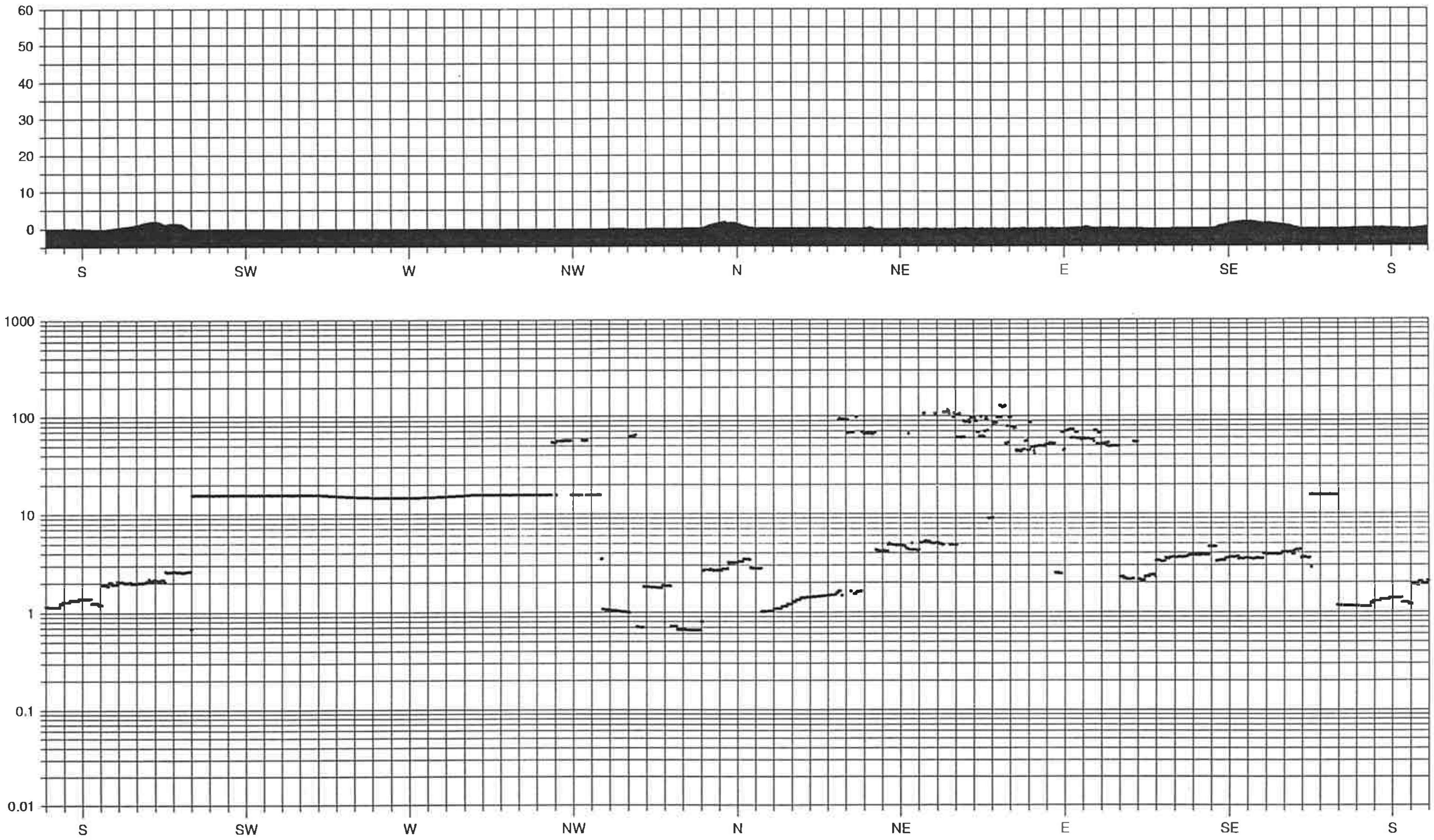

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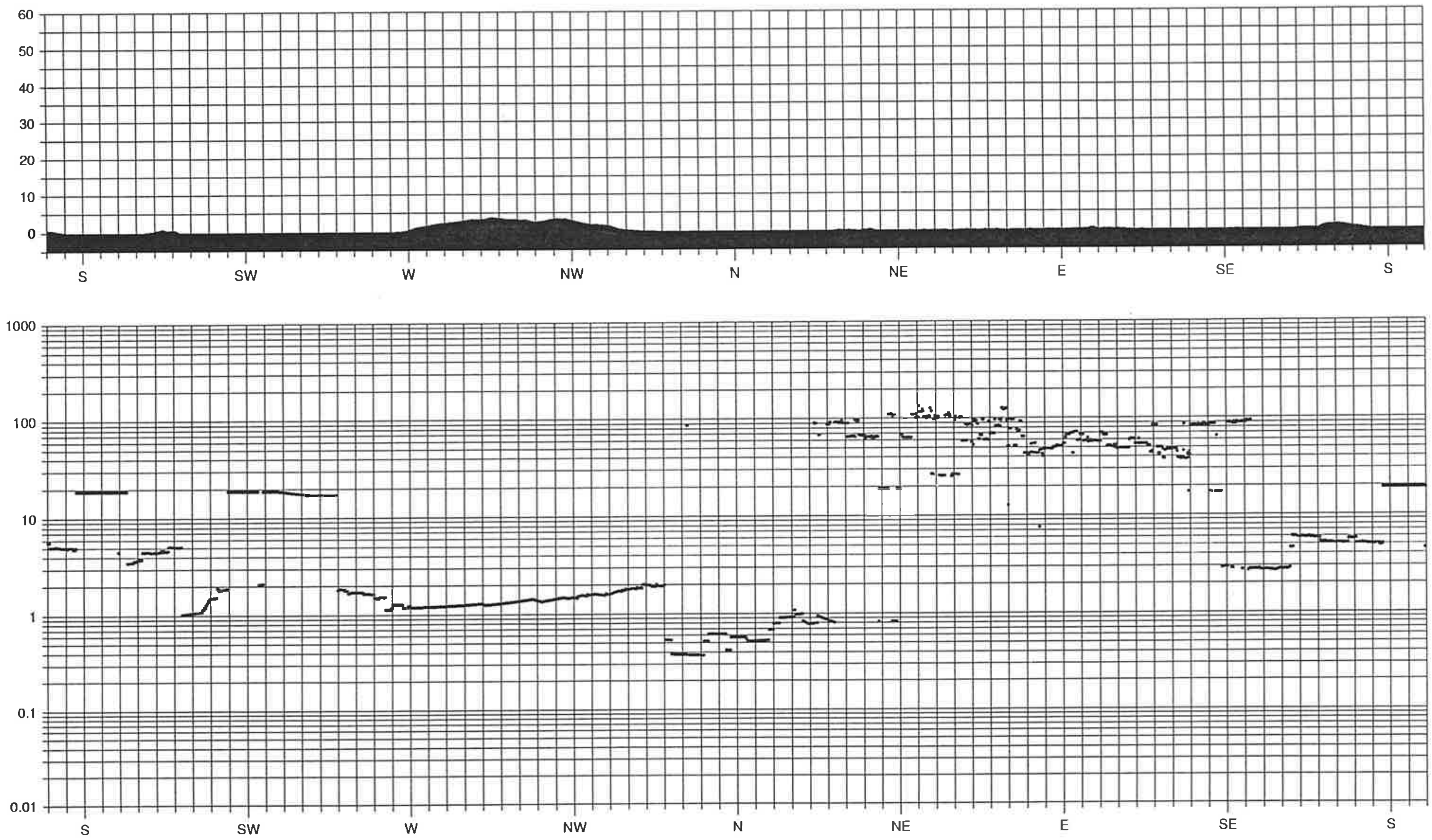

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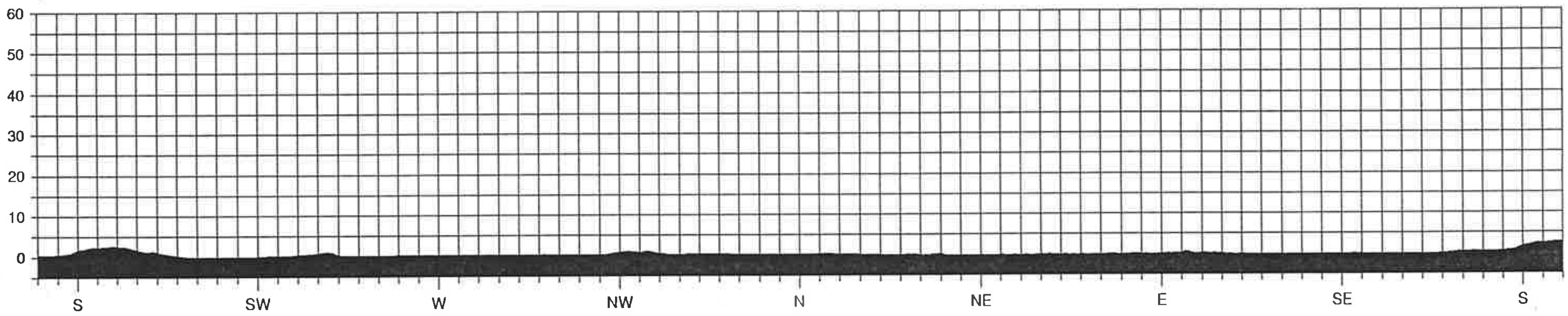

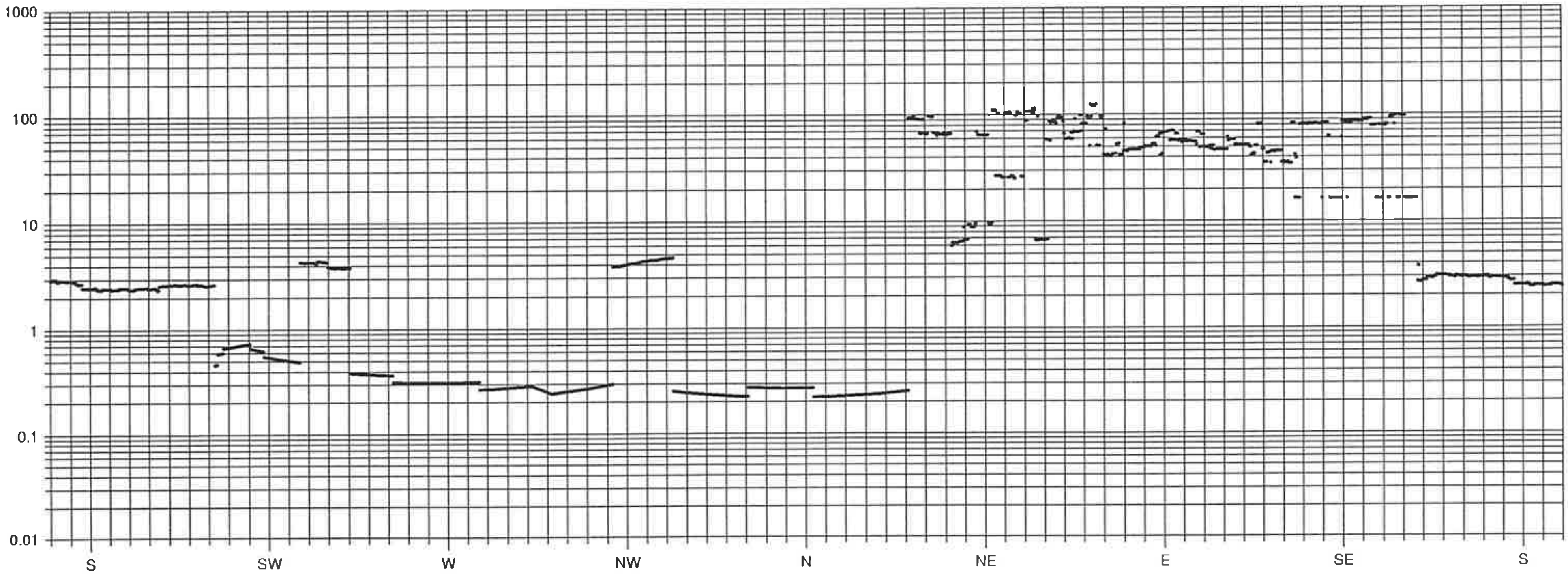

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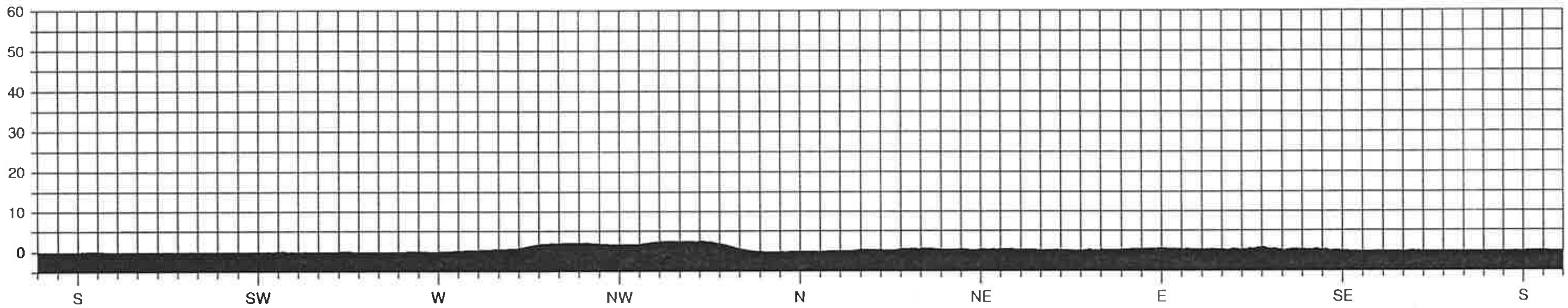

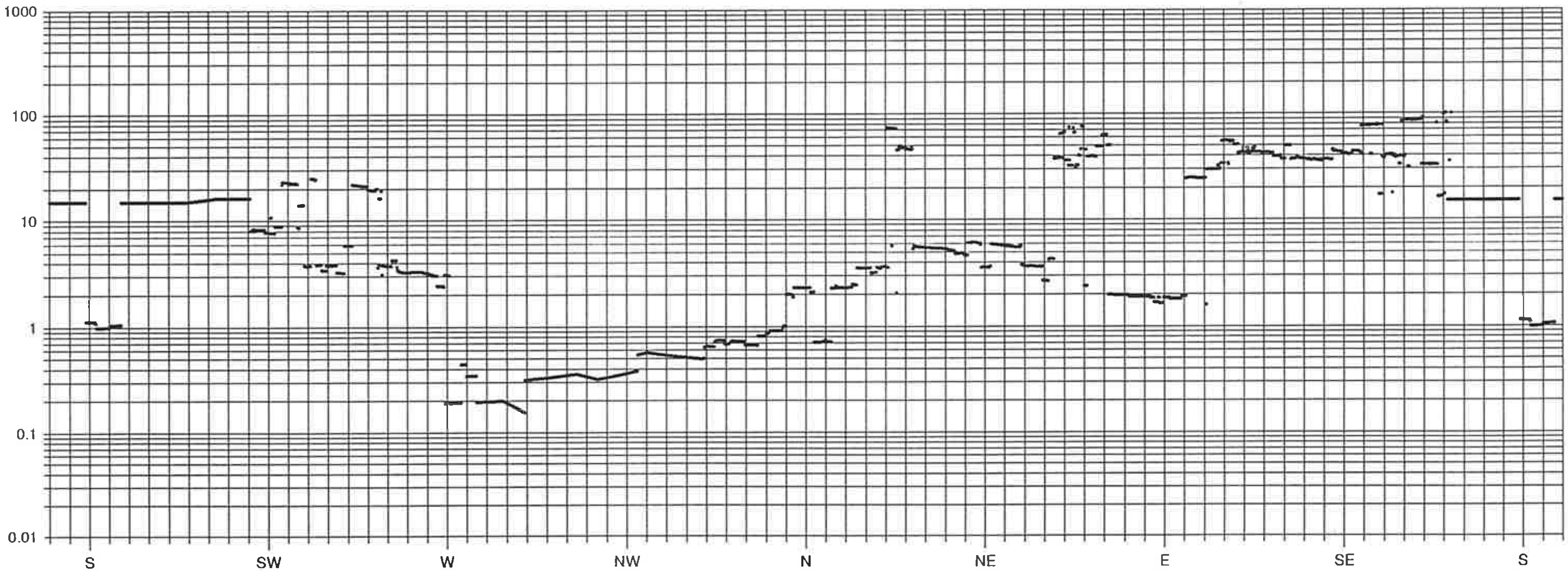

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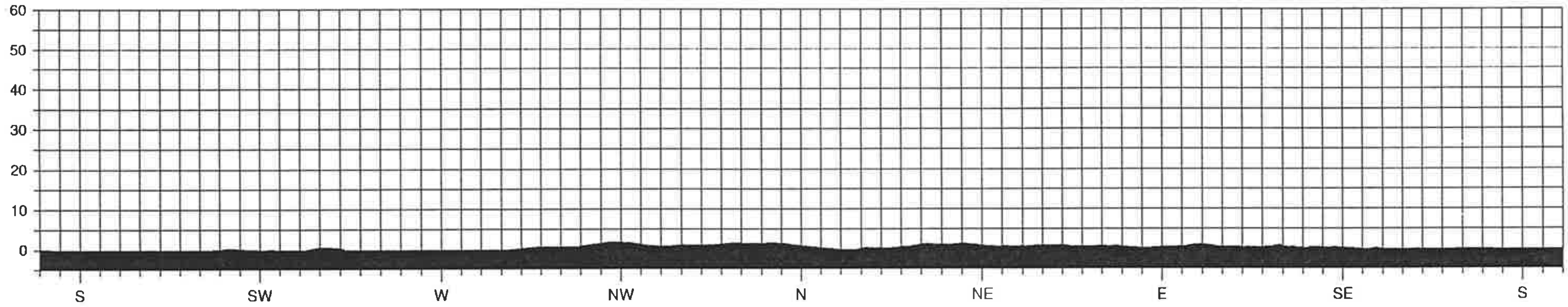

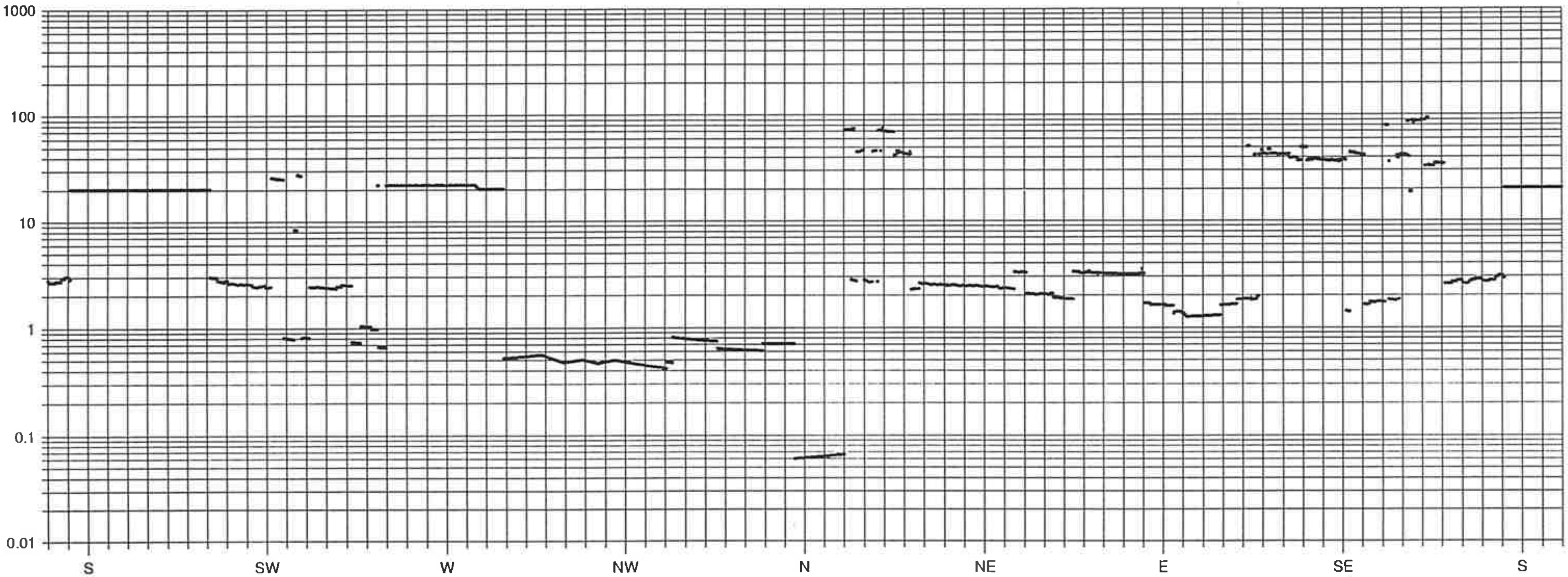

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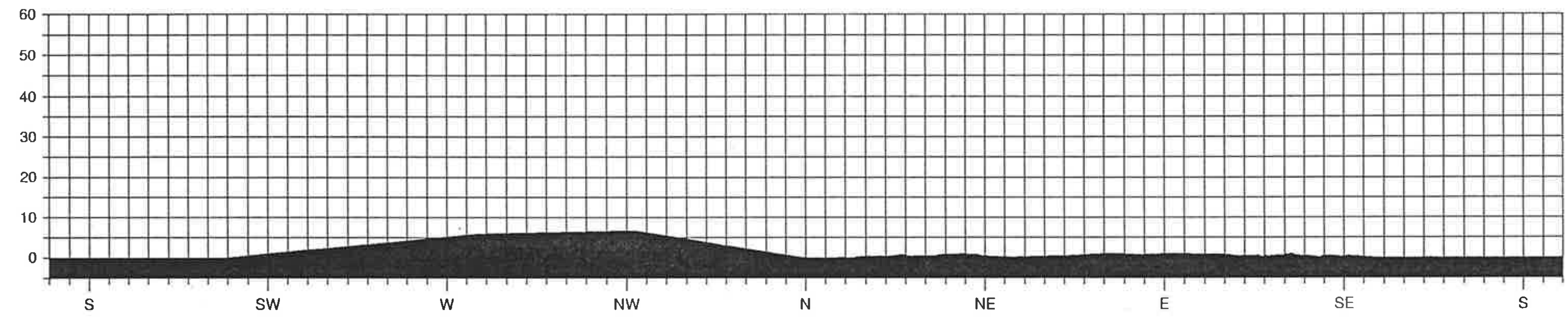

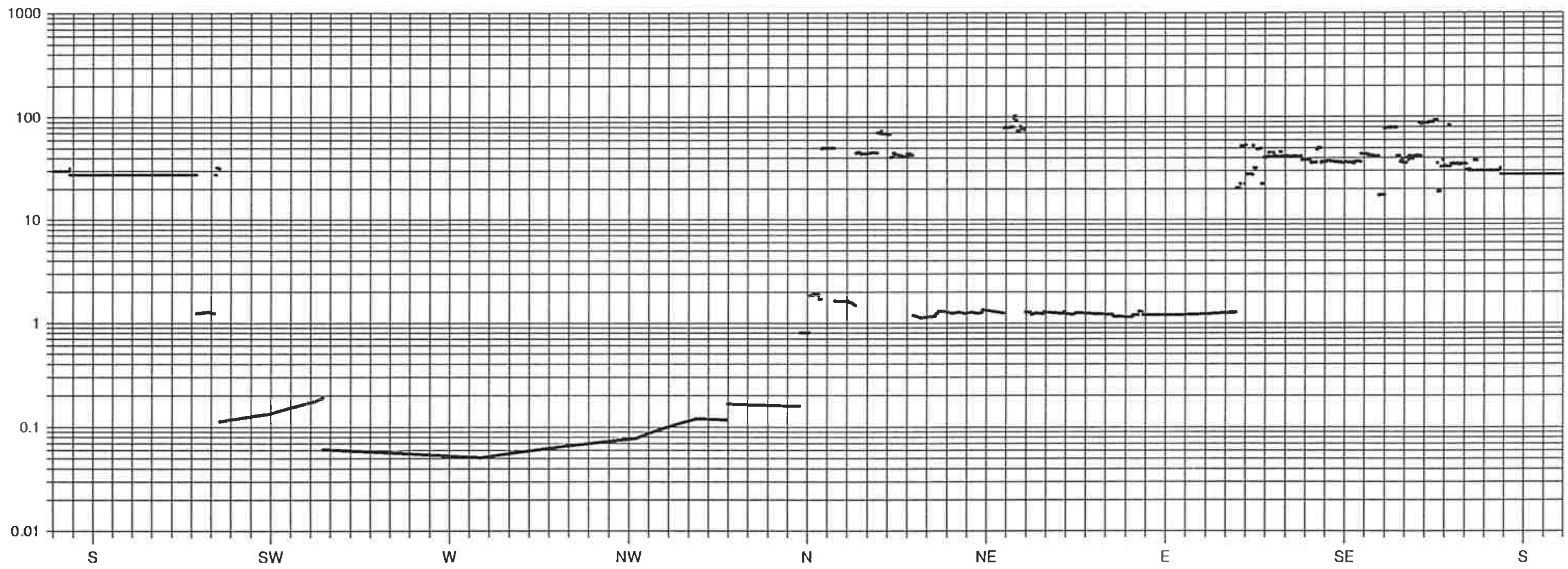

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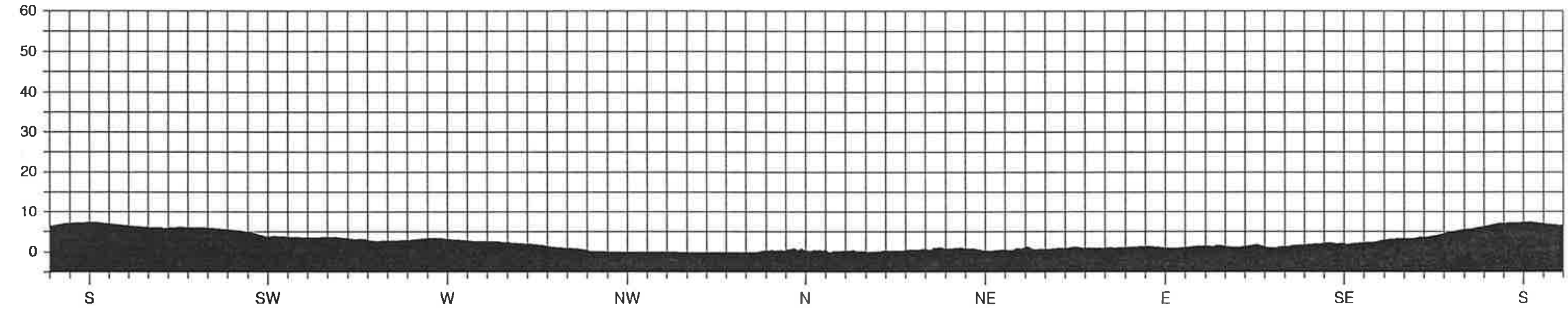

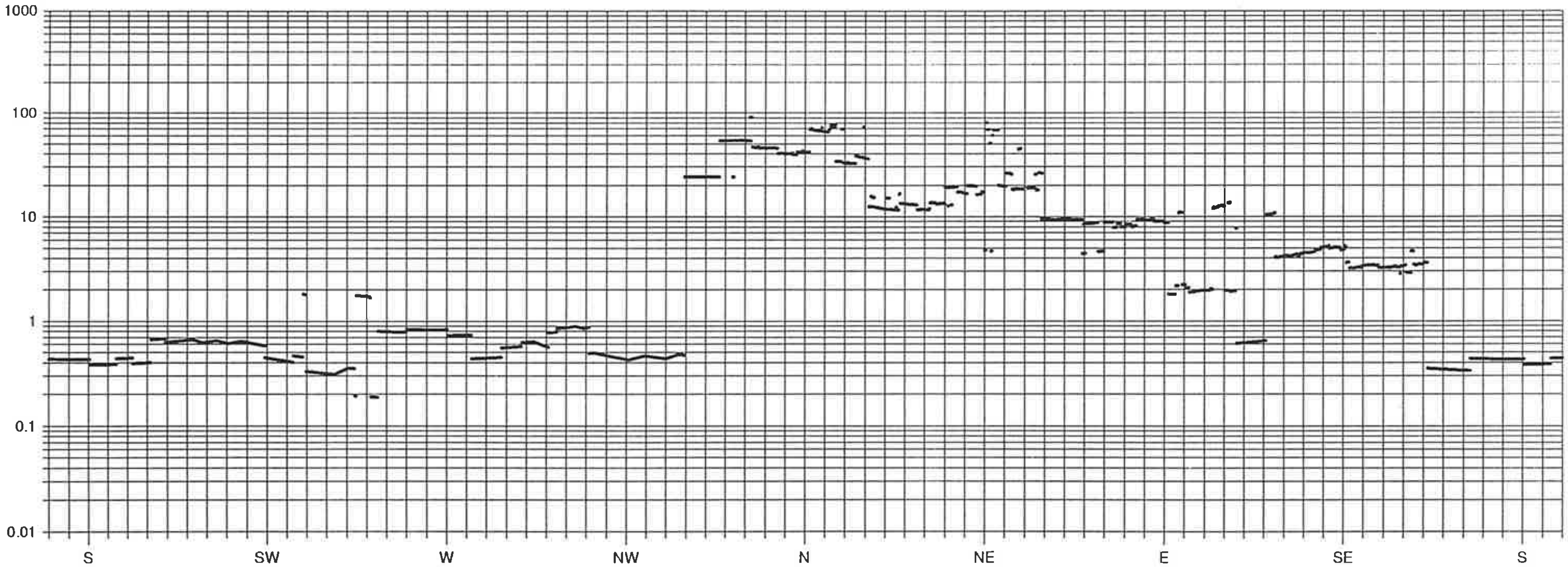

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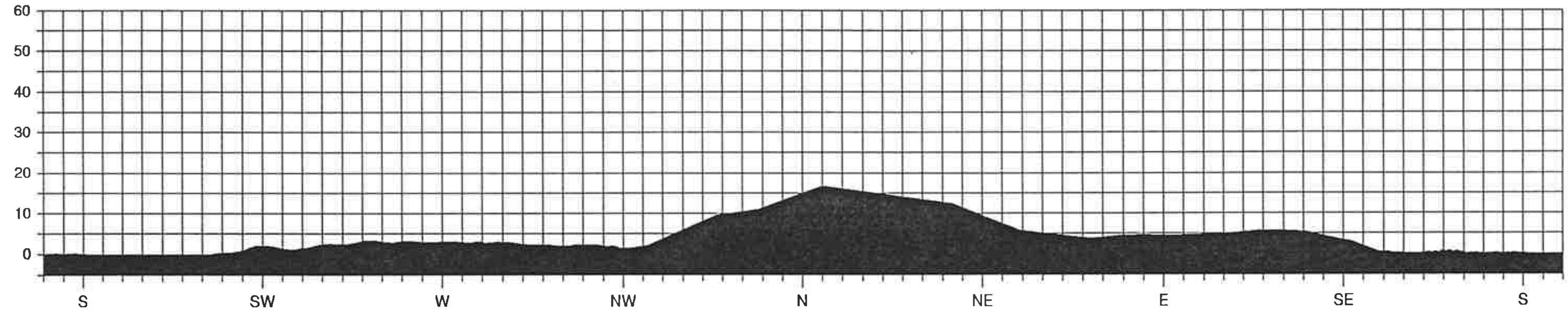

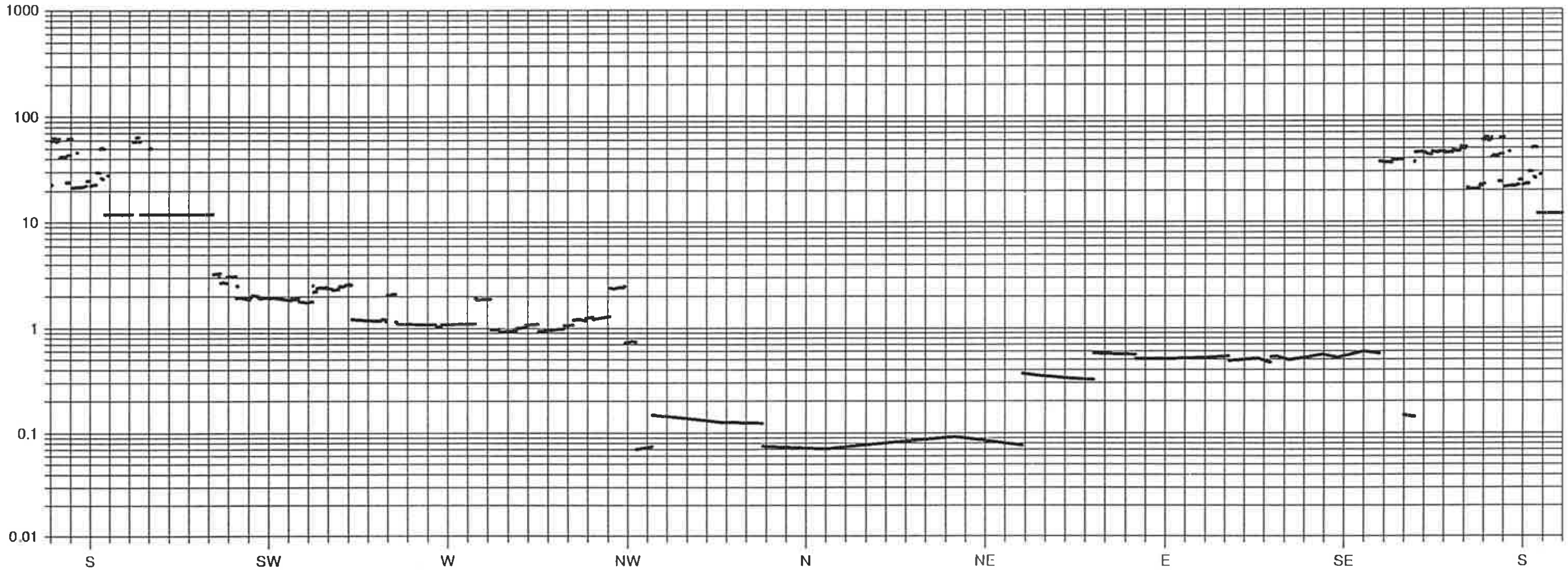

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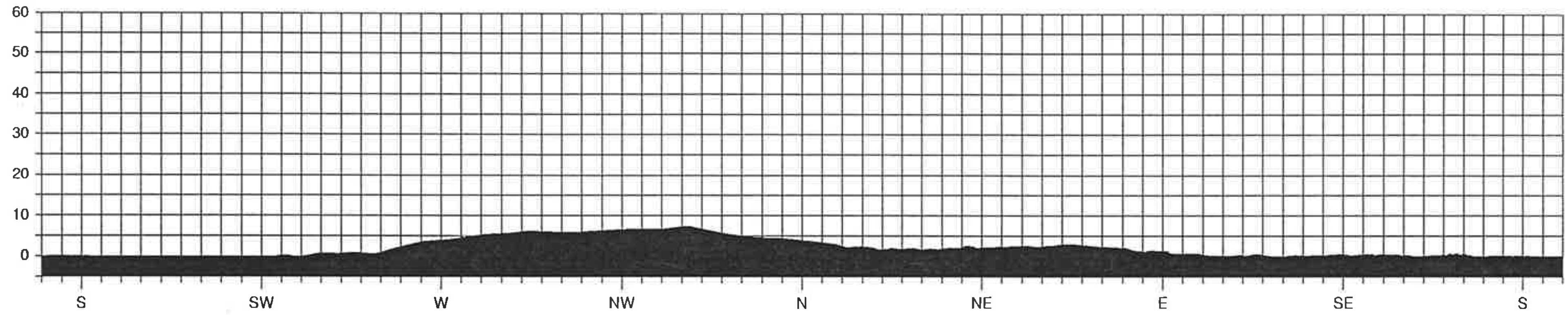

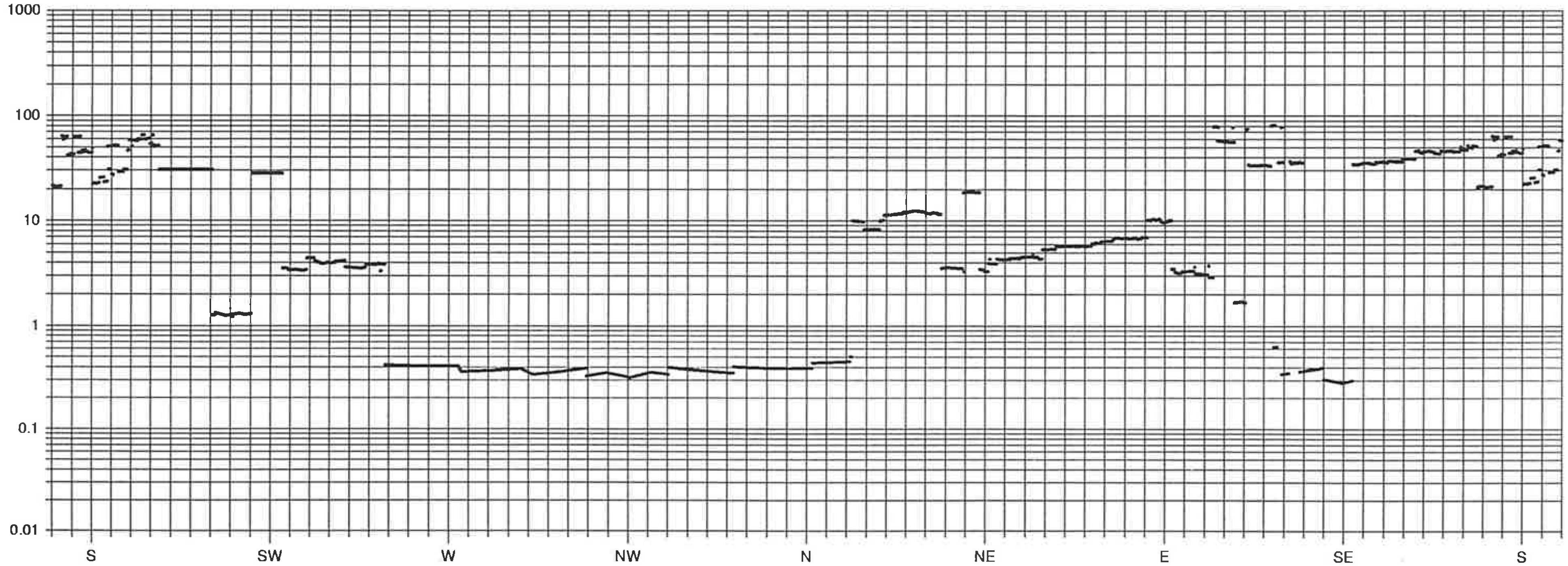

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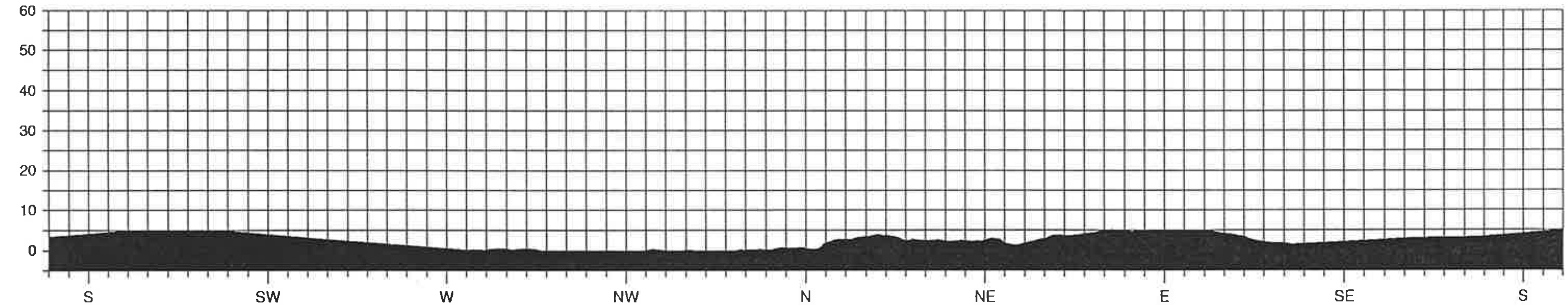

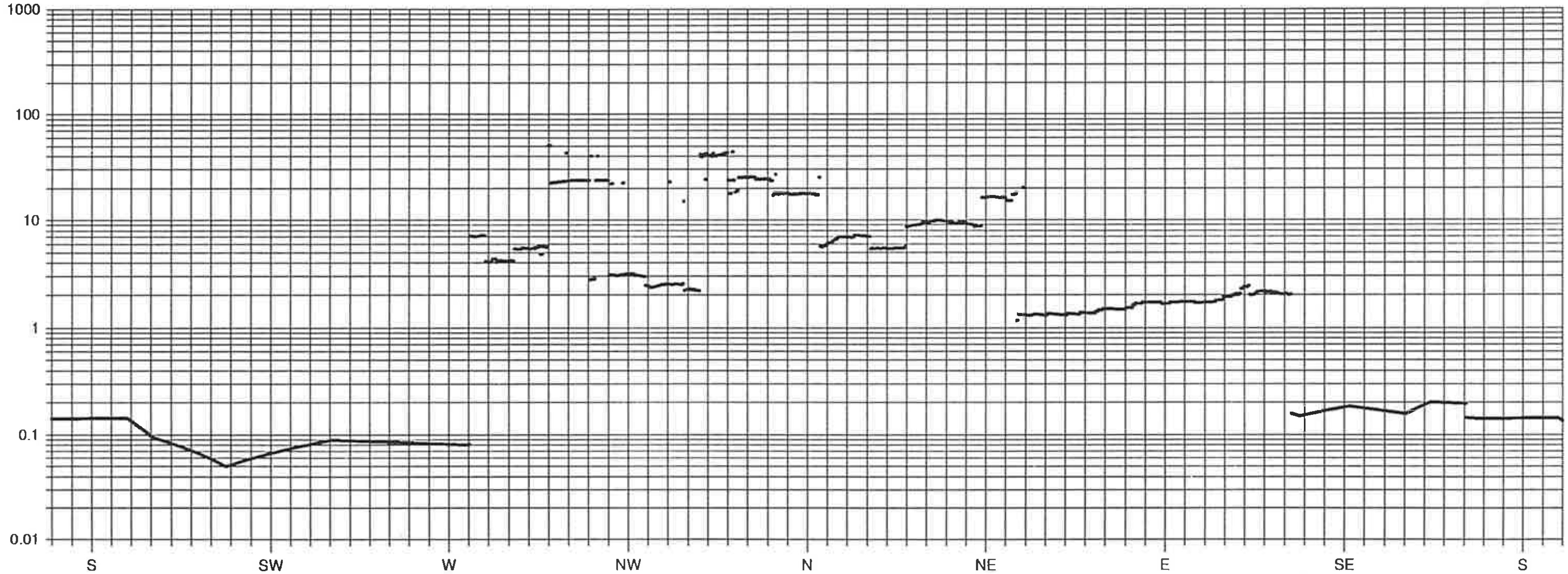

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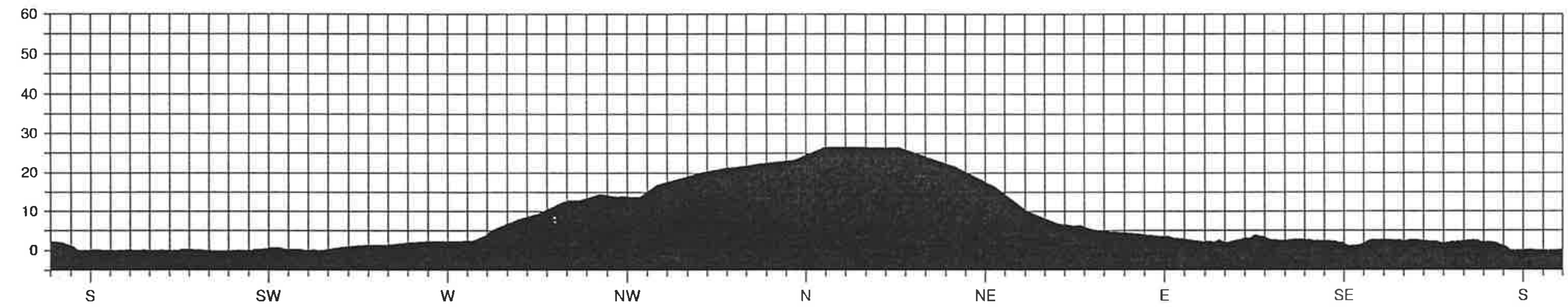

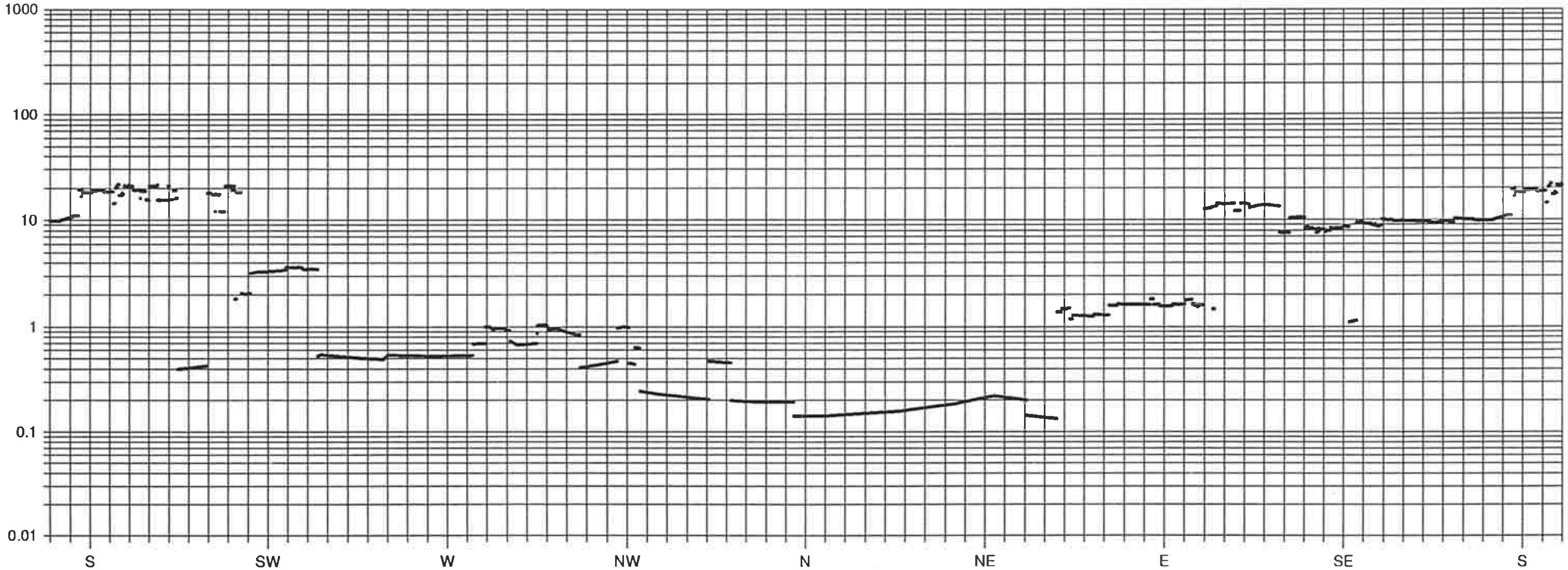

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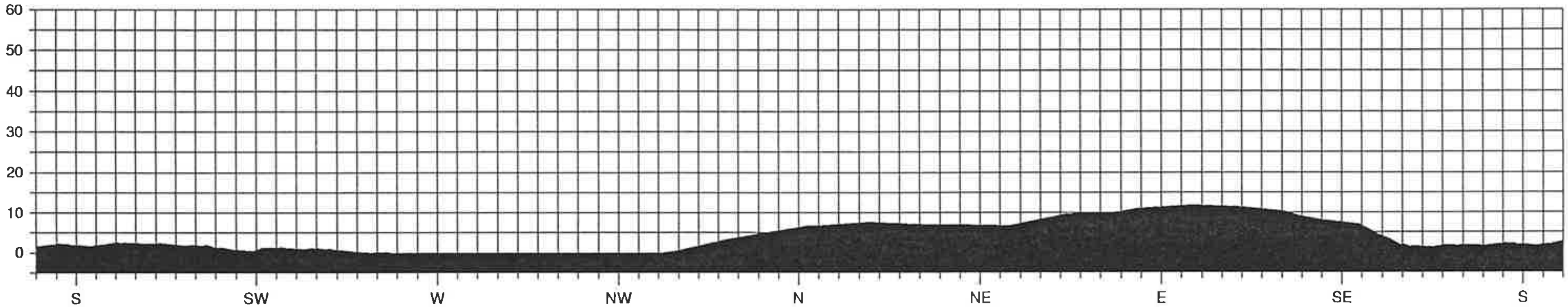

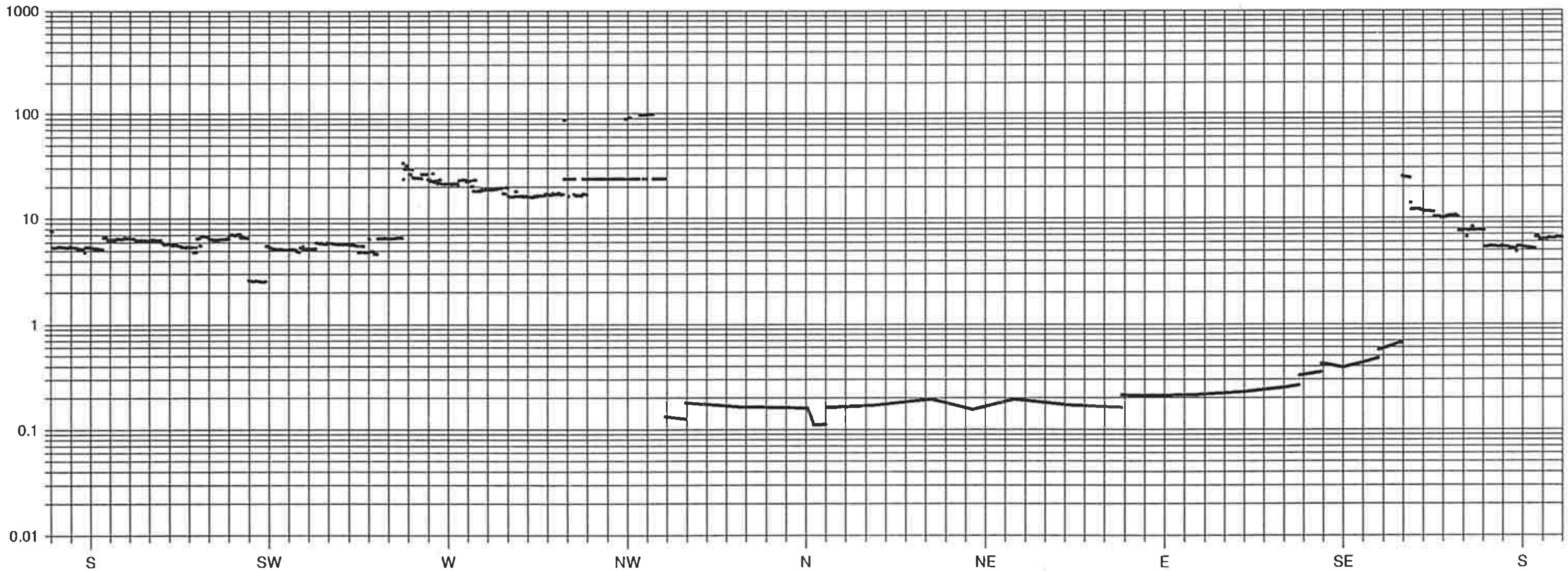

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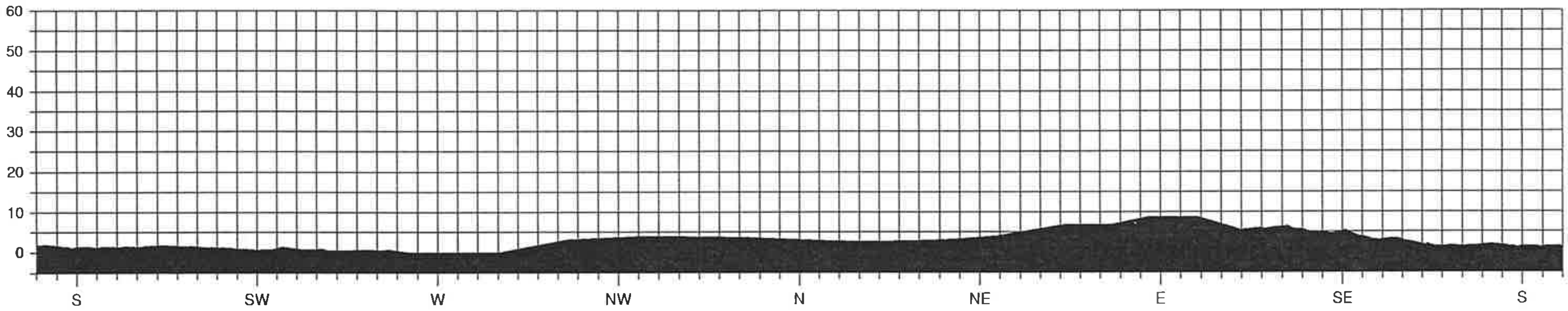

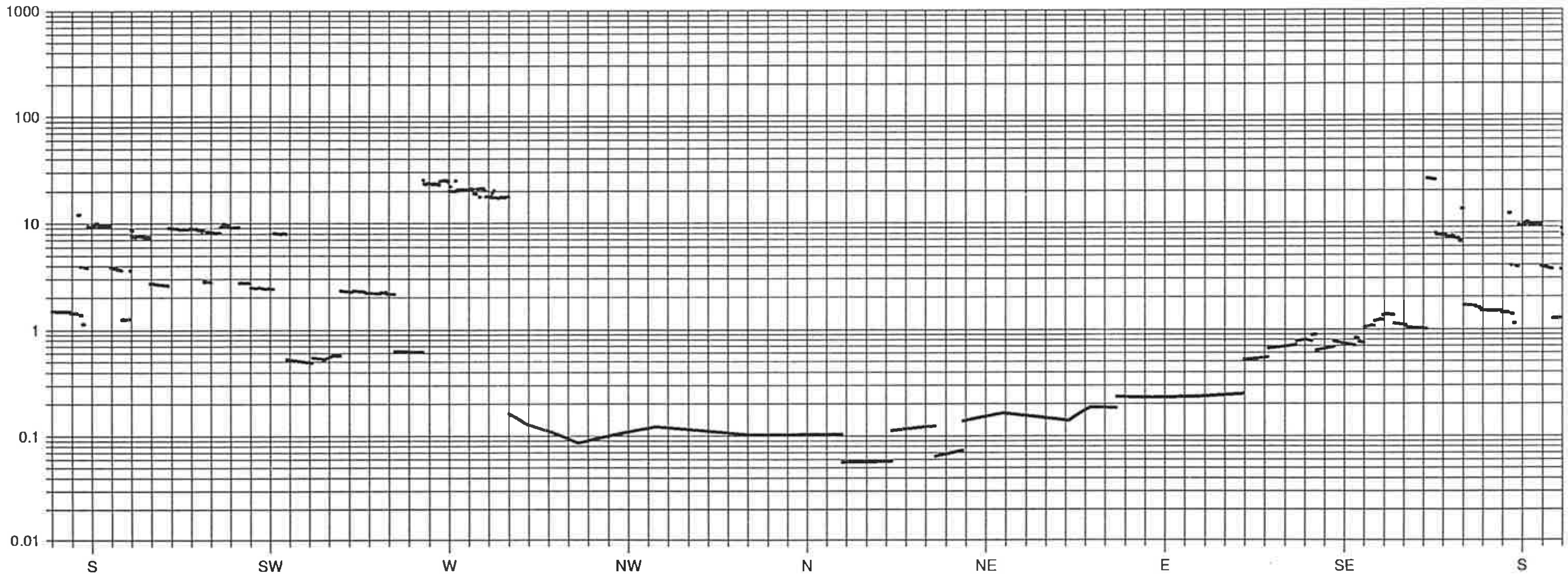

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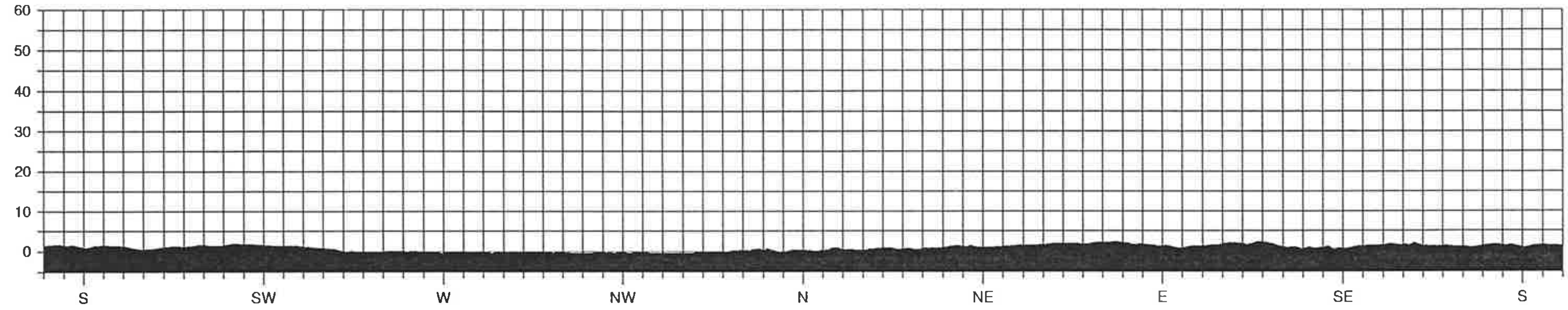

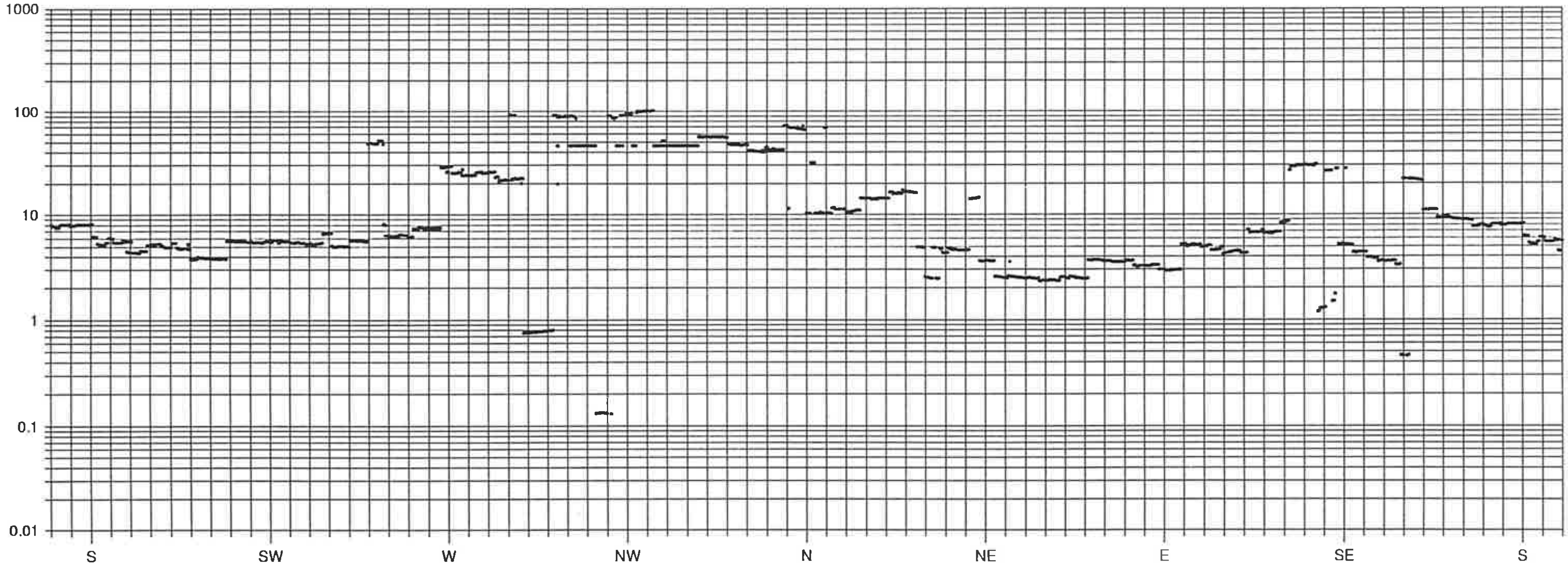

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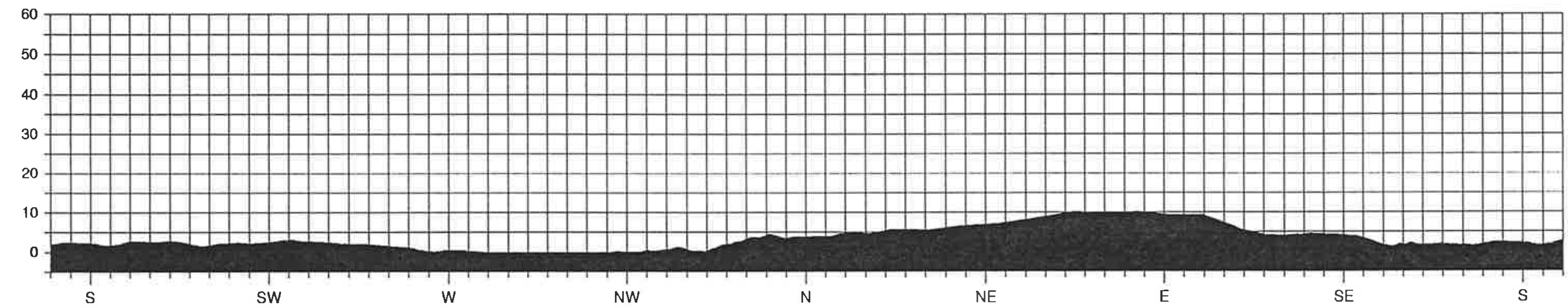

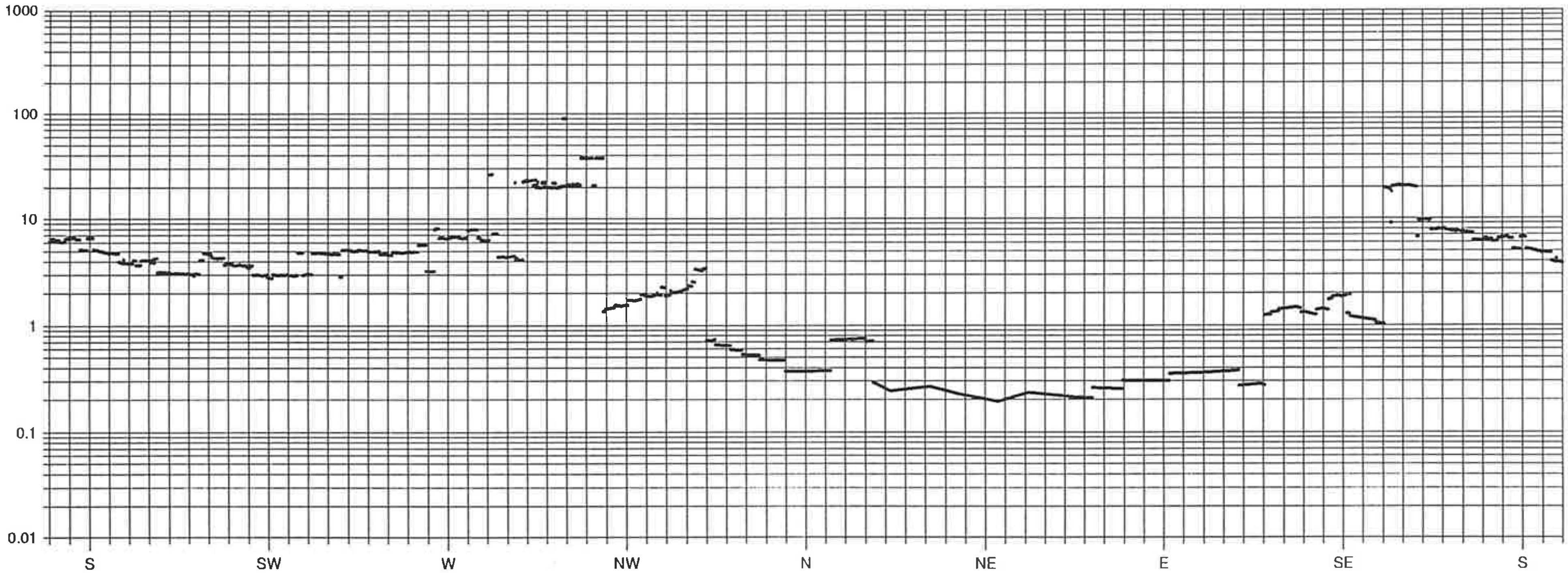

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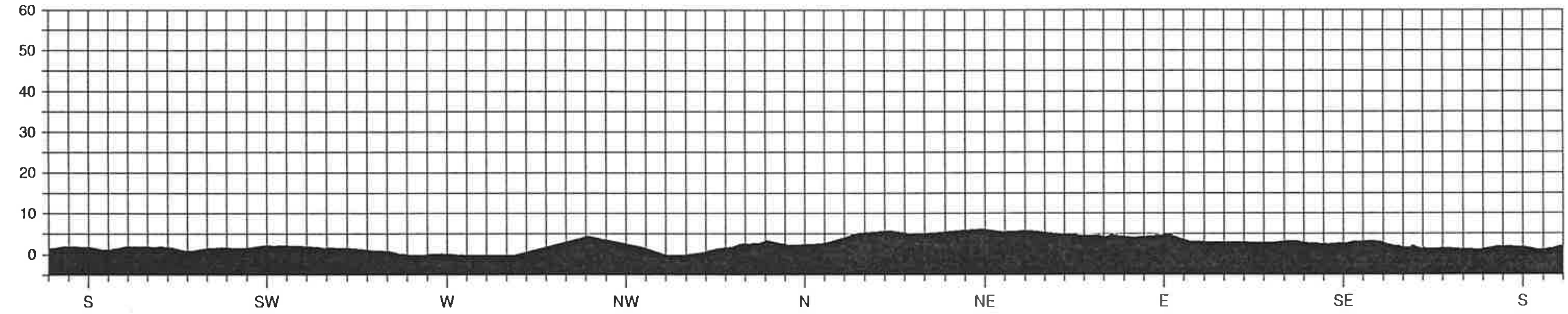

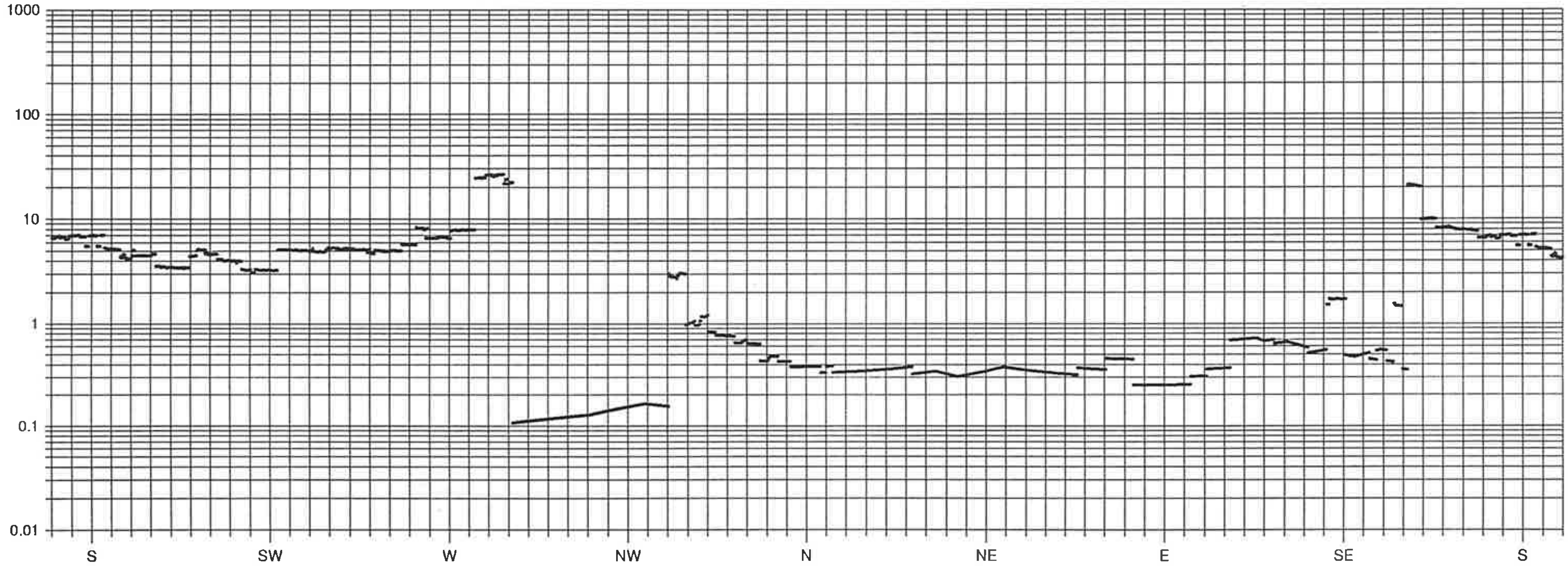

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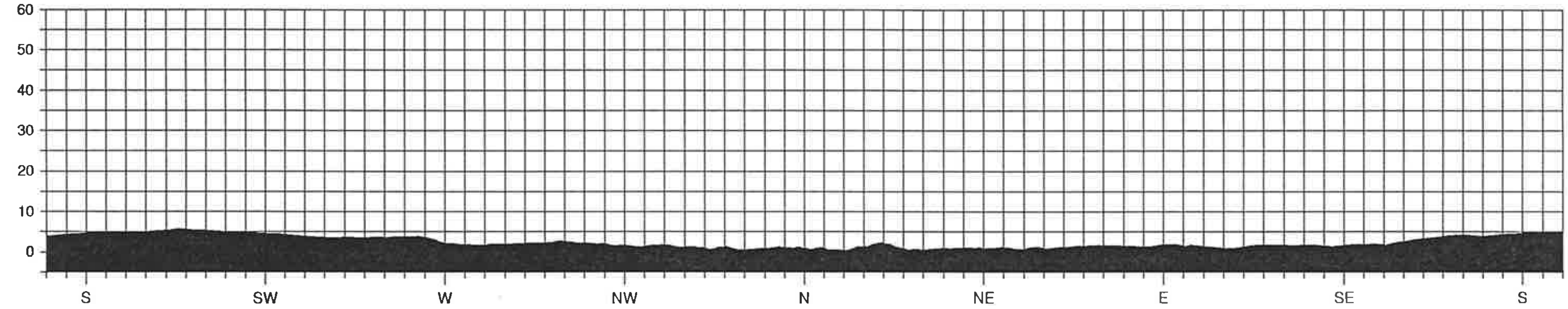

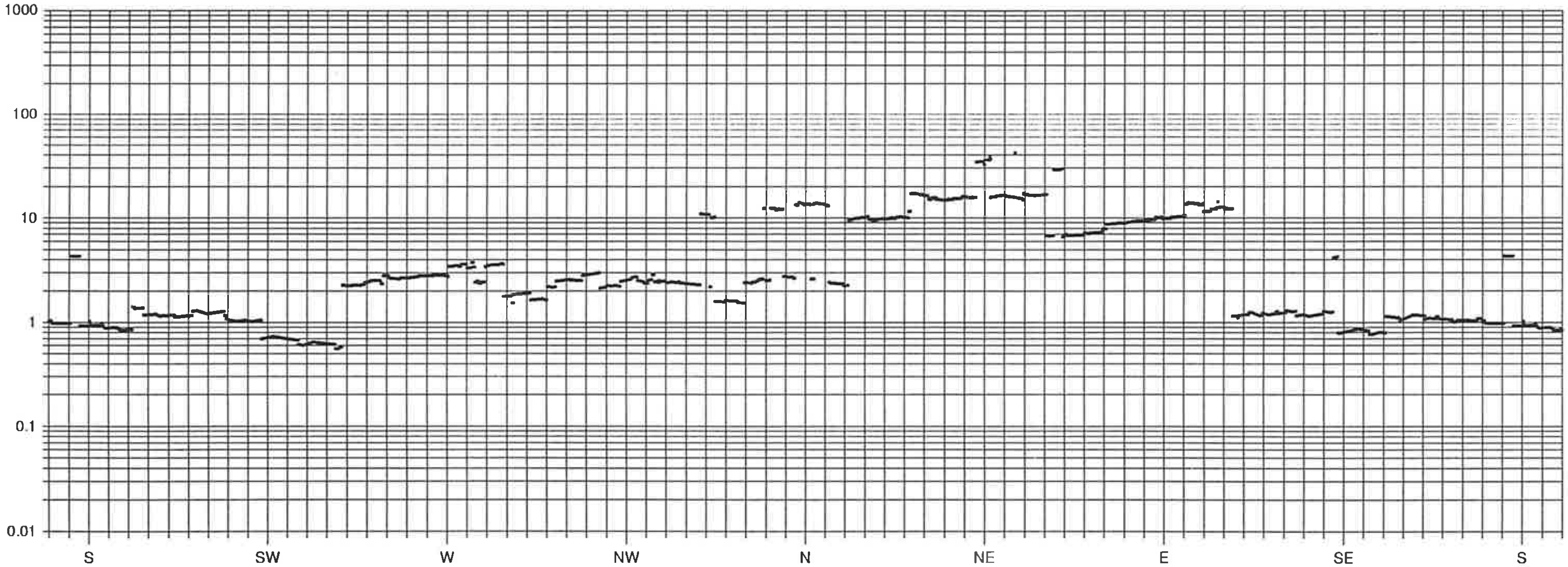

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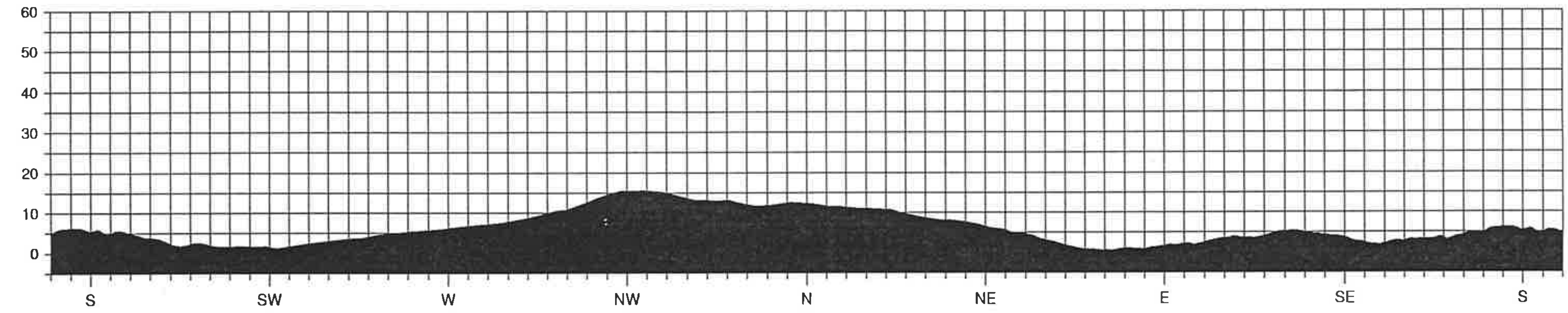

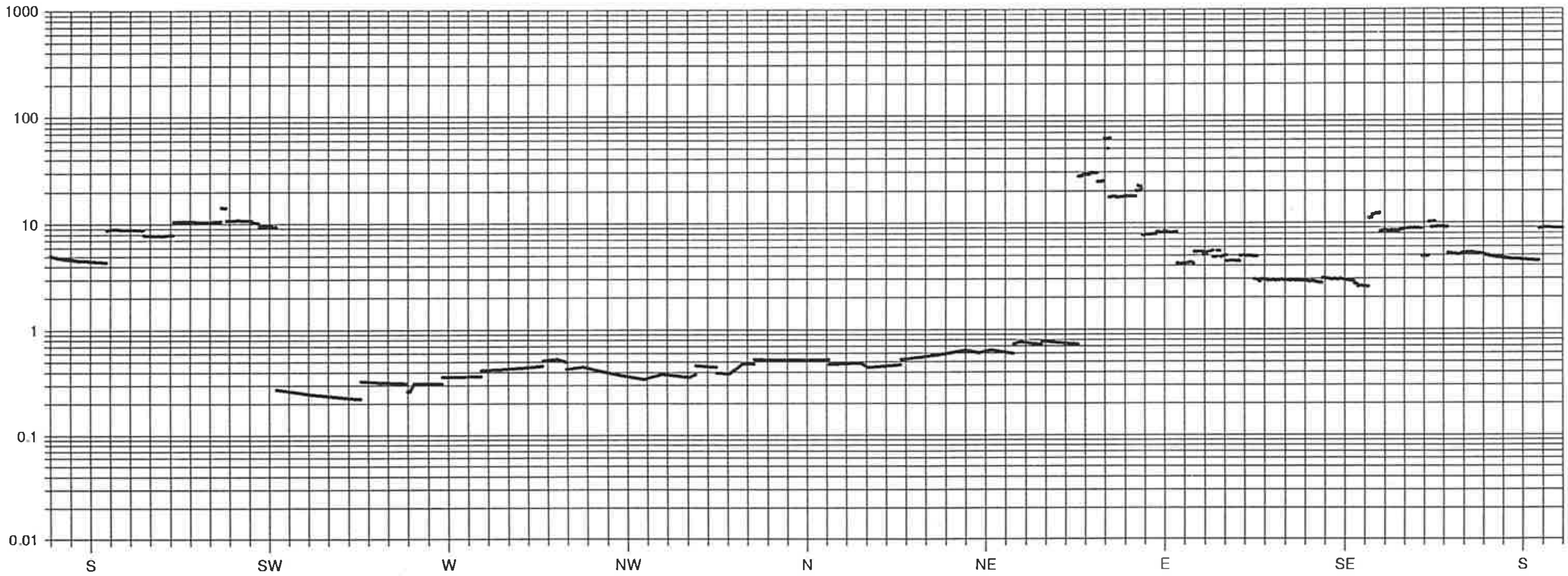

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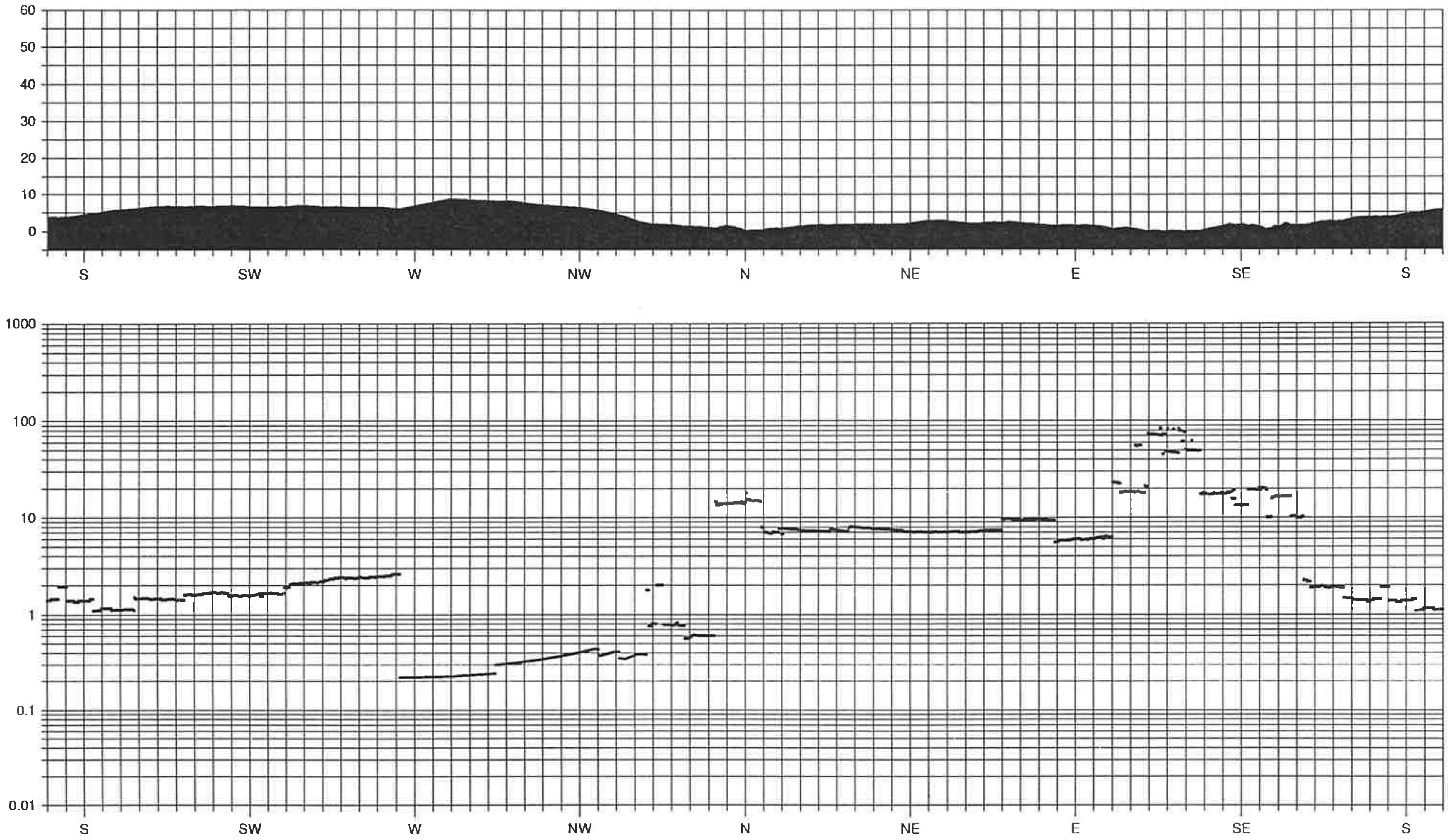

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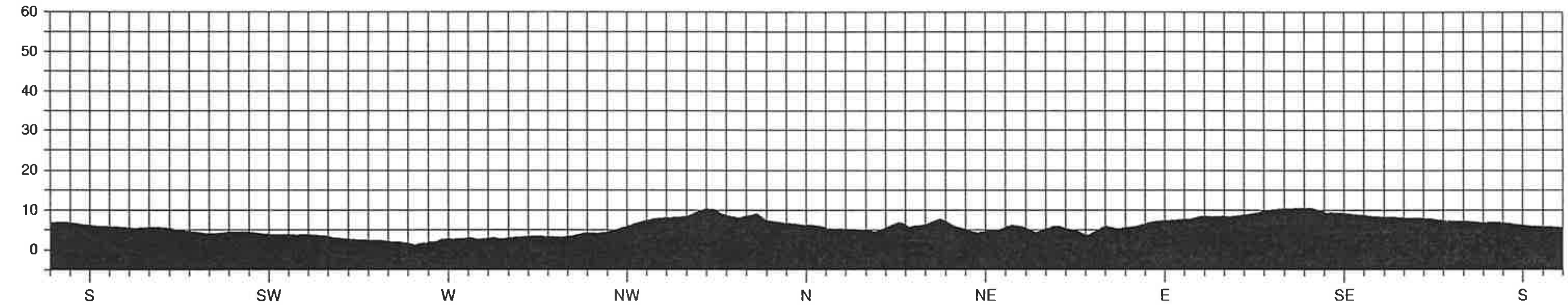

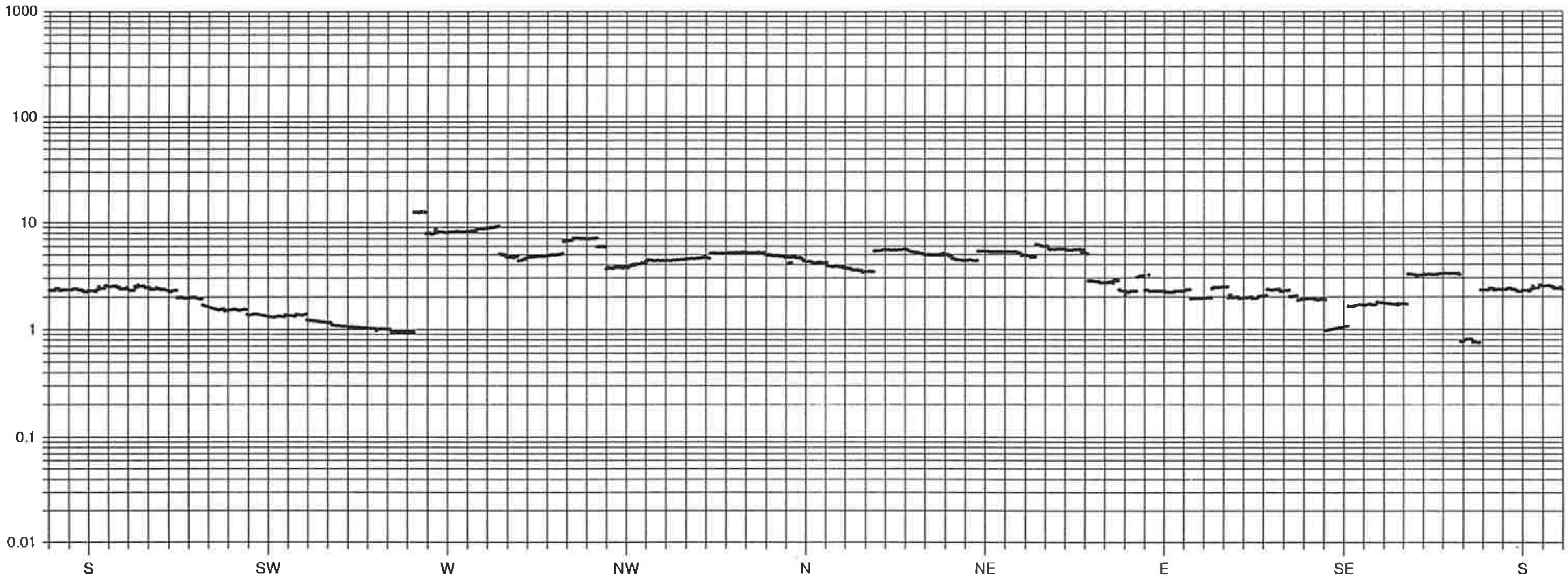

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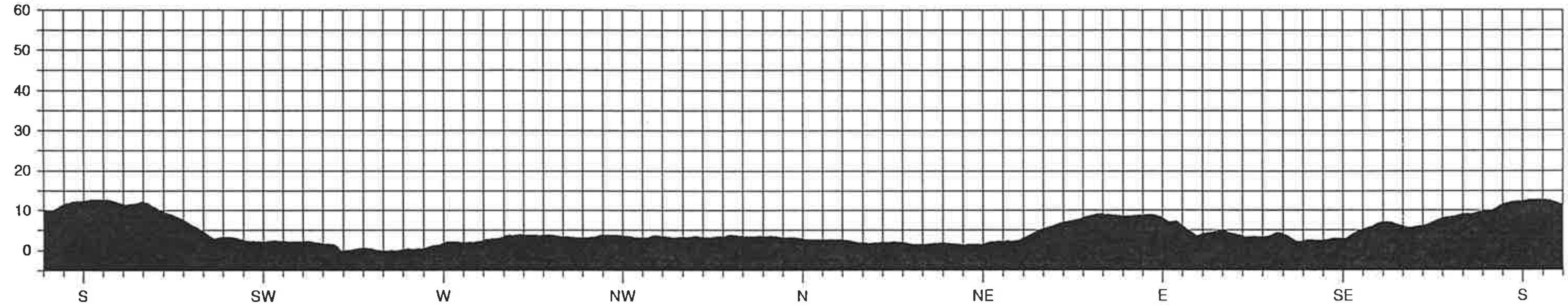

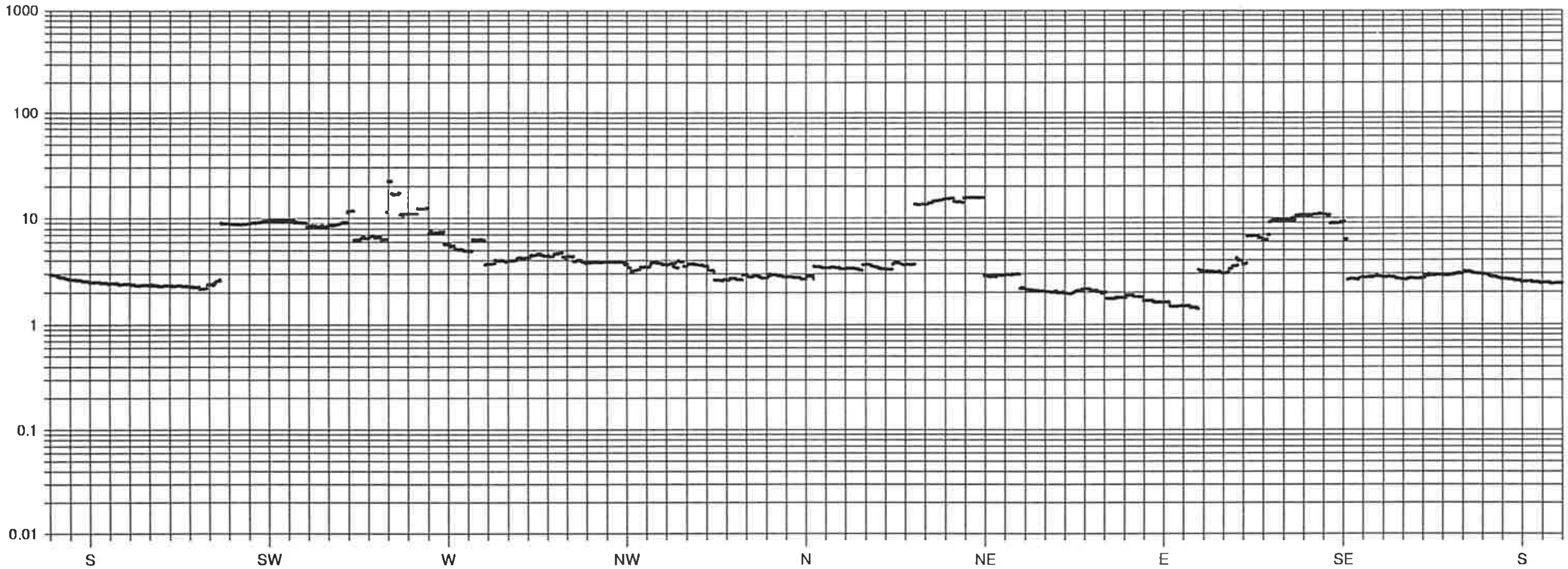

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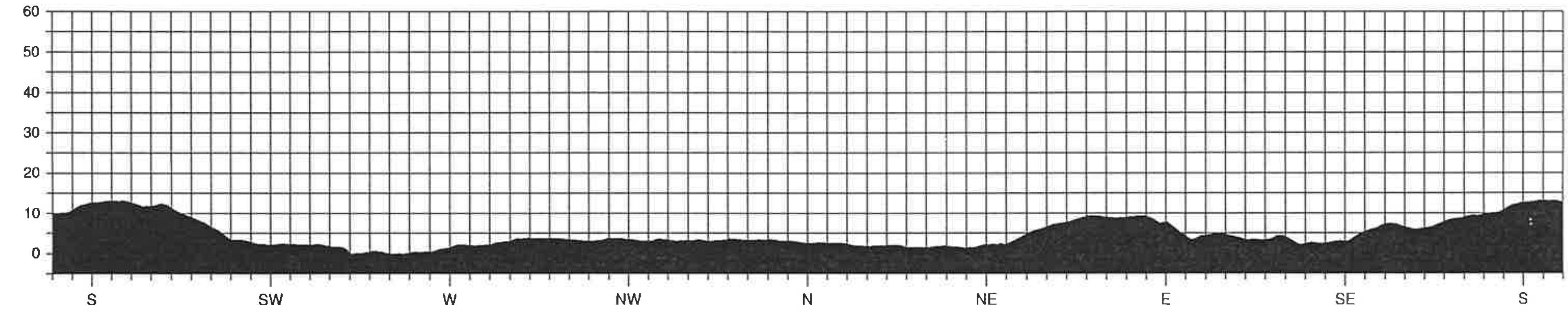

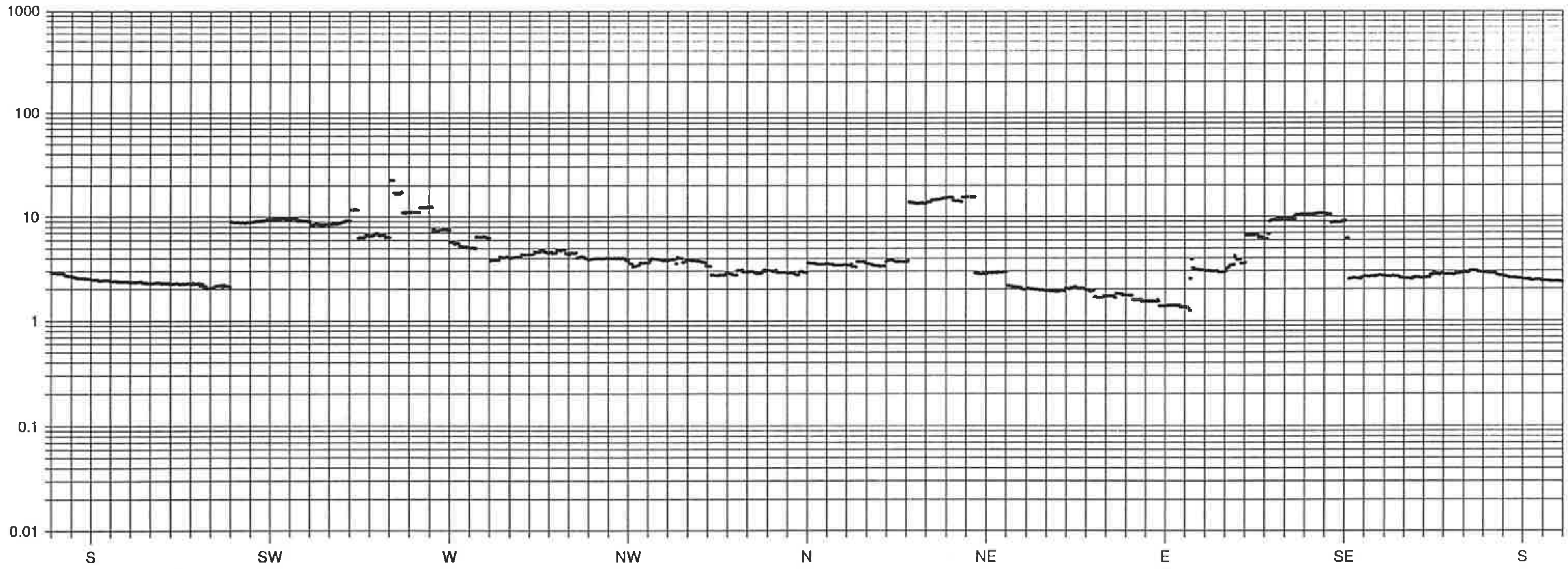

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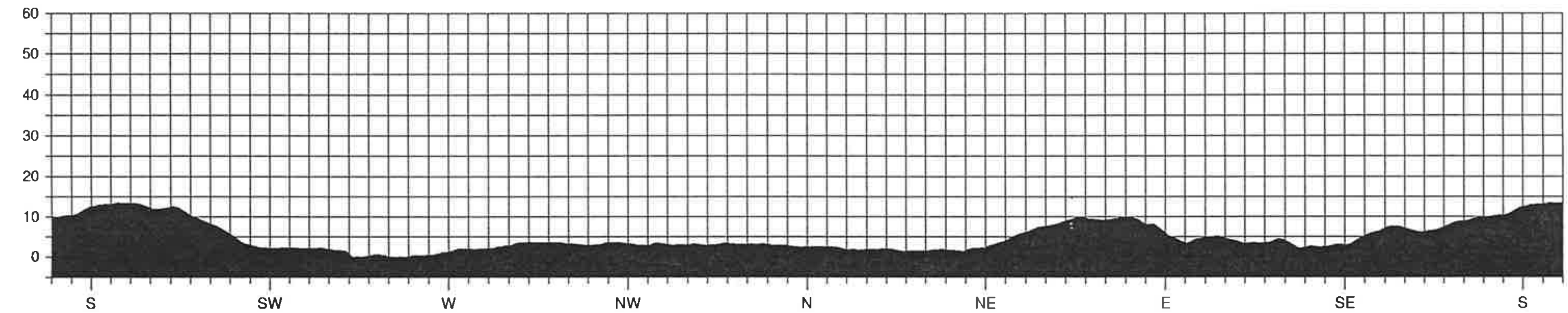

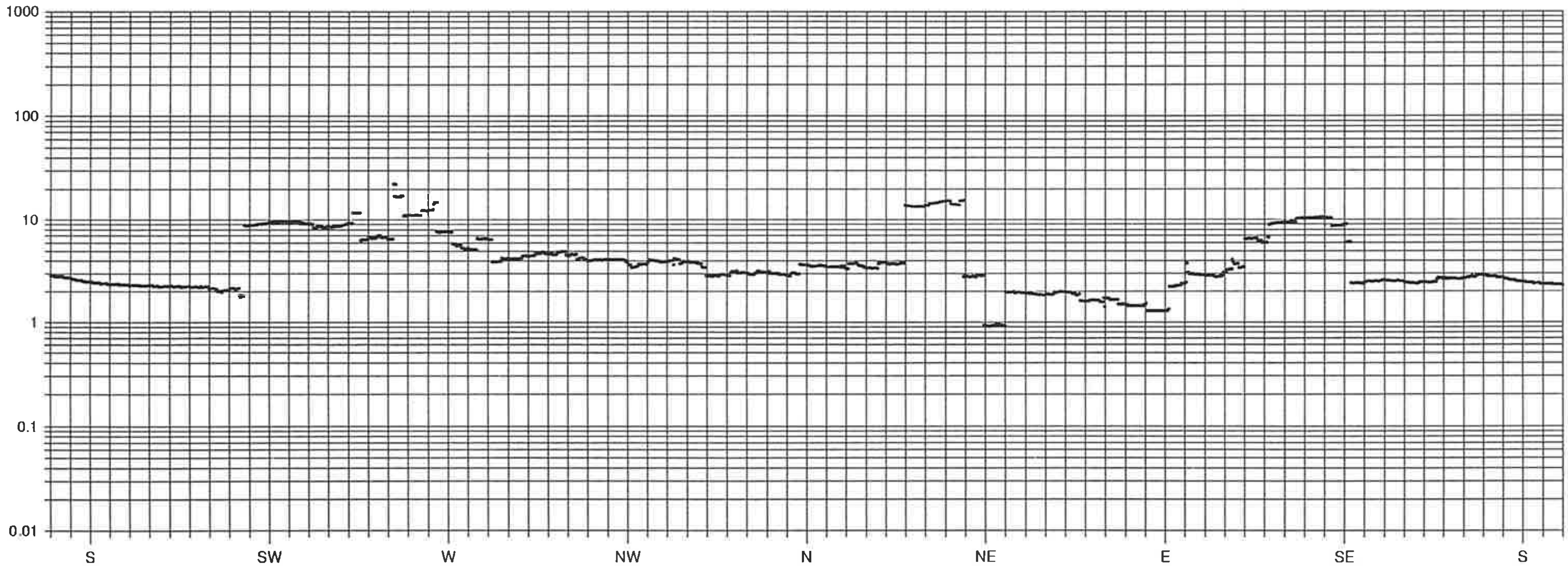

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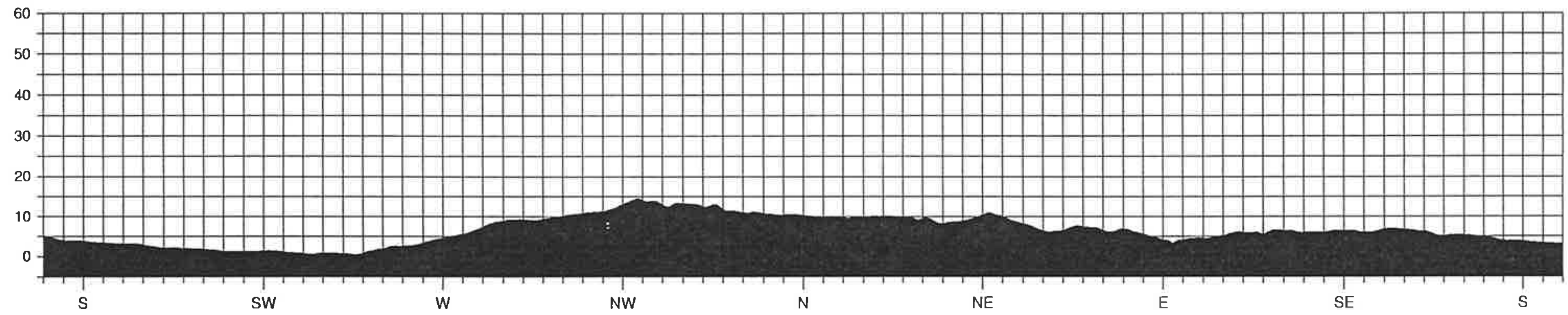

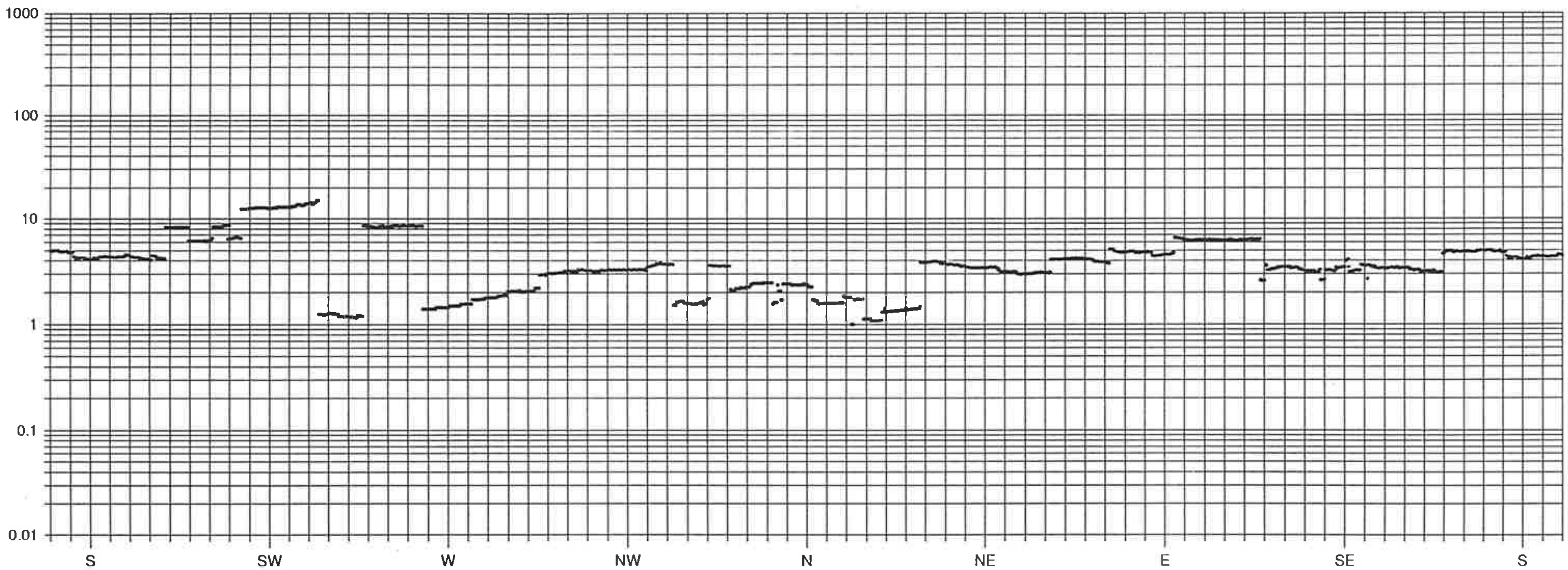

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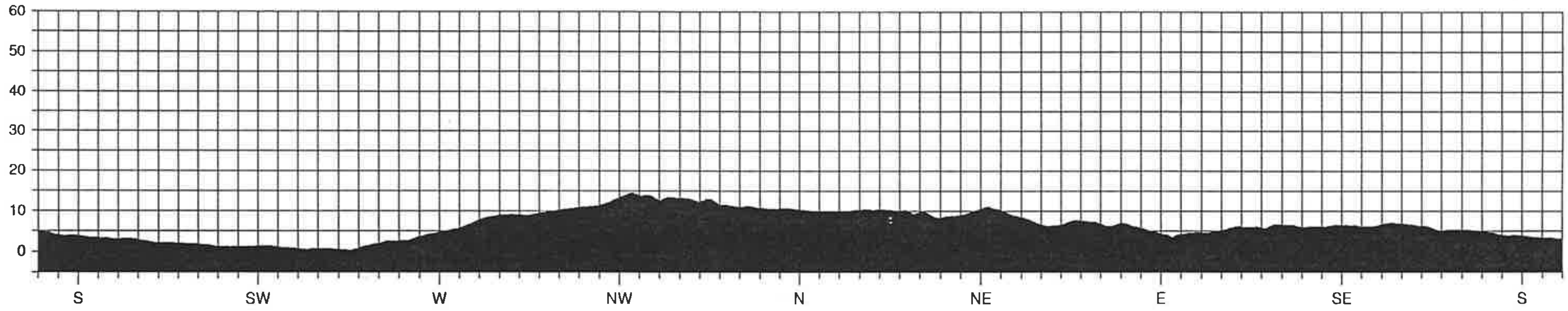

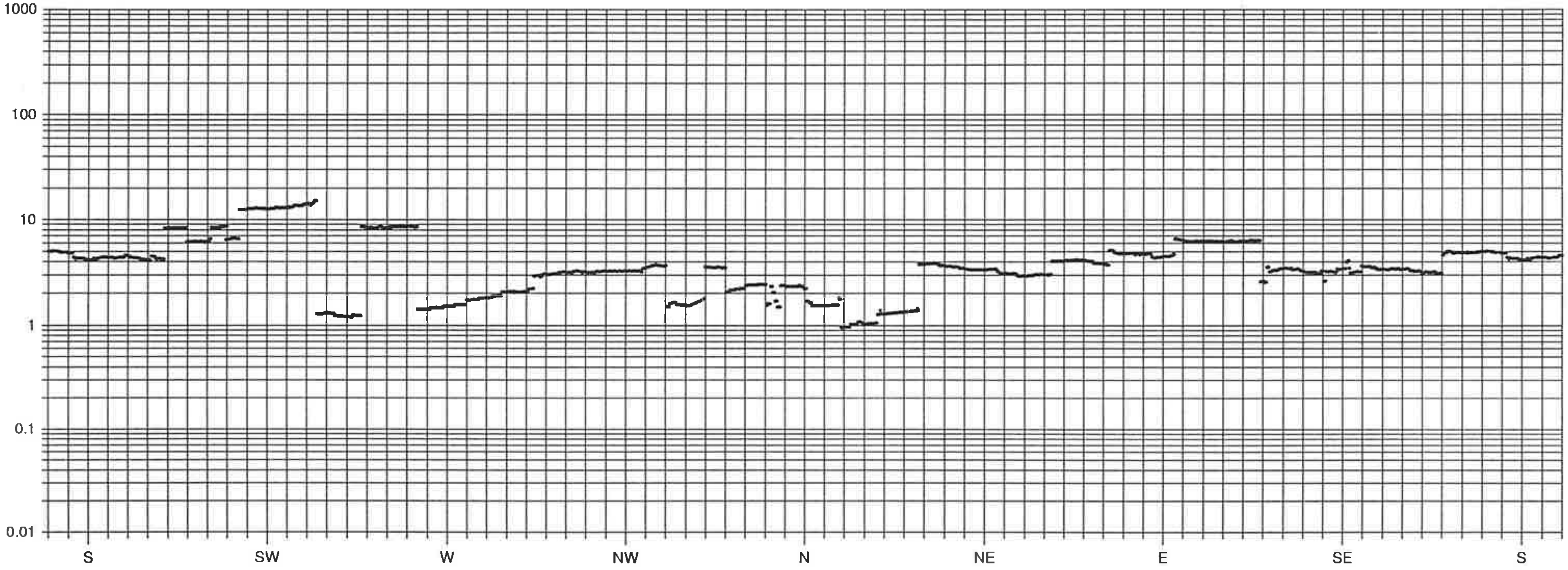

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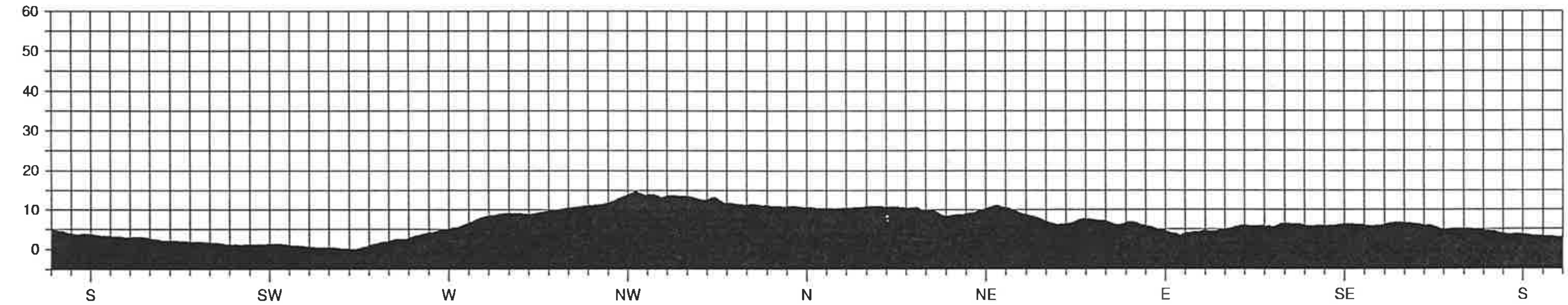

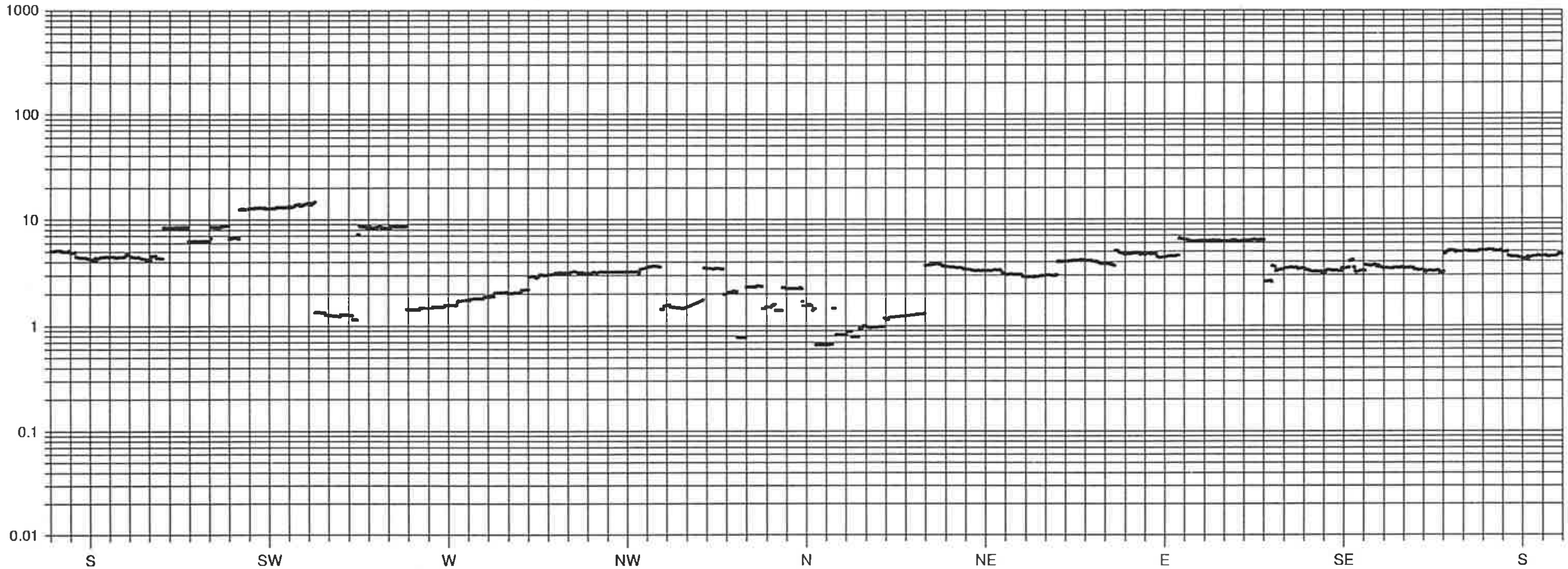

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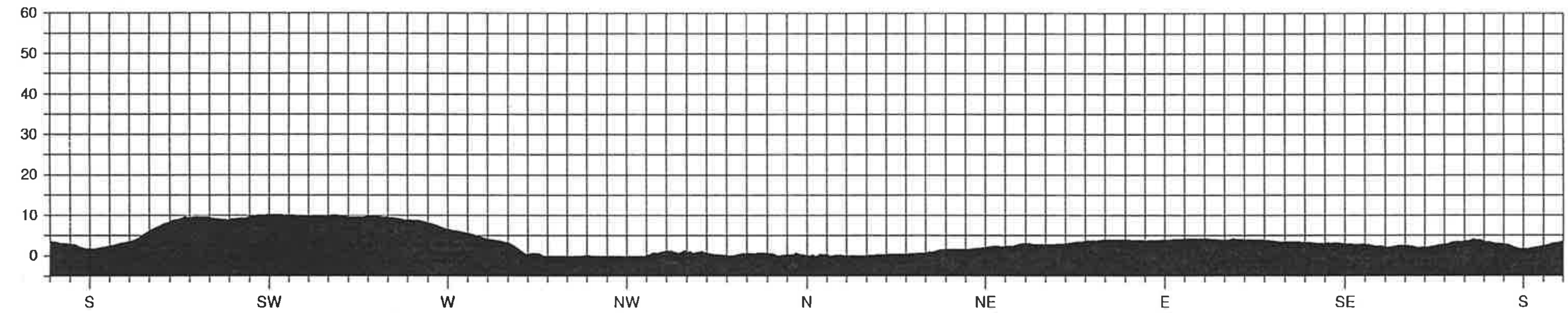

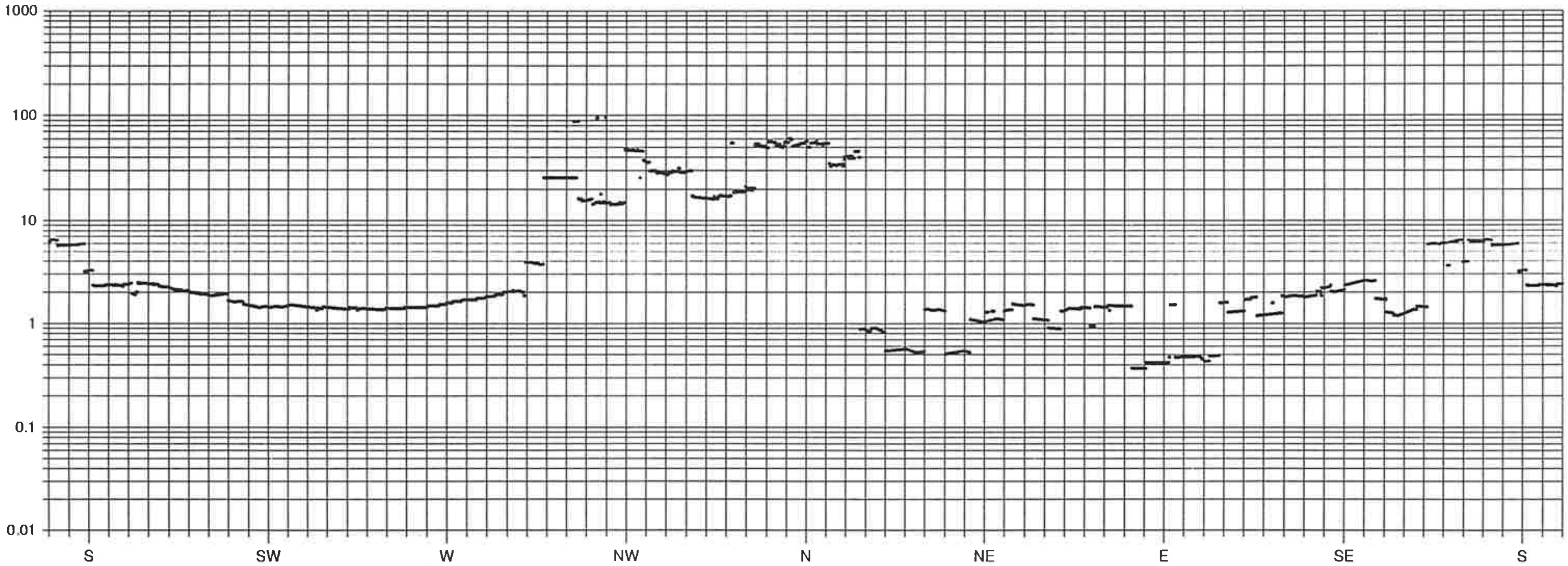

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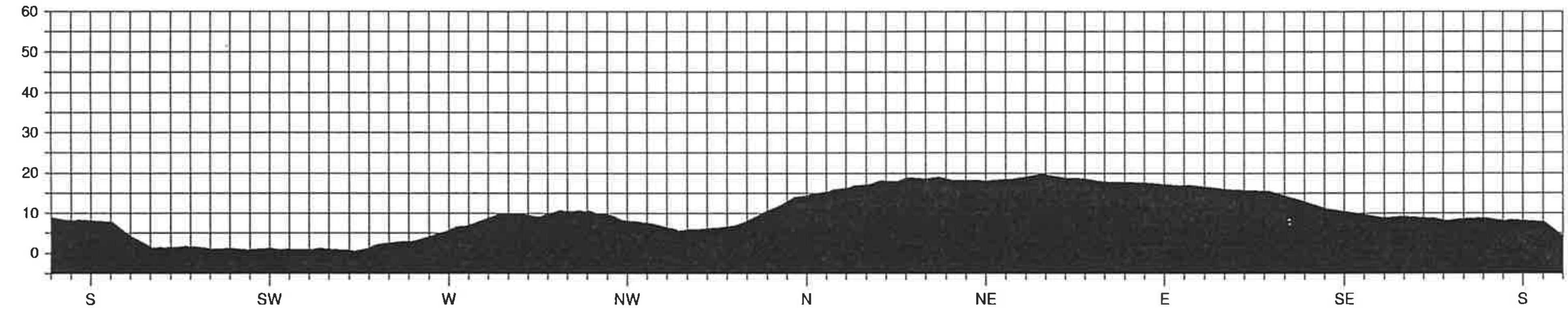
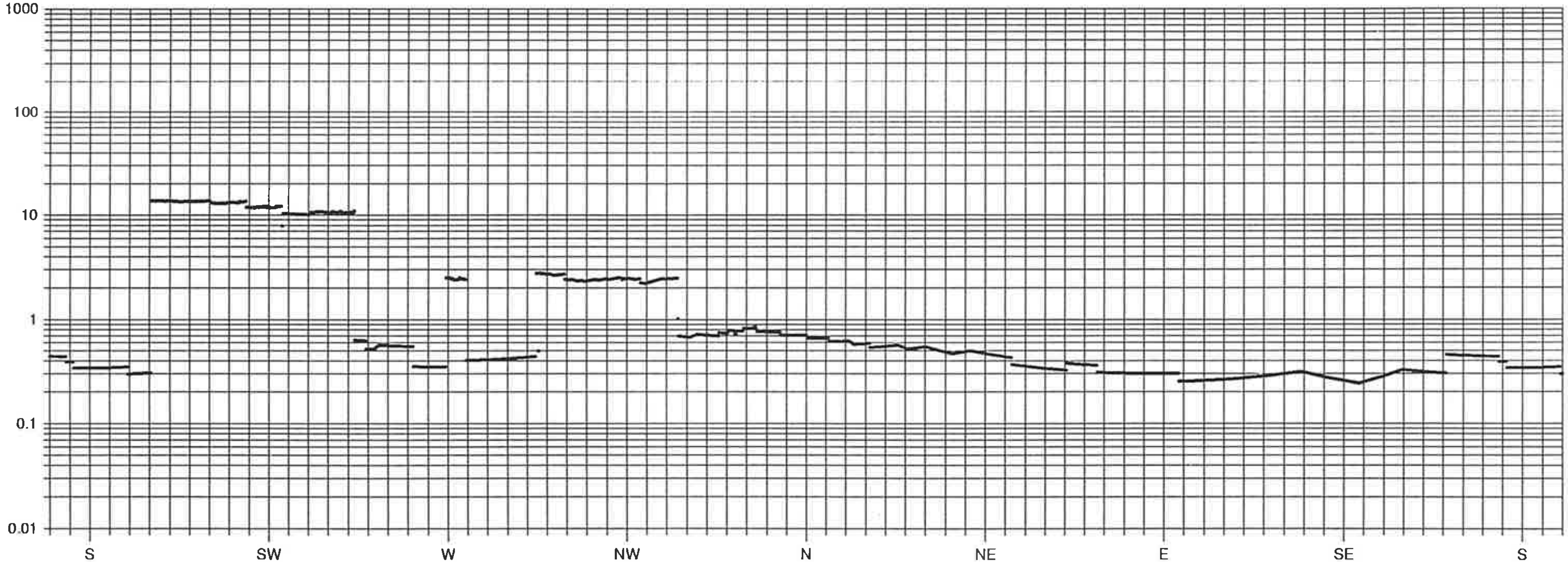




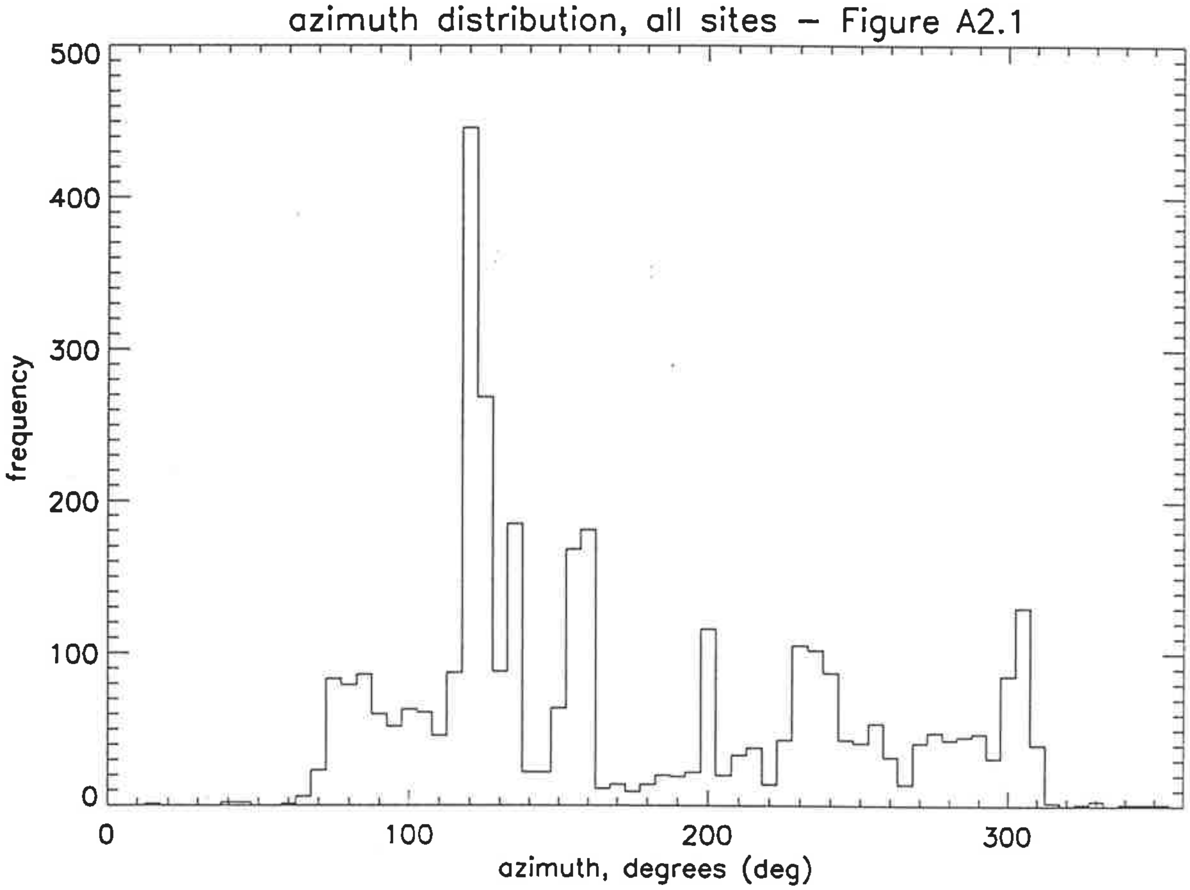
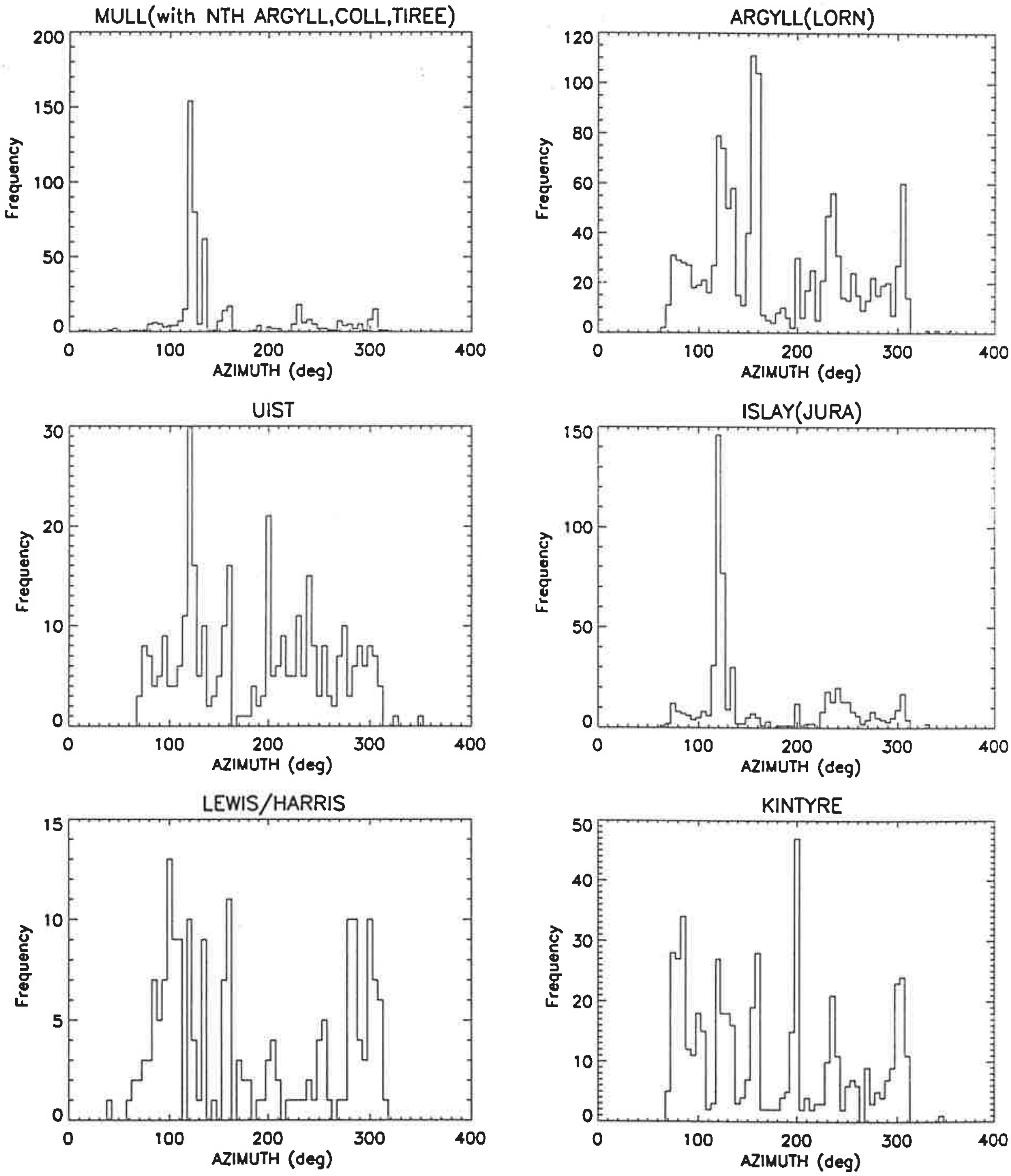

azimuth distribution, all sites – Figure A2.1
500
400
300
200
100
0
frequency
0
100
200
300
azimuth, degrees (deg)

Figure A2.2


MULL(with NTH ARGYLL,COLL,TIREE)
ARGYLL(LORN)
UIST
ISLAY(JURA)
LEWIS/HARRIS
KINTYRE
Frequency
AZIMUTH (deg)

Appendix 3

Maps showing Group 1 and Group Two sites where the green dots are the Group1 or Ruggles' sites and the purple dots are the Group2 sites.

ARGYLL – ZOOM

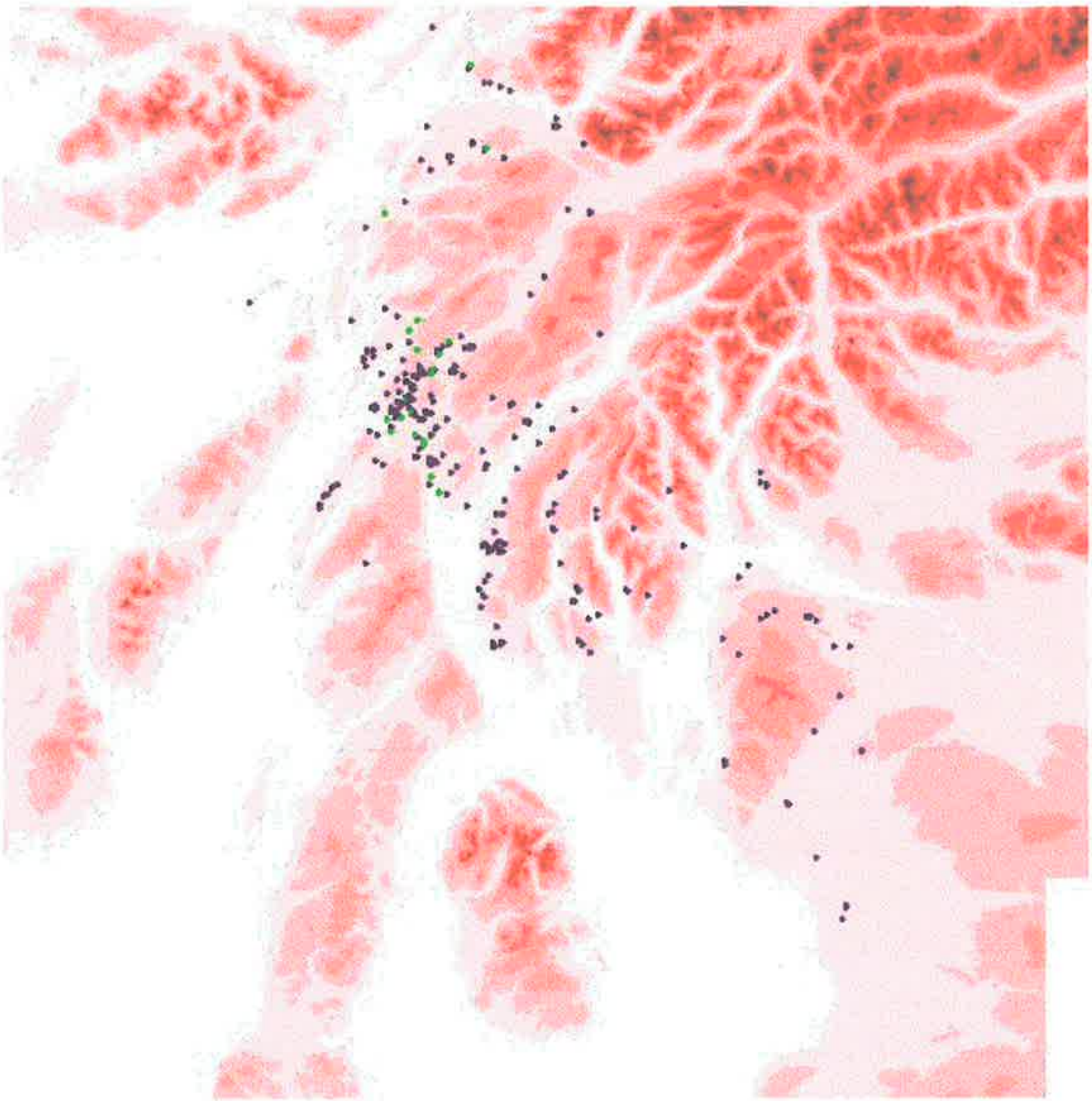


Figure A3.1

Appendix 3

Maps showing Group 1 and Group Two sites where the green dots are the Group1 or Ruggles' sites and the purple dots are the Group2 sites.

MULL -ZOOM

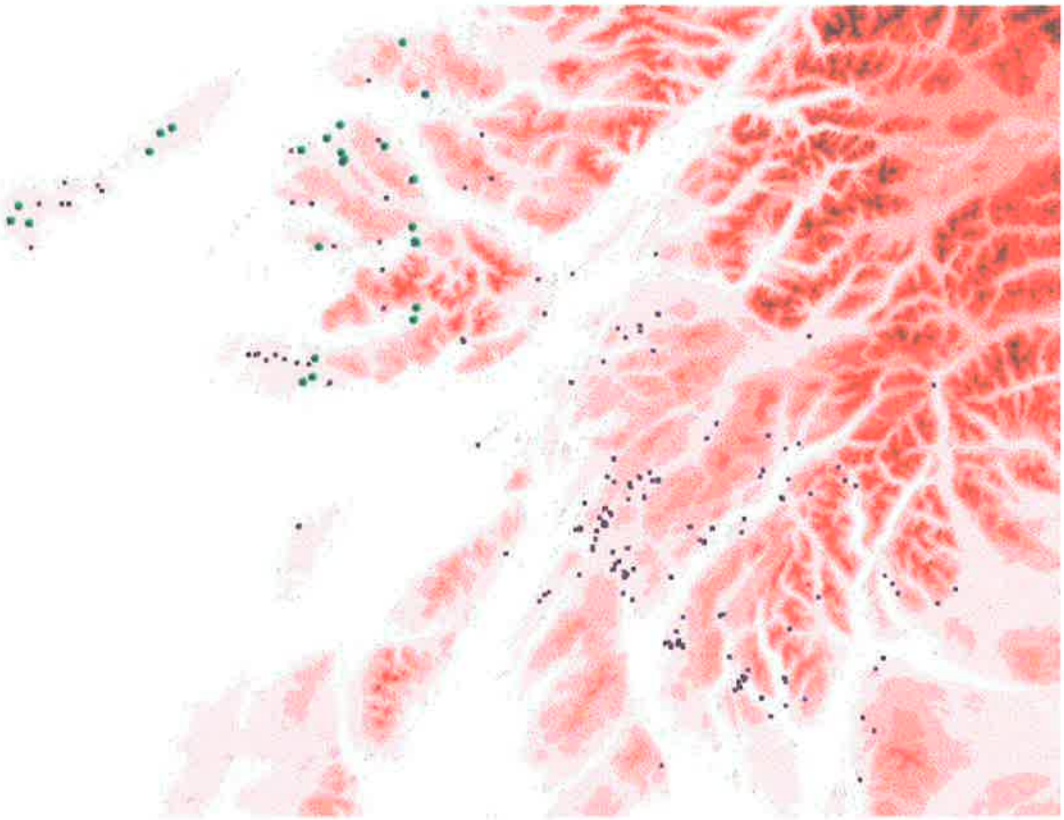


Figure A3.2

Appendix 3

Maps showing Group 1 and Group Two sites where the green dots are the Group1 or Ruggles' sites and the purple dots are the Group2 sites.

LEWIS/HARRIS -ZOOM

Figure A3.3

Appendix 3

Maps showing Group 1 and Group Two sites where the green dots are the Group1 or Ruggles' sites and the purple dots are the Group2 sites.

UIST - ZOOM

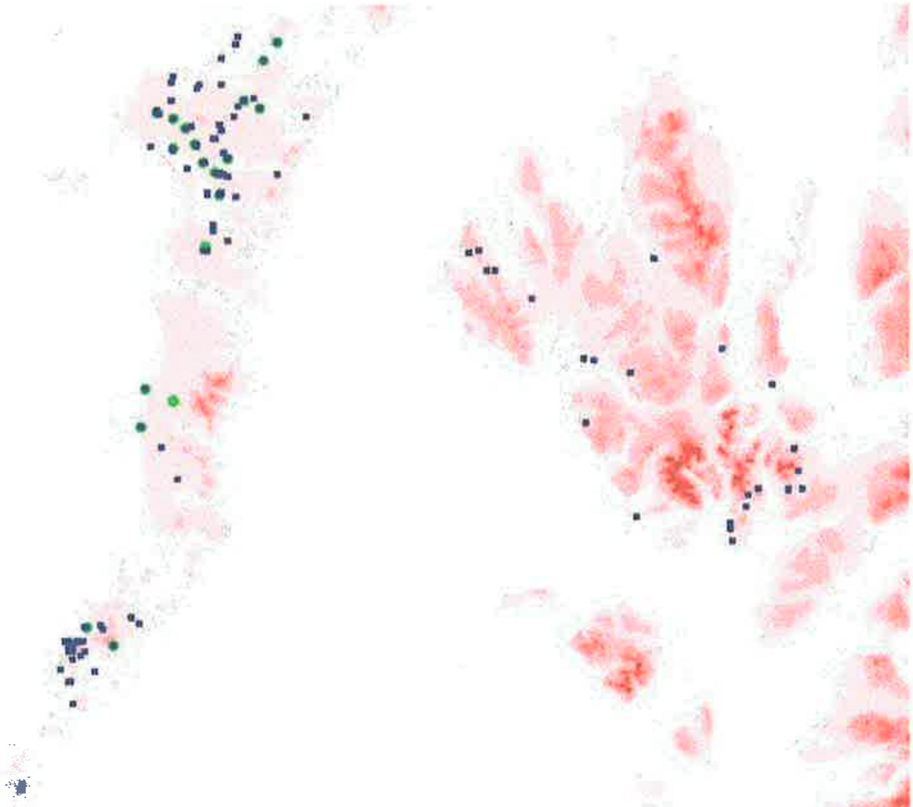


Figure A3.4

Appendix 3

Maps showing Group 1 and Group Two sites where the green dots are the Group1 or Ruggles' sites and the purple dots are the Group2 sites.

ISLAY/JURA - ZOOM

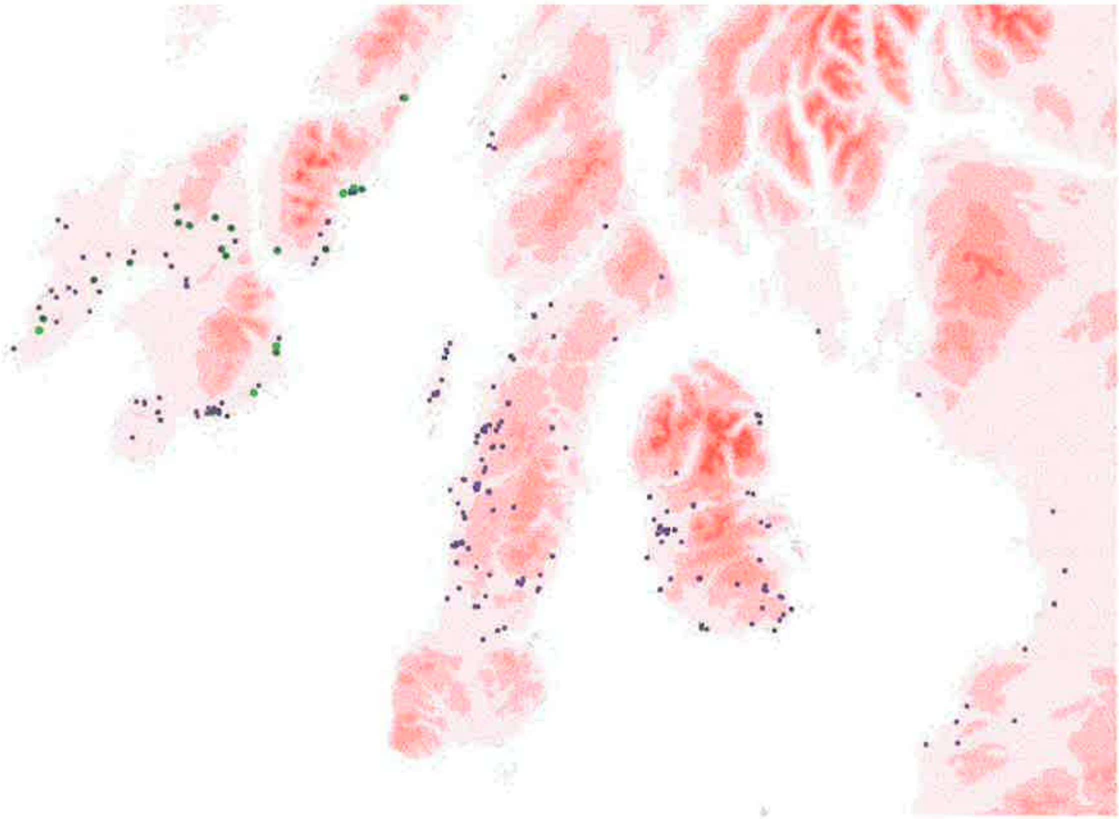


Figure A3.5

Appendix 3

Maps showing Group 1 and Group Two sites where the green dots are the Group1 or Ruggles' sites and the purple dots are the Group2 sites.

KINTYRE

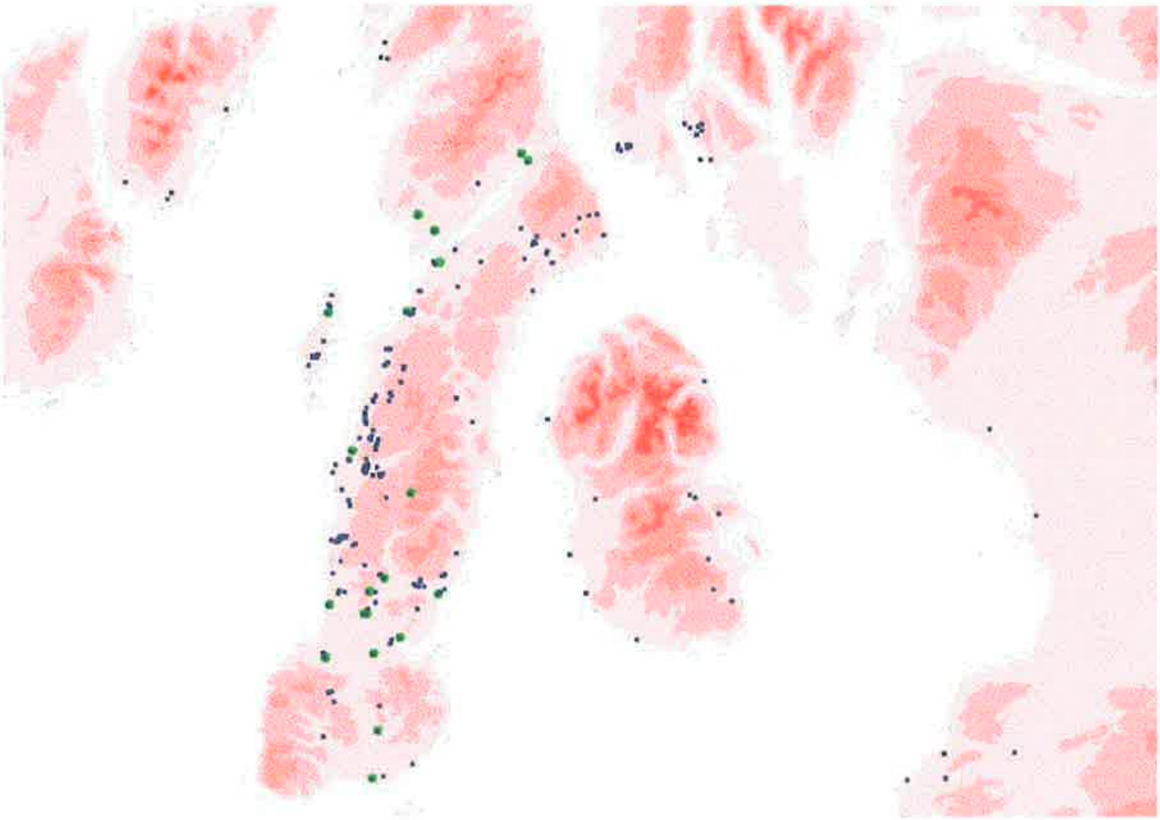
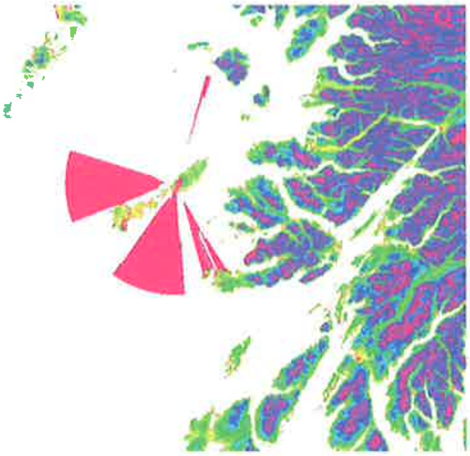


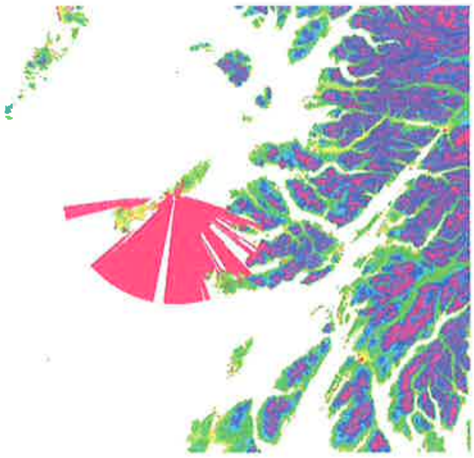
Figure A3.6

Appendix 4



CT1

CT2



CT3

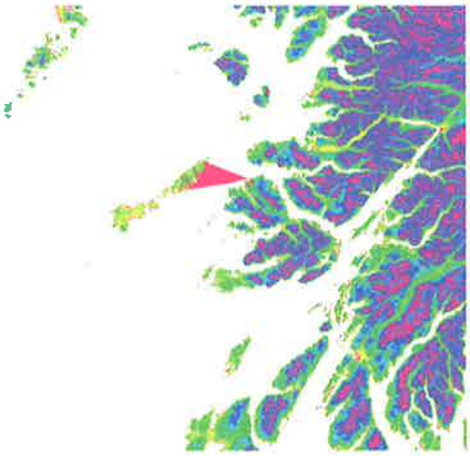
CT7

CT8

CT9

Viewsheds of Coll, Tiree, Mull and North Argyll generated by Grass Roots, modified by K. Simpson. Based on the Ordnance Survey 1:50 000 Landform PANORAMA map with permission of the Controller of Her Majesty's Stationery Office © Crown Copyright

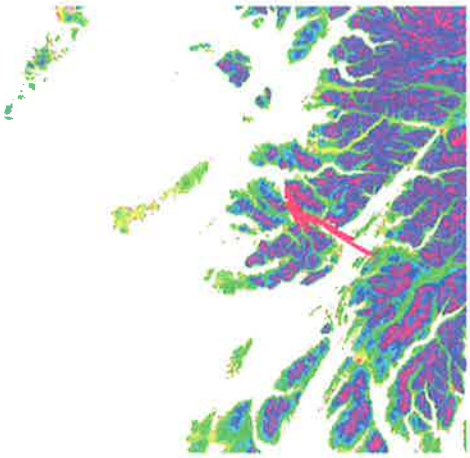
Appendix 4



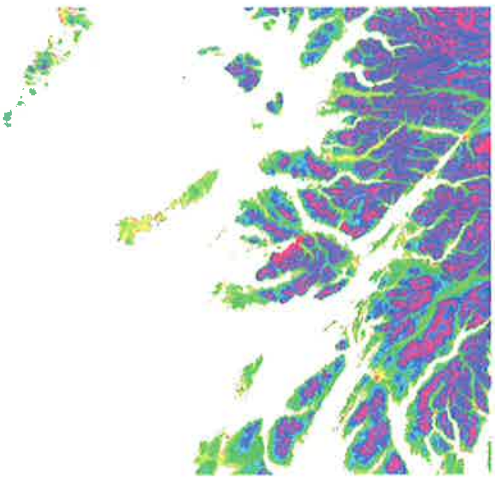
ML1

ML10

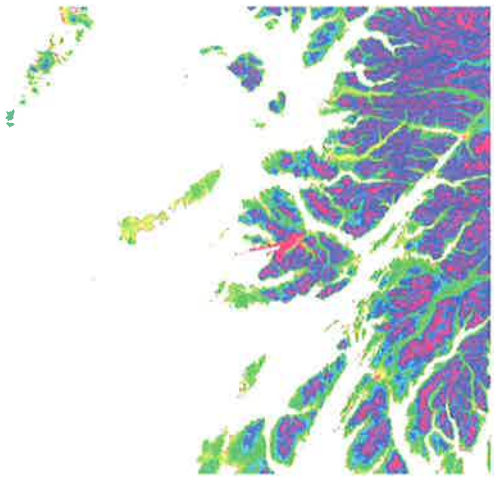
ML11



ML12



ML15

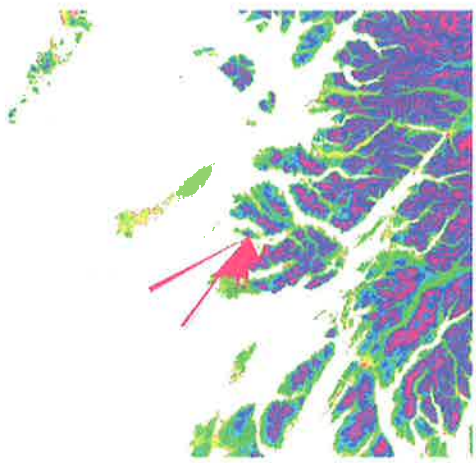


ML16a

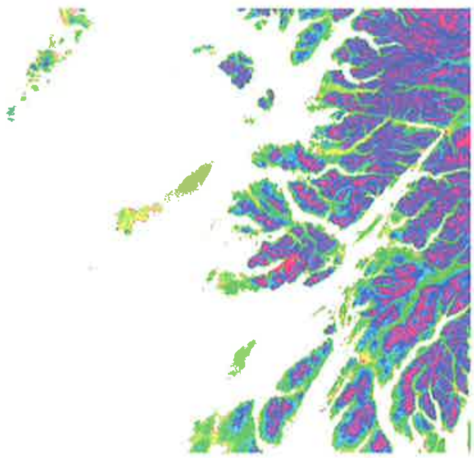
Viewsheds of Coll, Tiree, Mull and North Argyll generated by Grass Roots, modified by K. Simpson. Based on the Ordnance Survey 1:50 000 Landform PANORAMA map with permission of the Controller of Her Majesty's Stationery Office © Crown Copyright

Appendix 4

ML16b **ML16c**



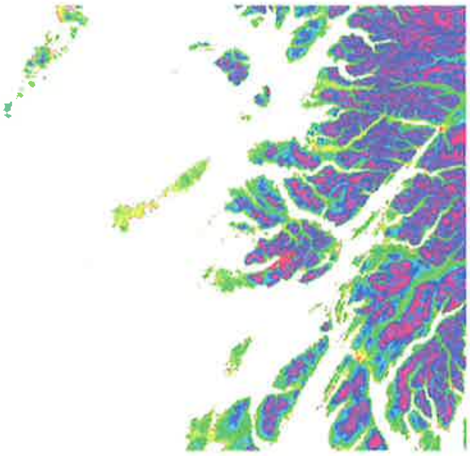
ML18 **ML2**



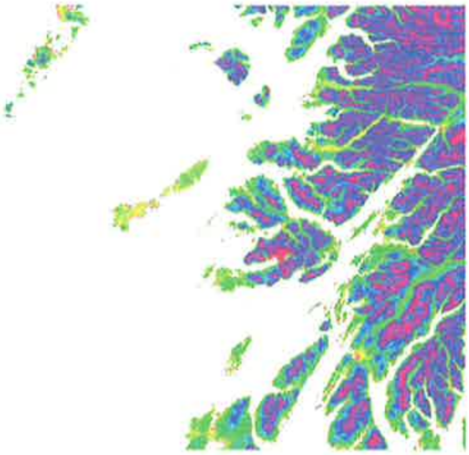
ML25a **ML25b**

Viewsheds of Coll, Tiree, Mull and North Argyll generated by Grass Roots, modified by K. Simpson. Based on the Ordnance Survey 1:50 000 Landform PANORAMA map with permission of the Controller of Her Majesty's Stationery Office © Crown Copyright

Appendix 4



ML25c

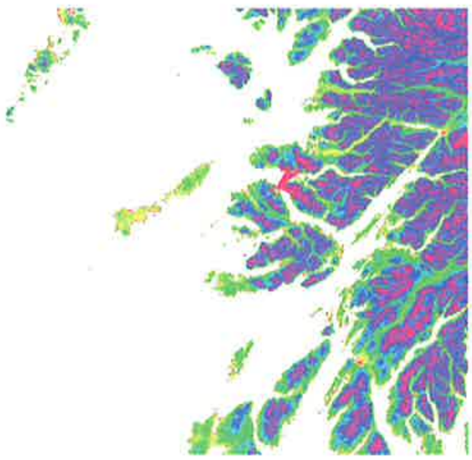


ML27

ML30

ML31

ML33



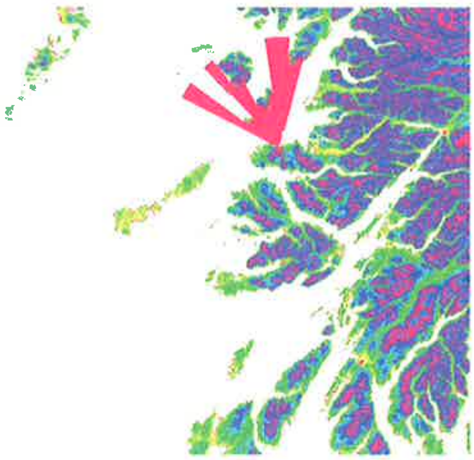
ML4

Viewsheds of Coll, Tiree, Mull and North Argyll generated by Grass Roots, modified by K. Simpson. Based on the Ordnance Survey 1:50 000 Landform PANORAMA map with permission of the Controller of Her Majesty's Stationery Office © Crown Copyright

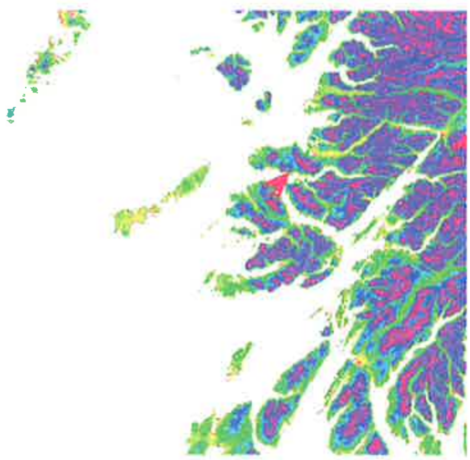
Appendix 4

ML7

ML9



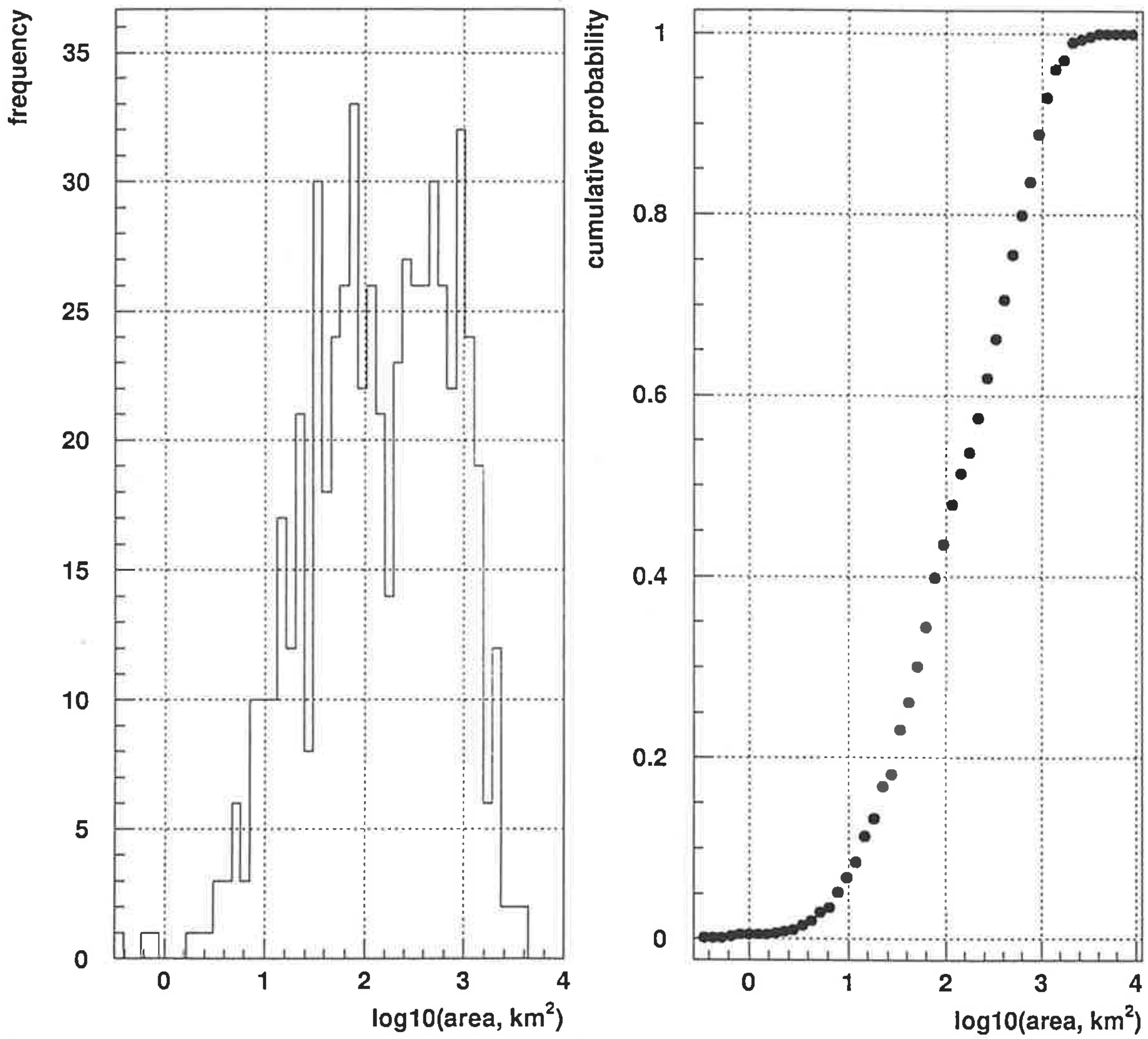
NA1



NA3

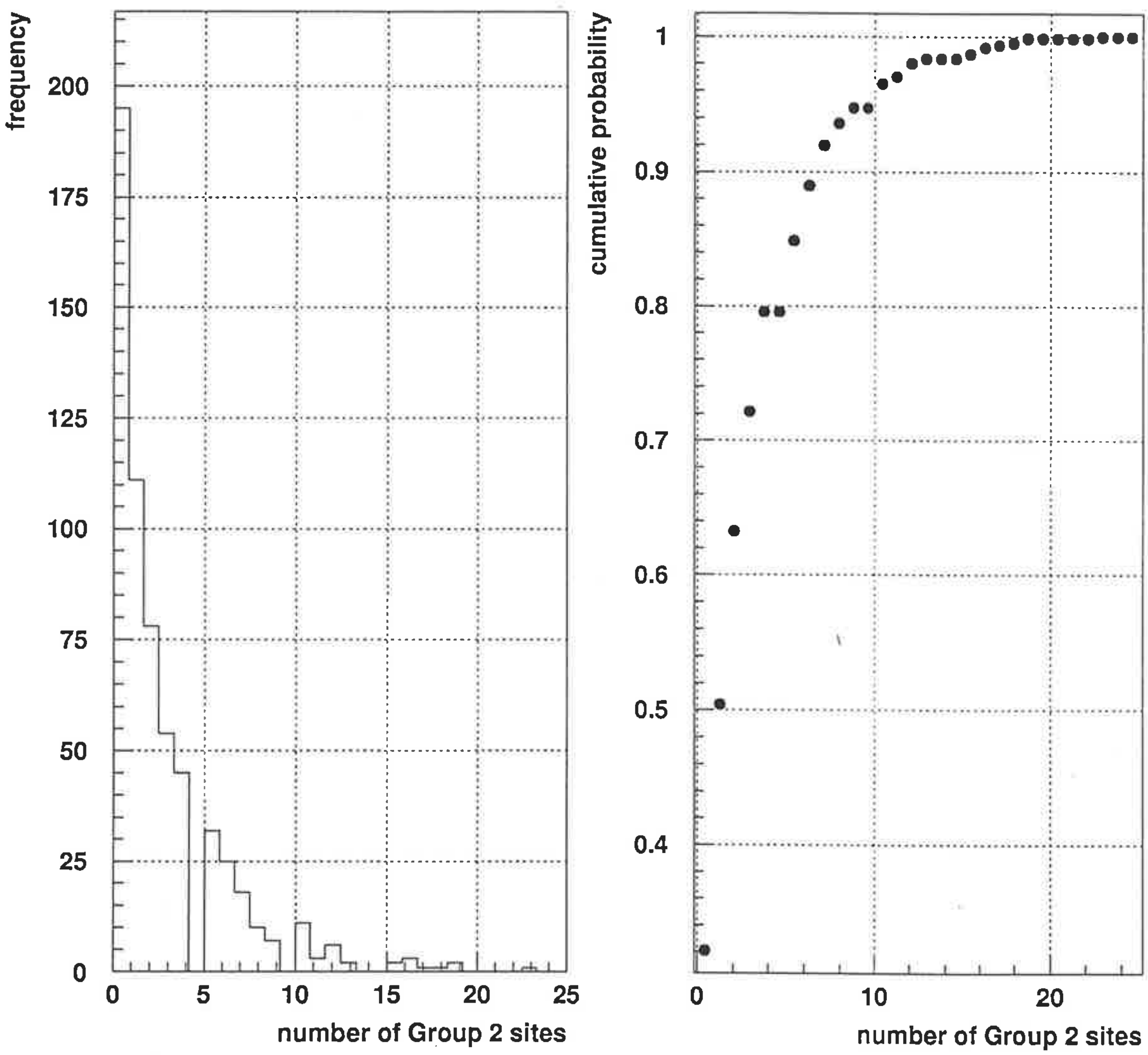
Viewsheds of Coll, Tiree, Mull and North Argyll generated by Grass Roots, modified by K. Simpson. Based on the Ordnance Survey 1:50 000 Landform PANORAMA map with permission of the Controller of Her Majesty's Stationery Office © Crown Copyright

Figure A5.1



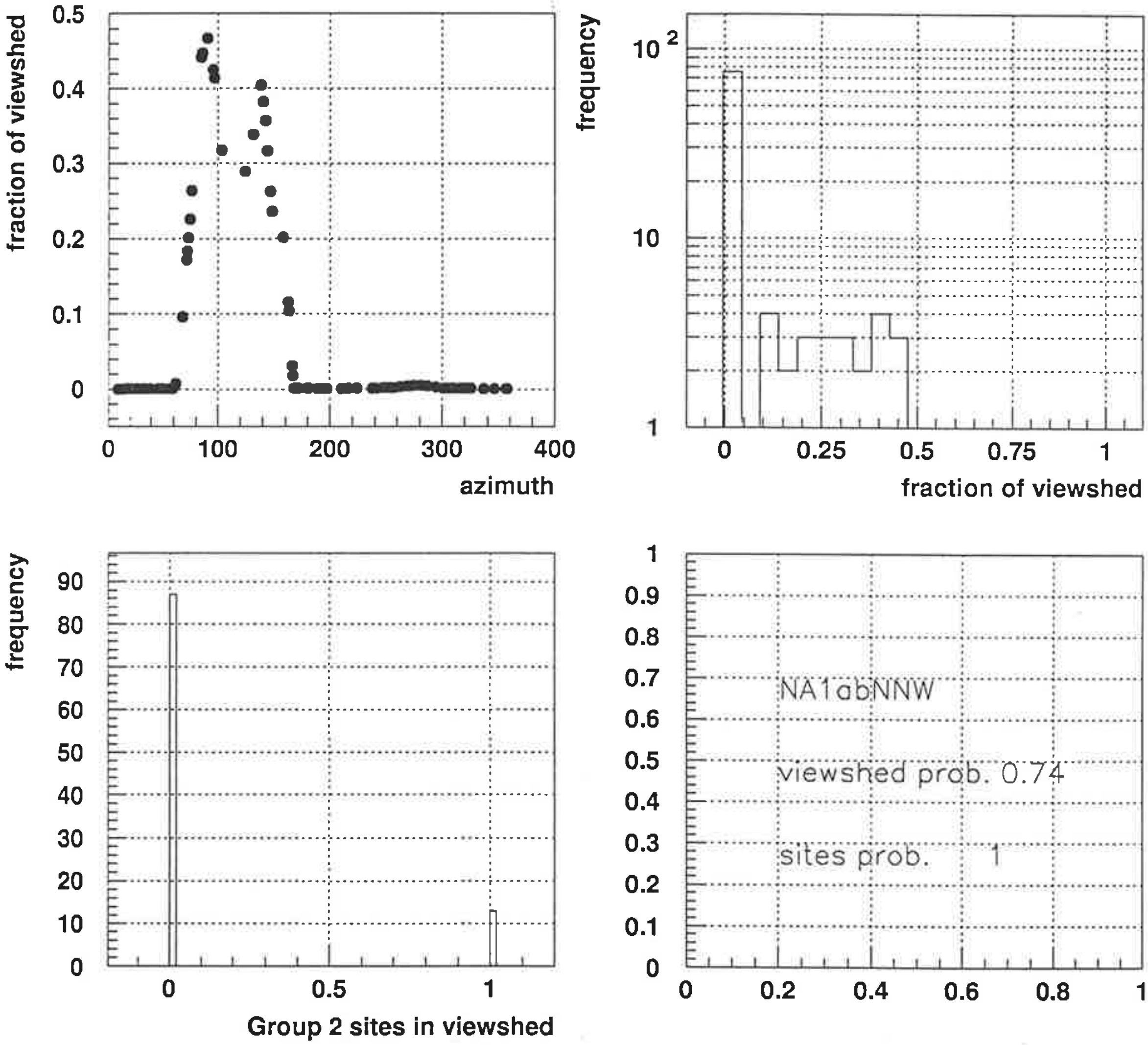
frequency
35
30
25
20
15
10
5
0
0
1
2
3
4
log10(area, km²)
cumulative probability
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
log10(area, km²)

Figure A5.2



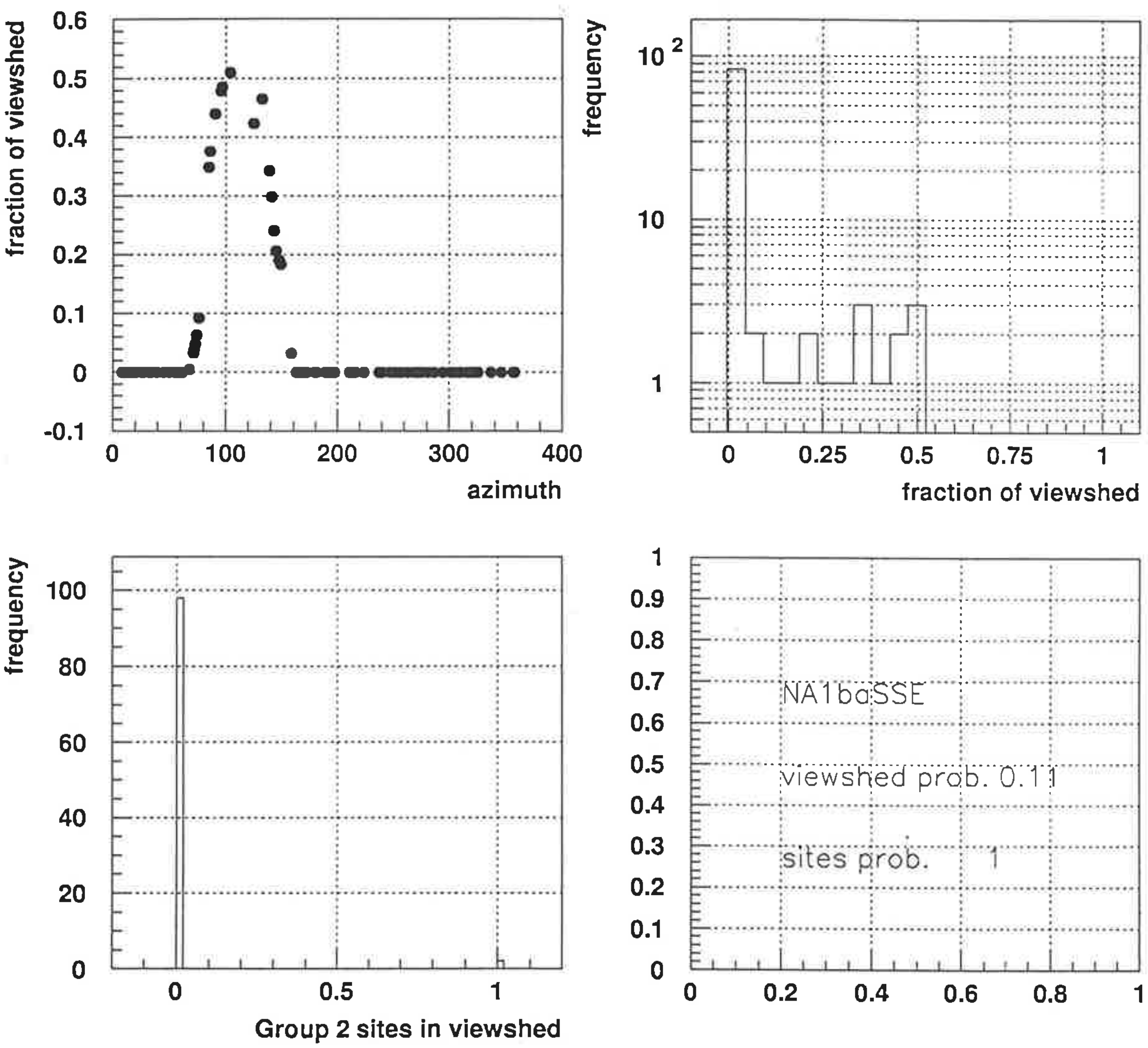
frequency
200
175
150
125
100
75
50
25
0
0
5
10
15
20
25
number of Group 2 sites
cumulative probability
1
0.9
0.8
0.7
0.6
0.5
0.4
0
10
20
number of Group 2 sites

Figure A5.3



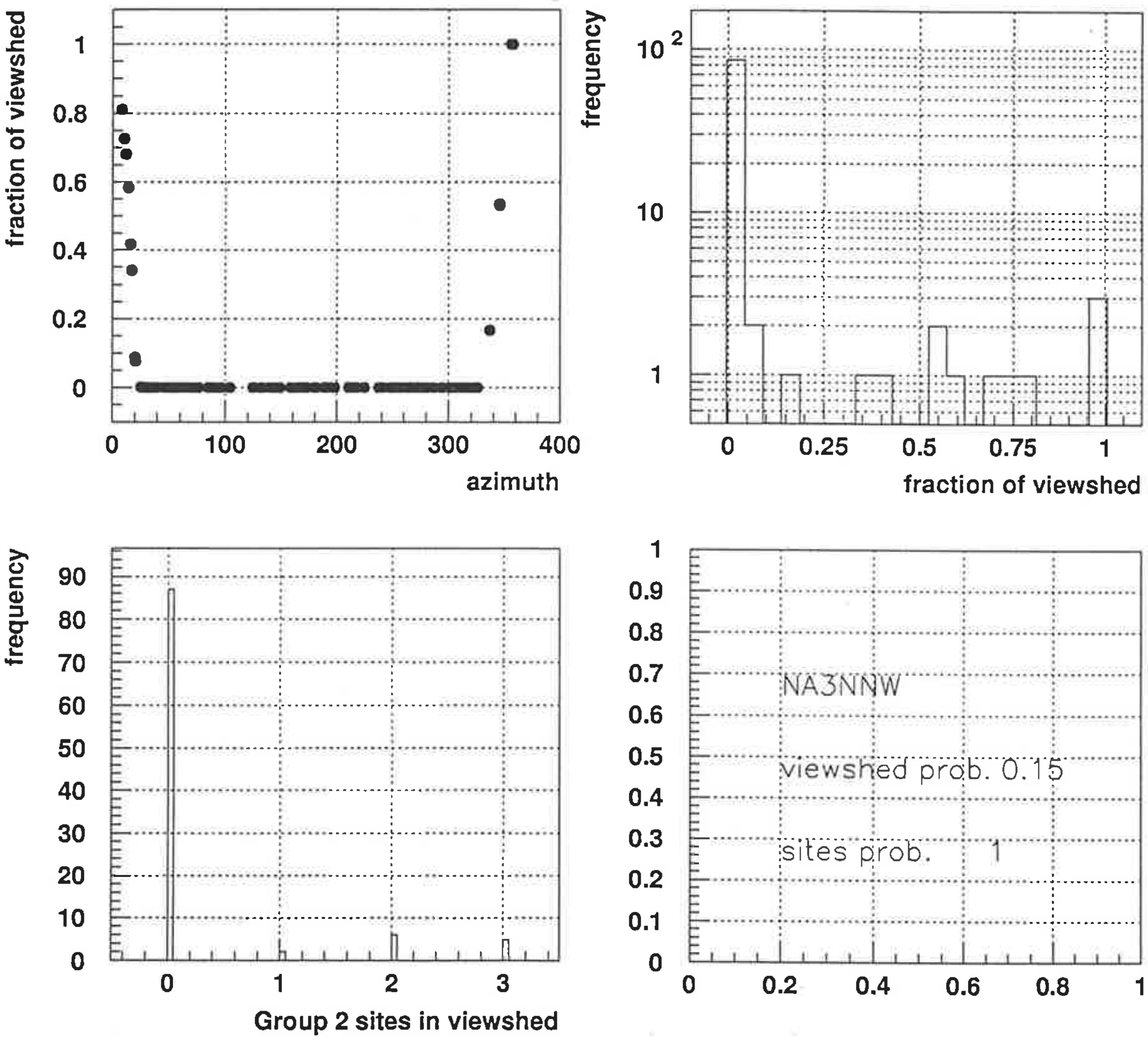
fraction of viewshed
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
azimuth
frequency
10 2
10
1
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
90
80
70
60
50
40
30
20
10
0
0
0.5
1
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
NA1abNNW
viewshed prob. 0.74
sites prob. 1

Figure A5.4



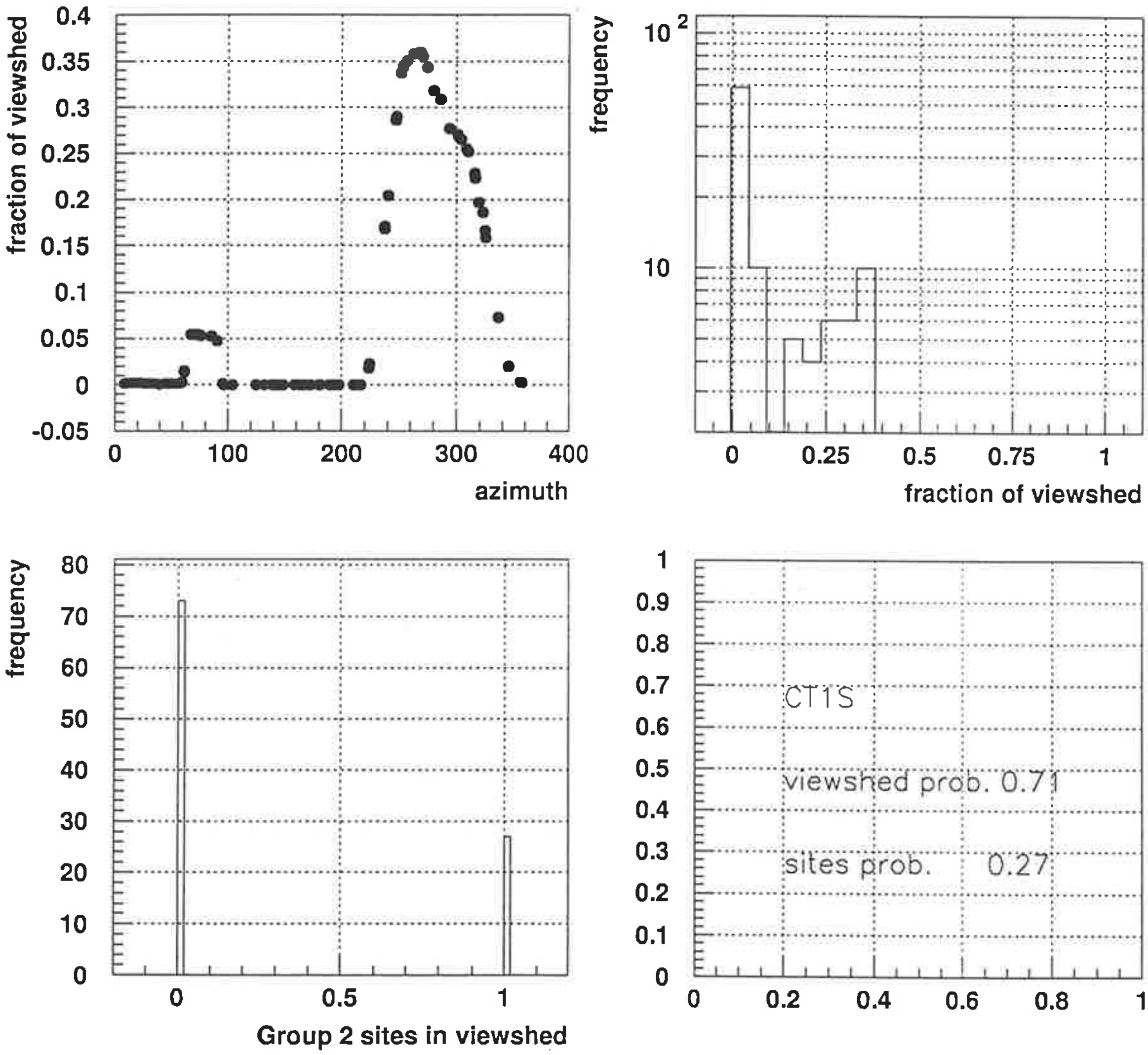
fraction of viewshed
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
100
200
300
400
azimuth
frequency
10 2
10
1
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
100
80
60
40
20
0
0
0.5
1
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
NA1baSSE
viewshed prob. 0.11
sites prob. 1

Figure A5.5



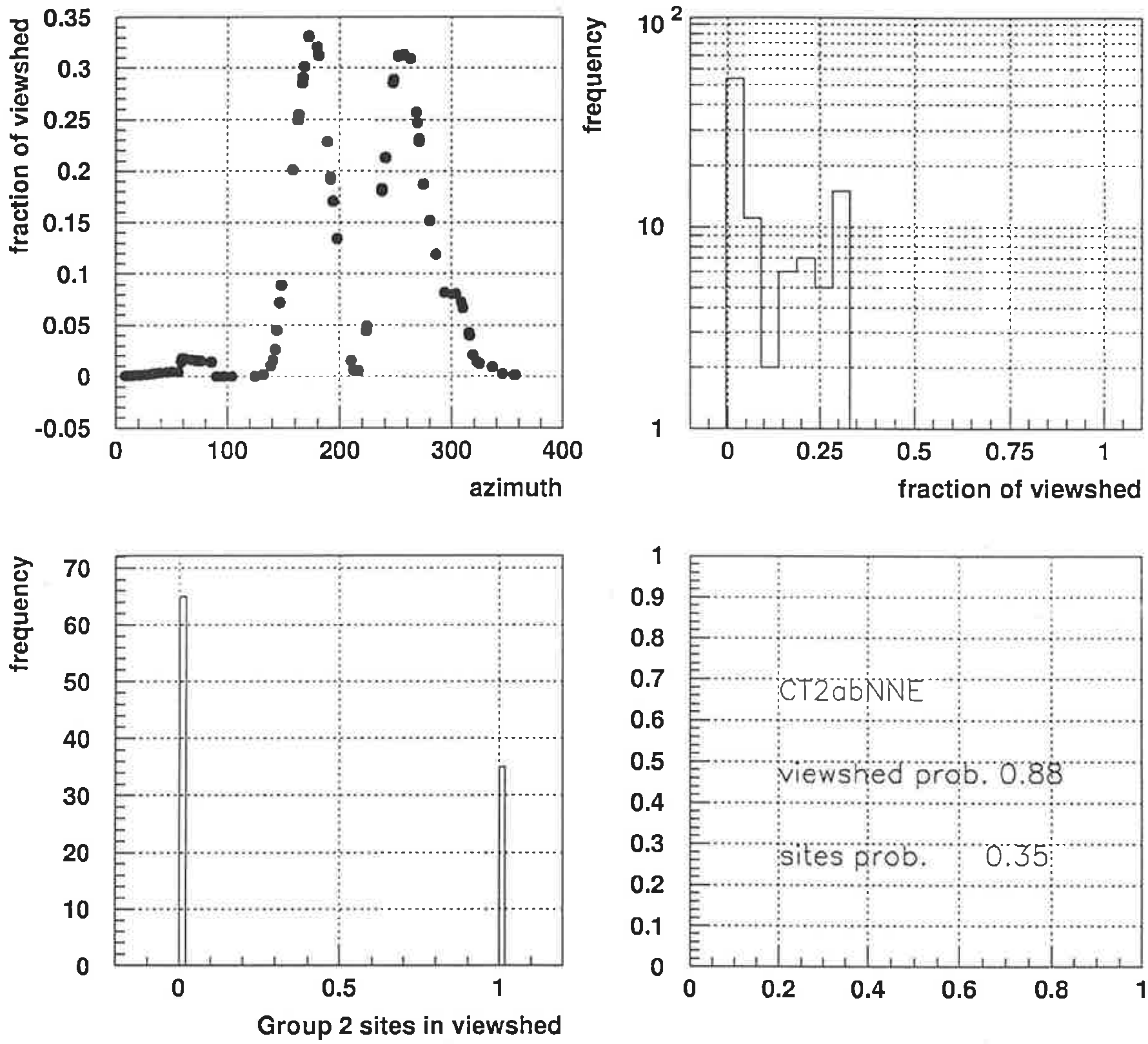
fraction of viewshed
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
azimuth
frequency
10 2
10
1
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
90
80
70
60
50
40
30
20
10
0
0
1
2
3
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
NA3NNW
viewshed prob. 0.15
sites prob. 1

Figure A5.6



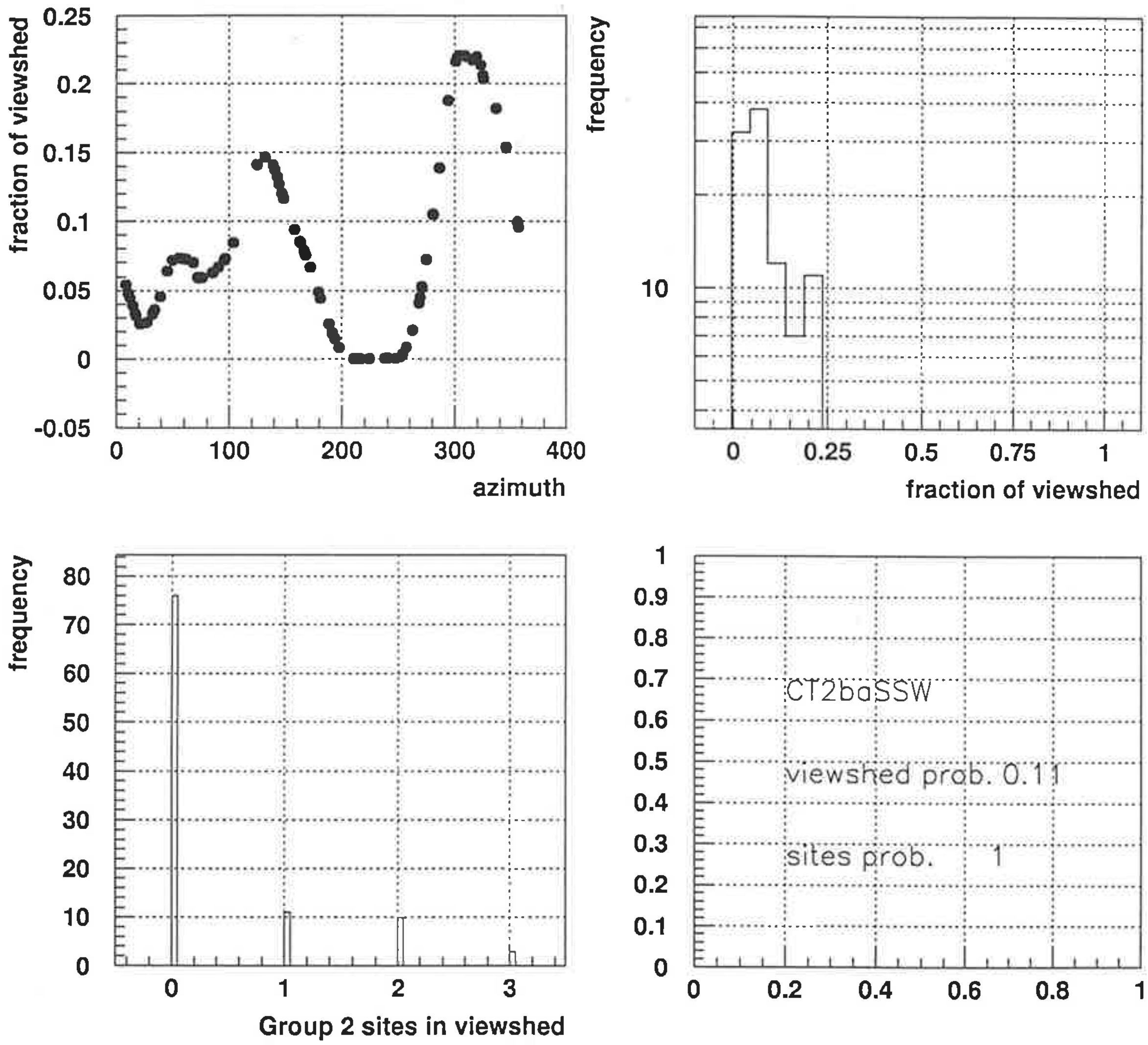
fraction of viewshed
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
100
200
300
400
azimuth
frequency
10^2
10
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
80
70
60
50
40
30
20
10
0
0
0.5
1
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
CT1S
viewshed prob. 0.71
sites prob. 0.27

Figure A5.7



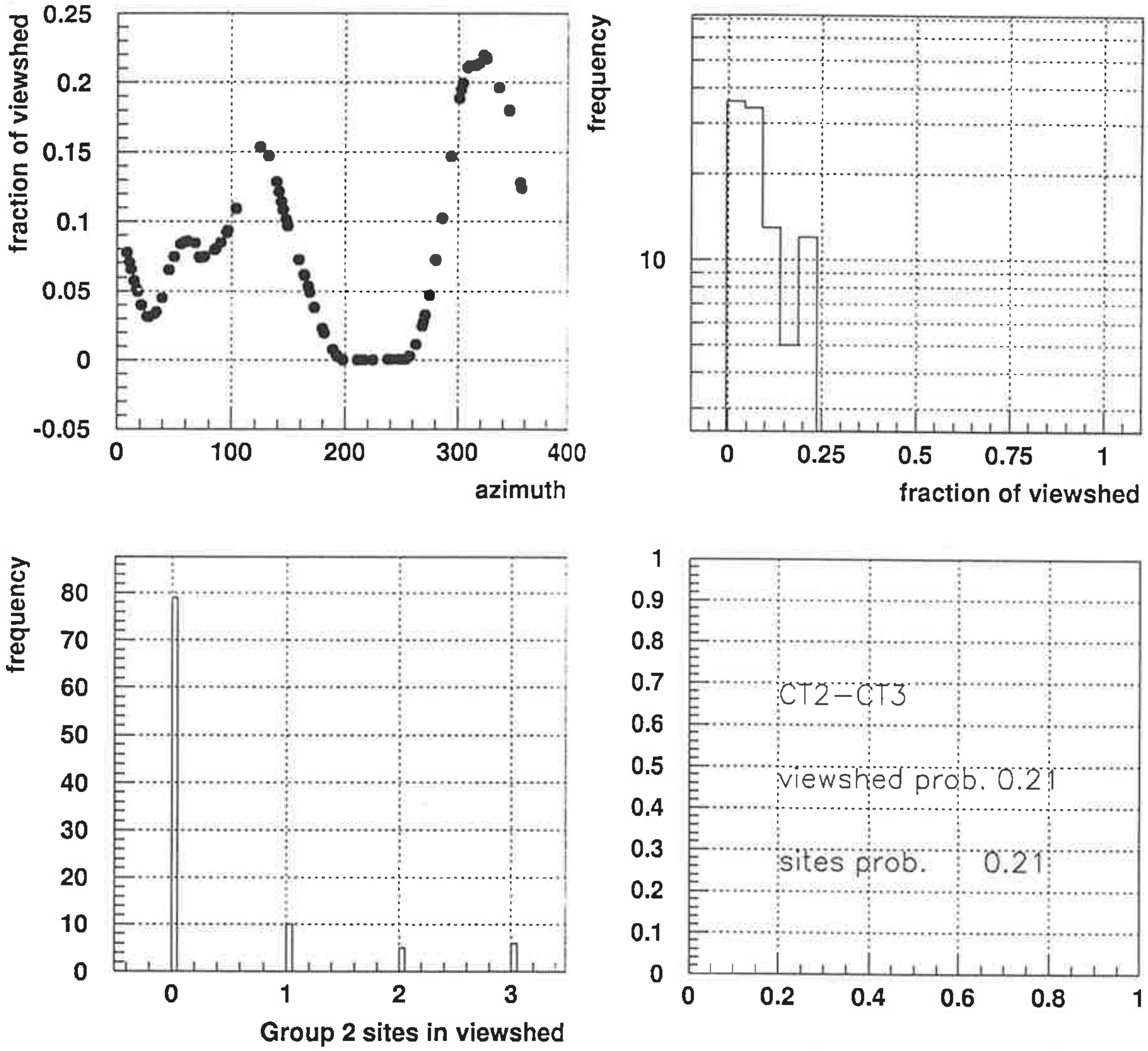
fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
CT2abNNE
viewshed prob. 0.88
sites prob. 0.35

Figure A5.8



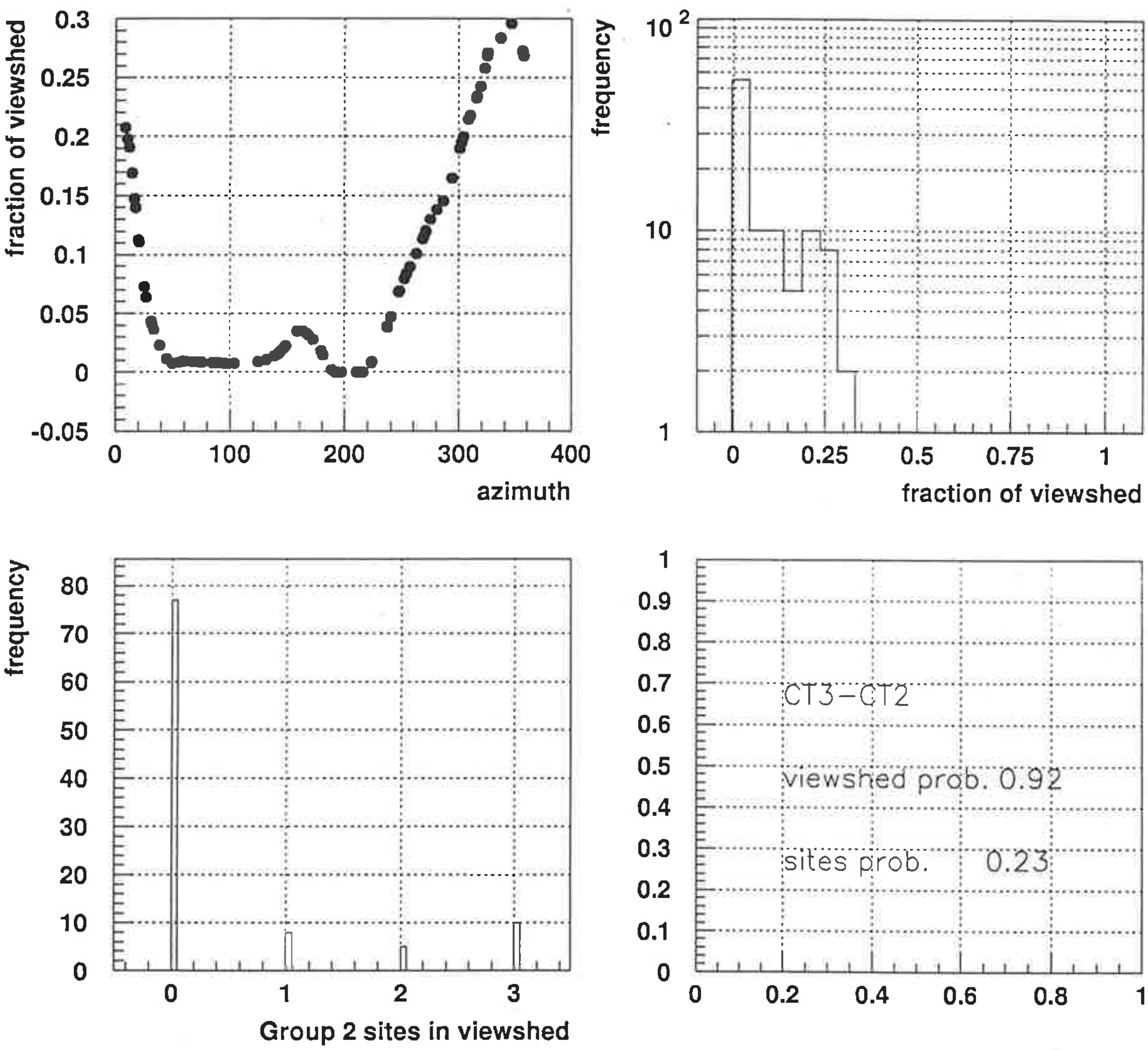
fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
CT2baSSW
viewshed prob. 0.11
sites prob. 1

Figure A5.9



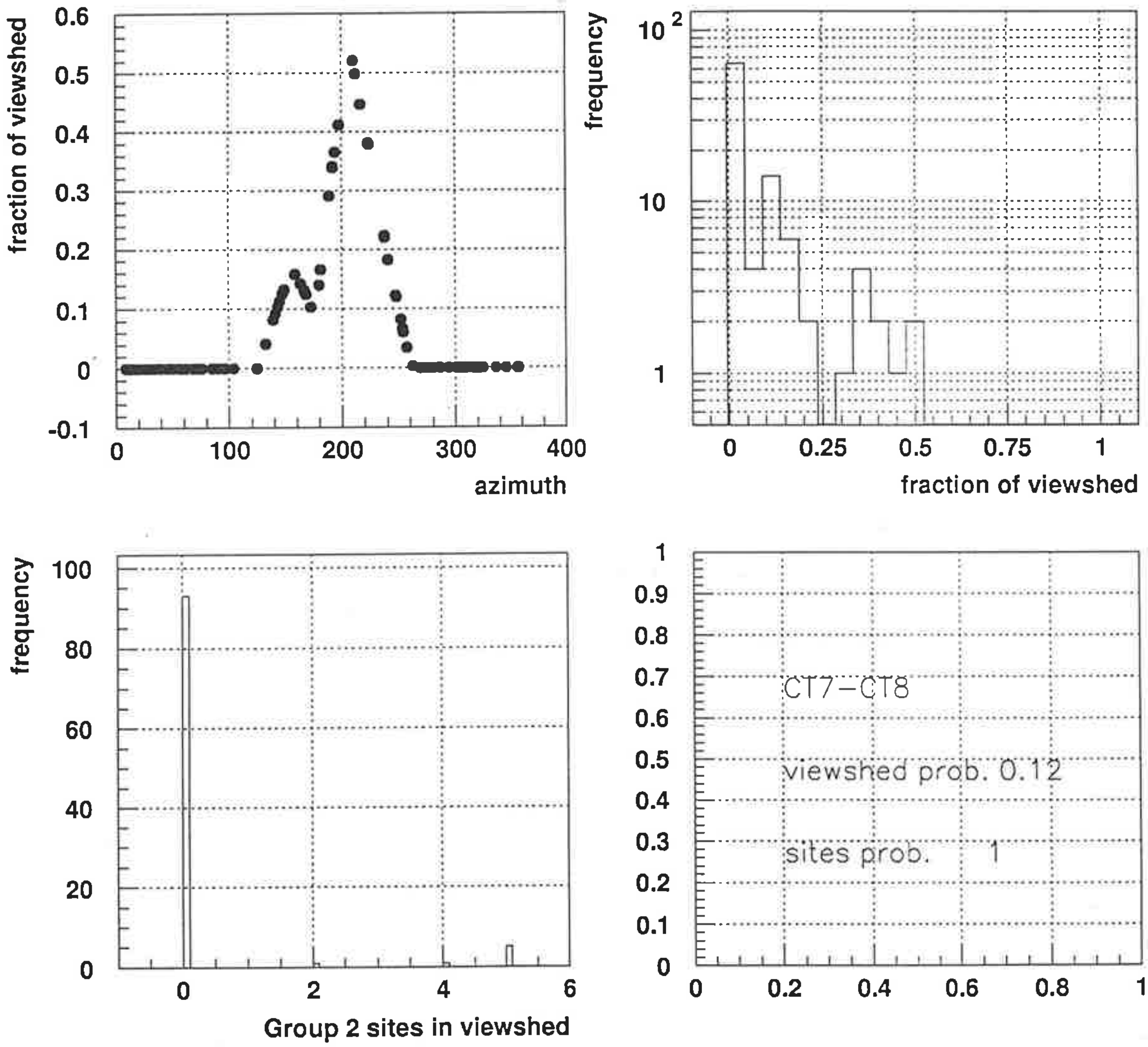
fraction of viewshed
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
100
200
300
400
azimuth
frequency
10
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
80
70
60
50
40
30
20
10
0
0
1
2
3
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
CT2–CT3
viewshed prob. 0.21
sites prob. 0.21

Figure A5.10



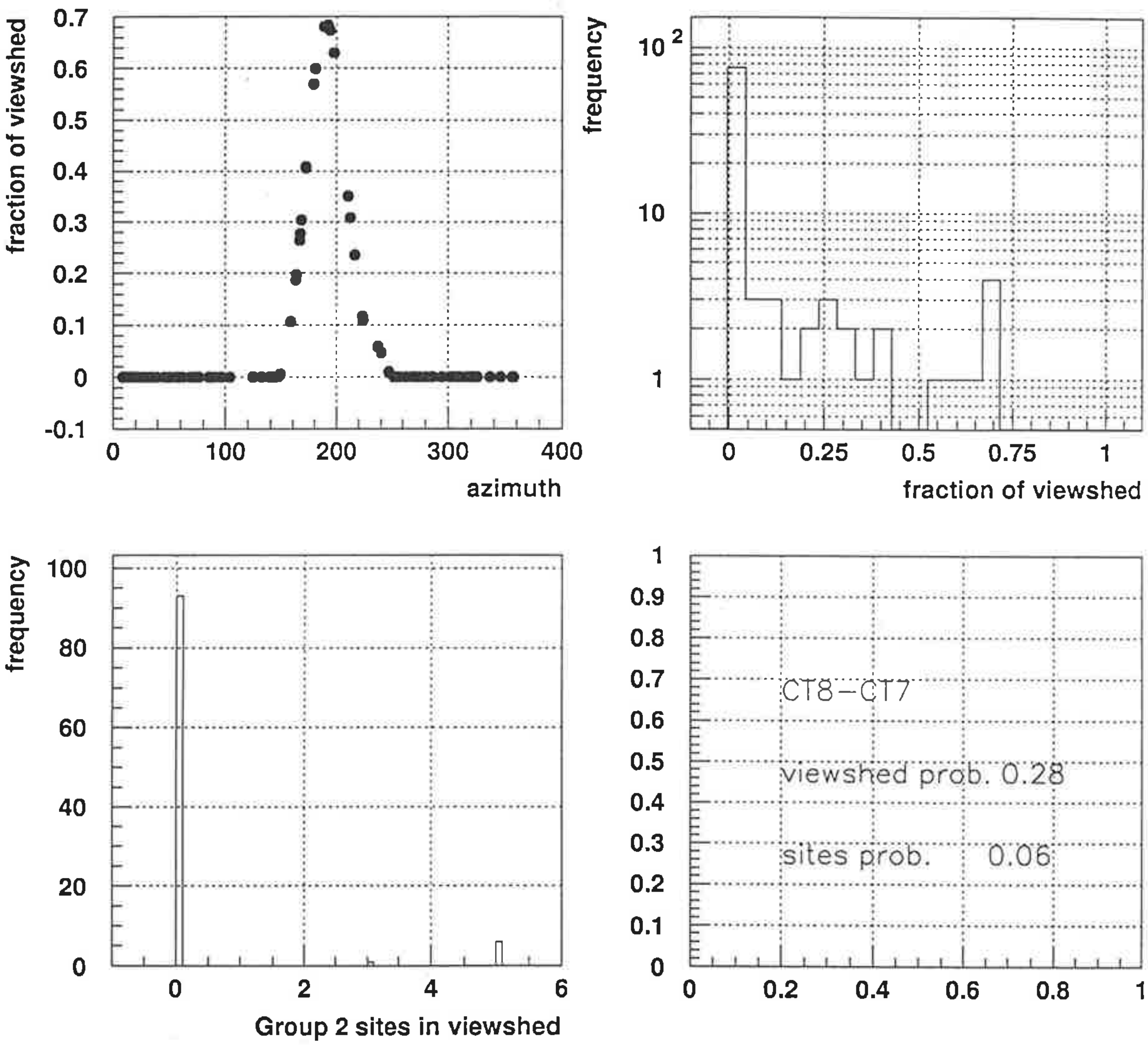
fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
CT3–CT2
viewshed prob. 0.92
sites prob. 0.23

Figure A5.11



fraction of viewshed
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
100
200
300
400
azimuth
frequency
10^2
10
1
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
100
80
60
40
20
0
0
2
4
6
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
CT7−CT8
viewshed prob. 0.12
sites prob. 1

Figure A5.12



fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
CT8–CT7
viewshed prob. 0.28
sites prob. 0.06

Figure A5.13

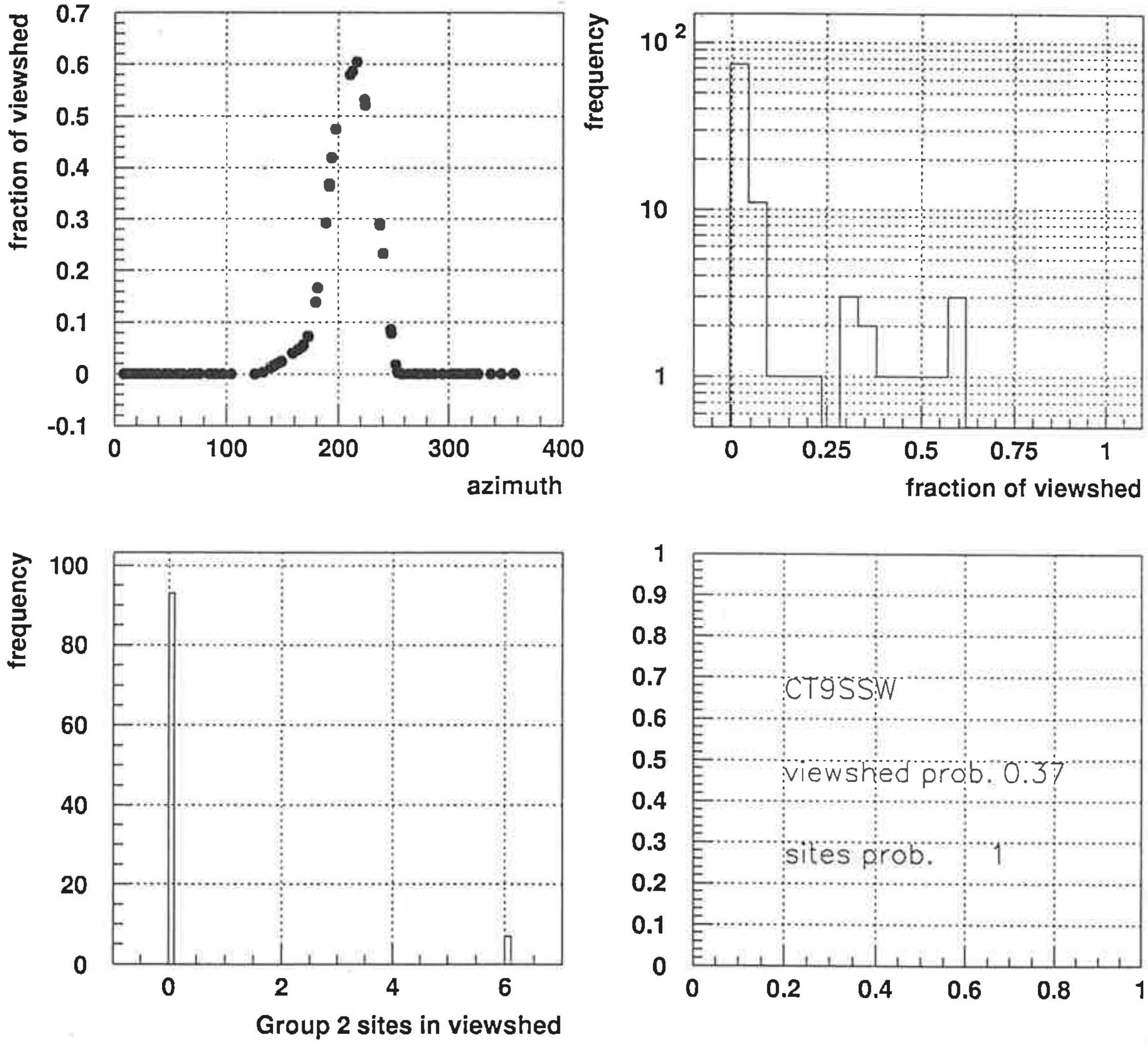
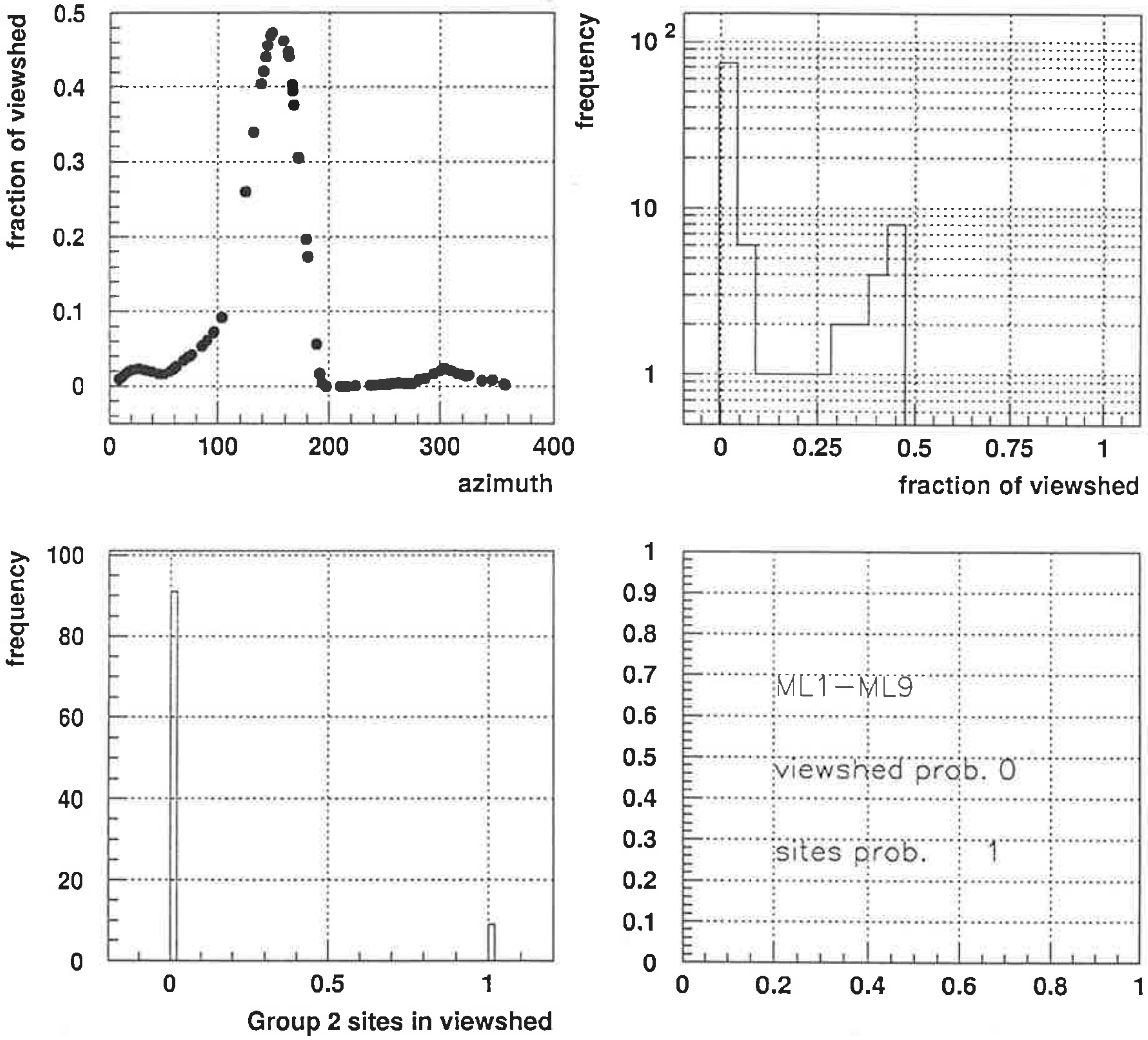
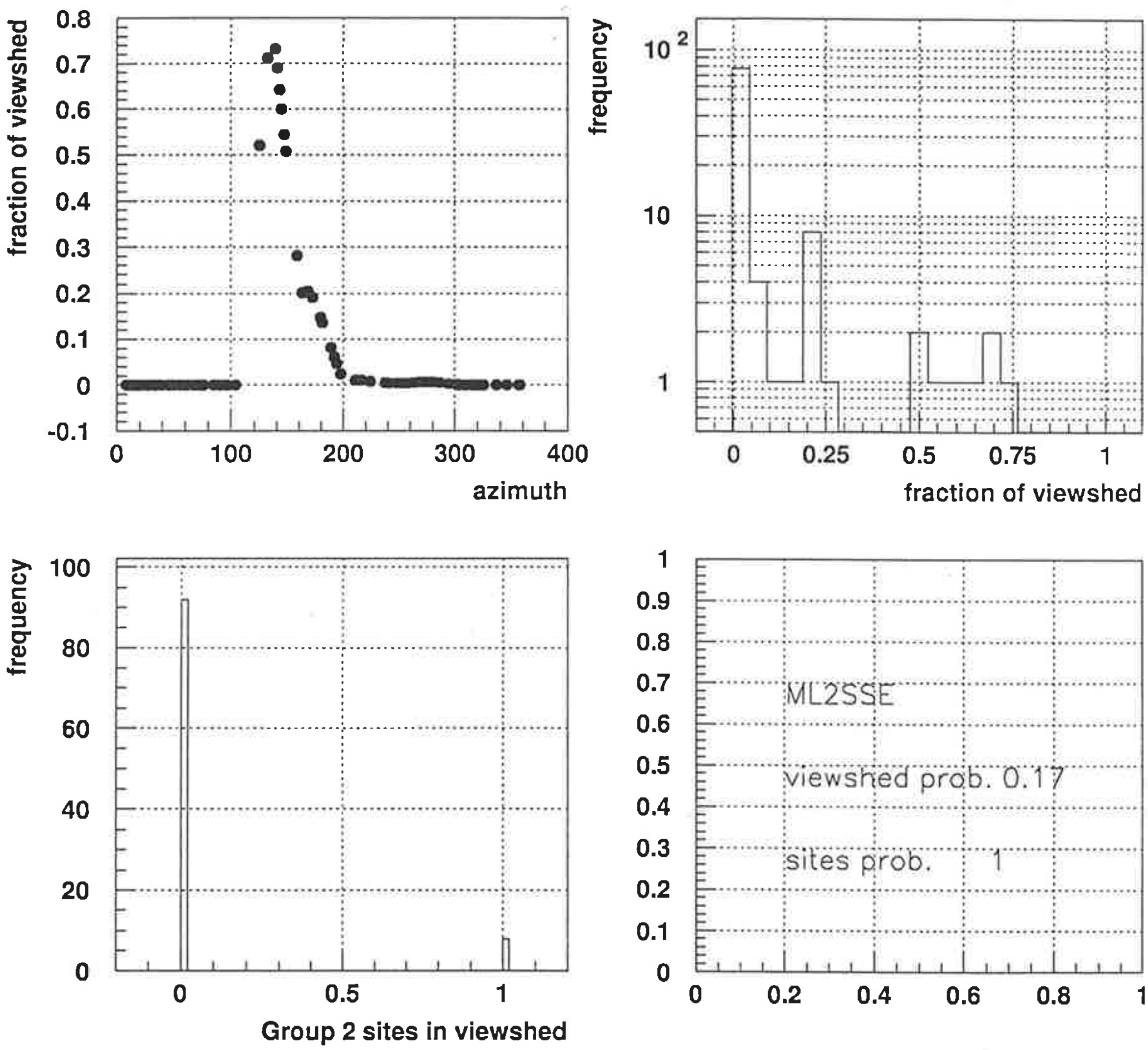

fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
CT9SSW
viewshed prob. 0.37
sites prob. 1

Figure A5.14



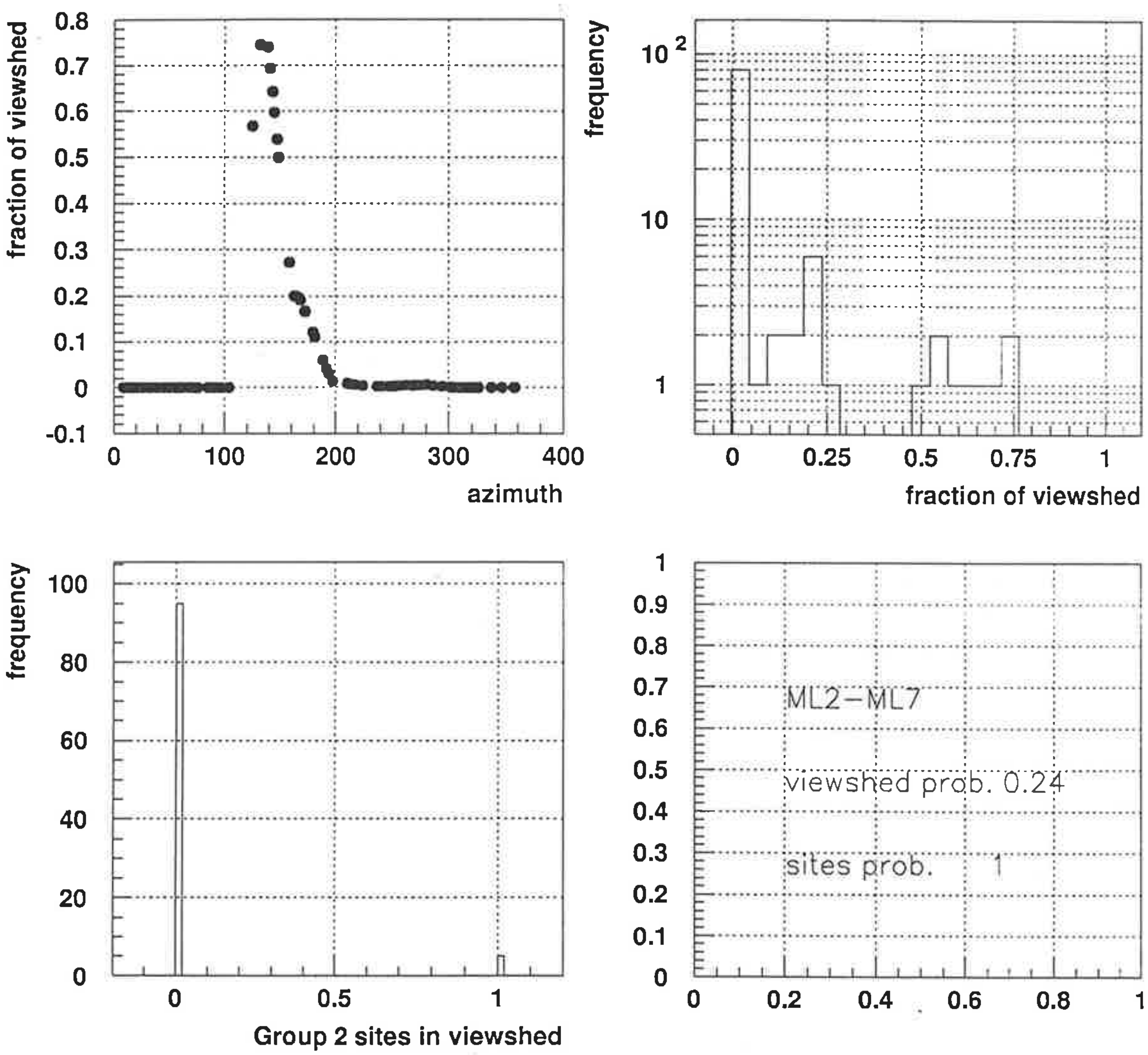
fraction of viewshed
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
azimuth
frequency
10^2
10
1
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
100
80
60
40
20
0
0
0.5
1
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
ML1−ML9
viewshed prob. 0
sites prob. 1

Figure A5.15



fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML2SSE
viewshed prob. 0.17
sites prob. 1

Figure A5.16



fraction of viewshed
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
100
200
300
400
azimuth
frequency
10^2
10
1
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
100
80
60
40
20
0
0
0.5
1
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
ML2–ML7
viewshed prob. 0.24
sites prob. 1

Figure A5.17

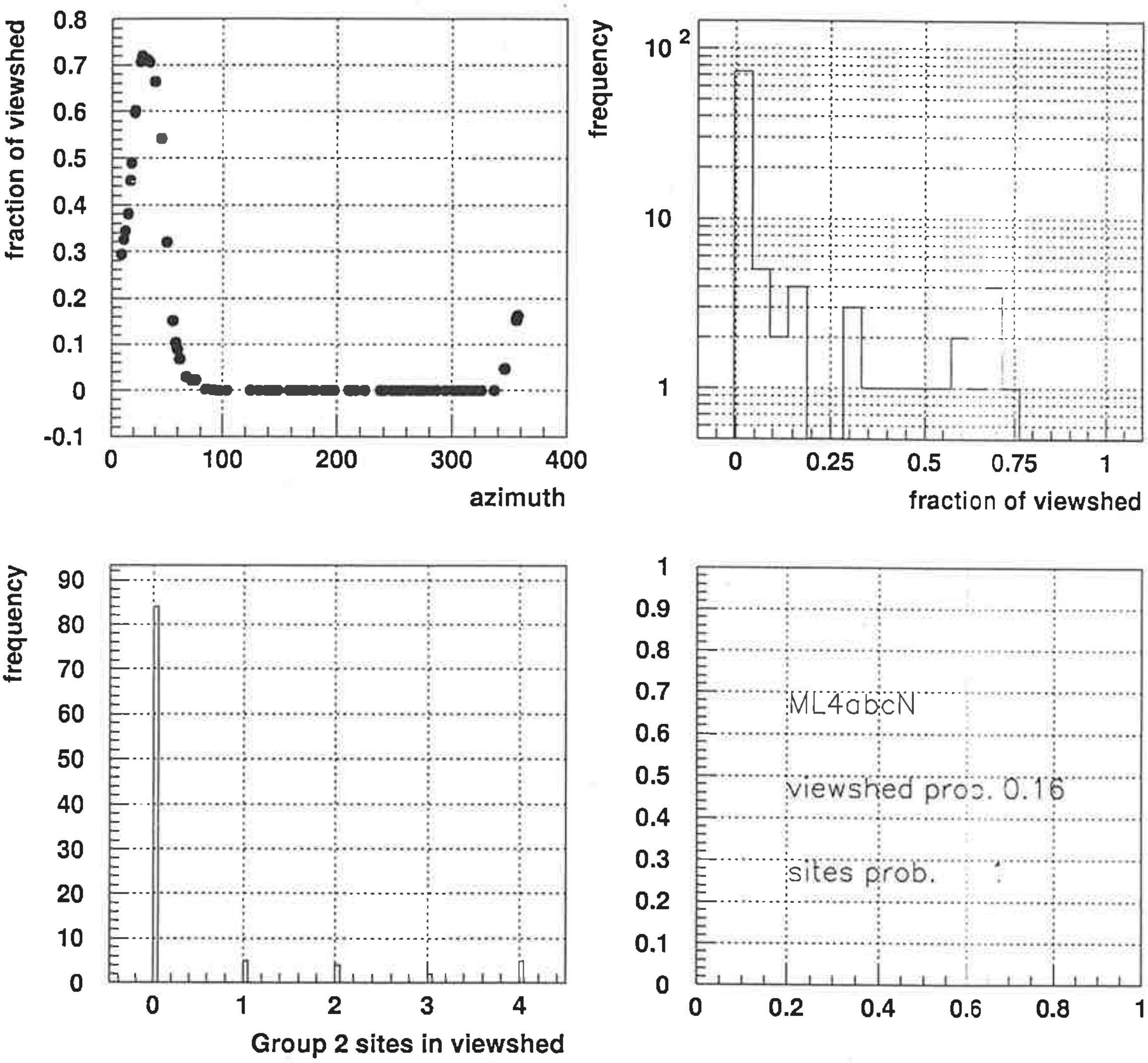
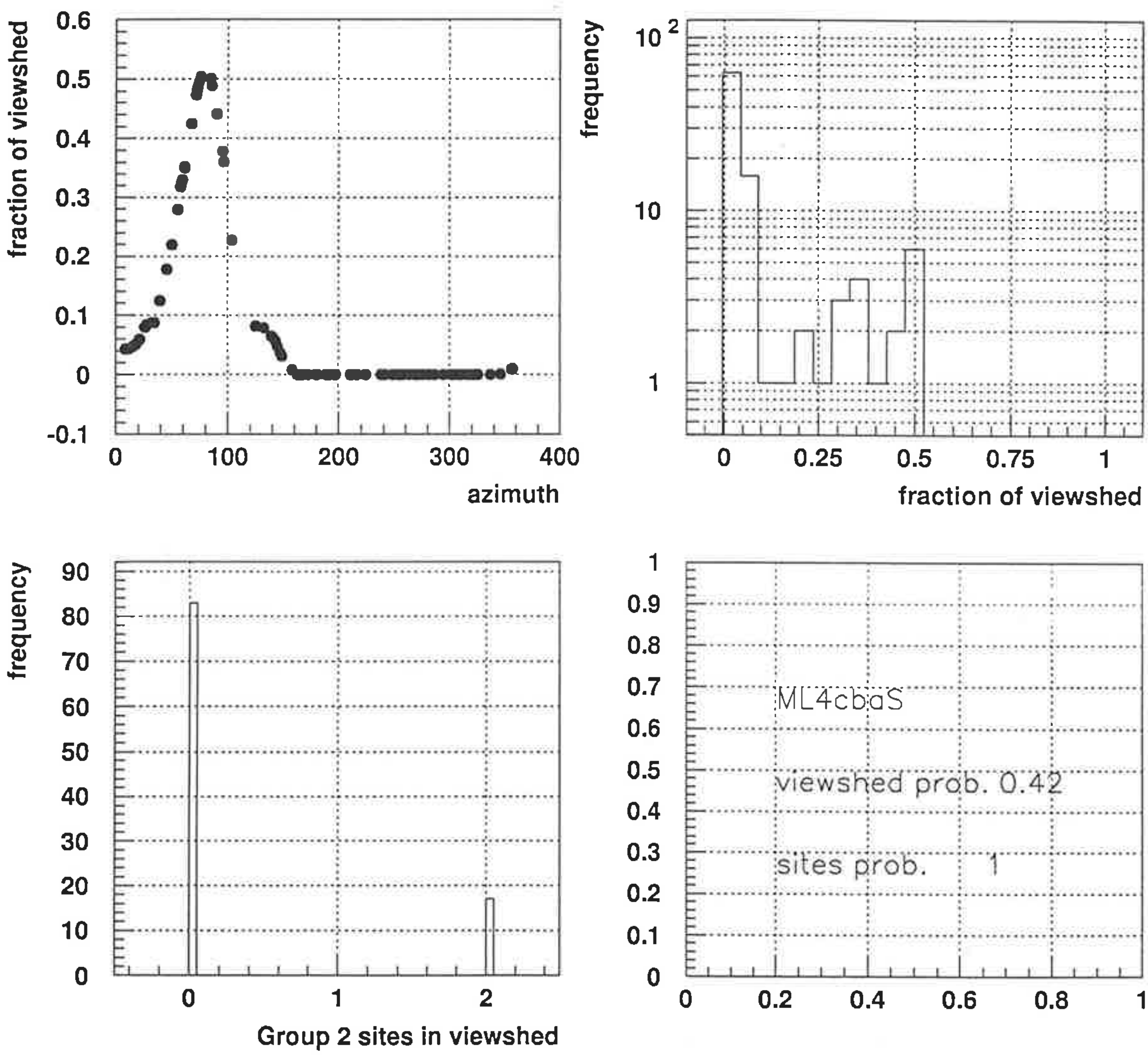

fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML4abcN
viewshed prob. 0.16
sites prob. 1

Figure A5.18



fraction of viewshed
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
100
200
300
400
azimuth
frequency
10^2
10
1
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
90
80
70
60
50
40
30
20
10
0
0
1
2
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
ML4cbaS
viewshed prob. 0.42
sites prob. 1

Figure A5.19

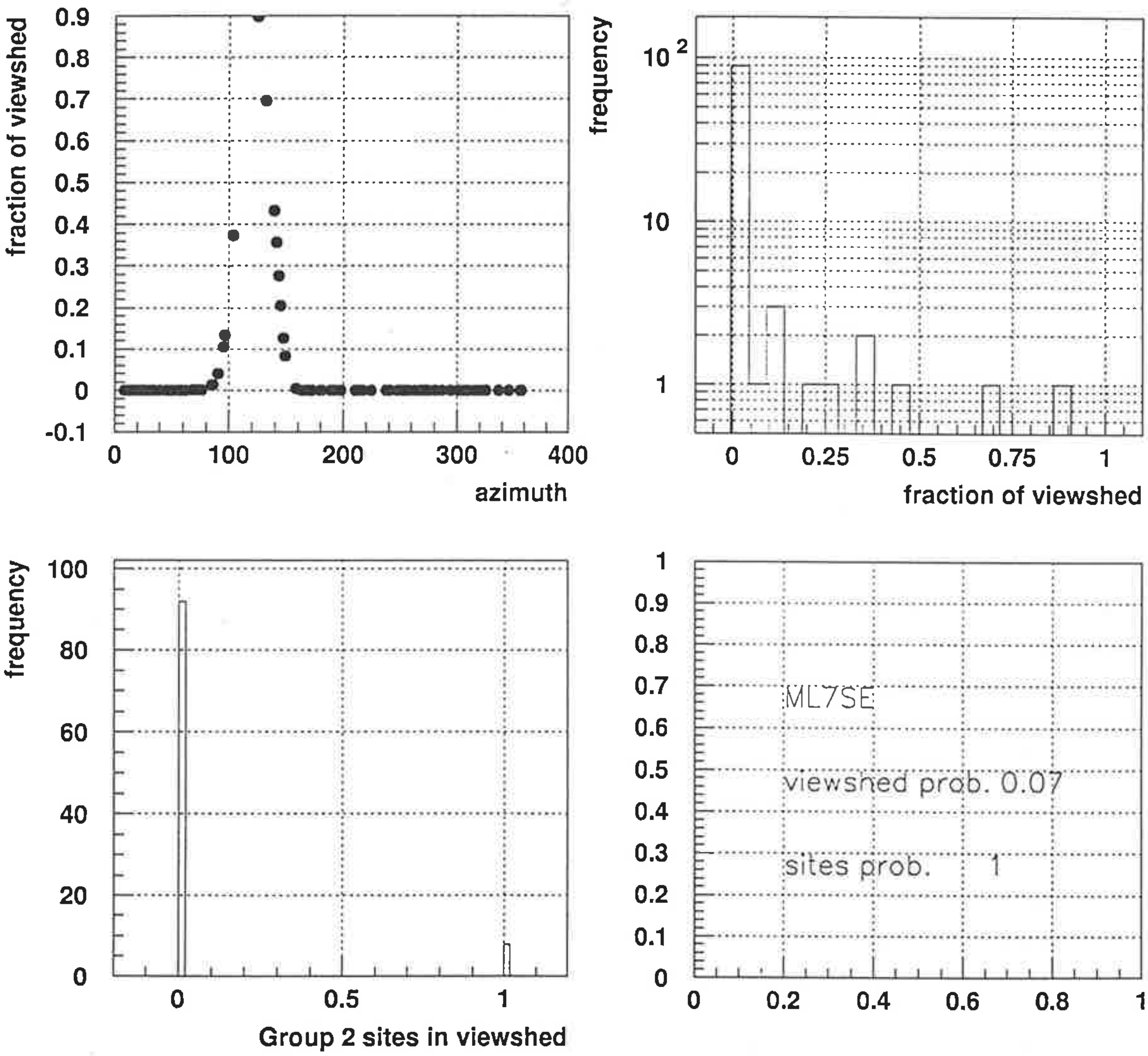
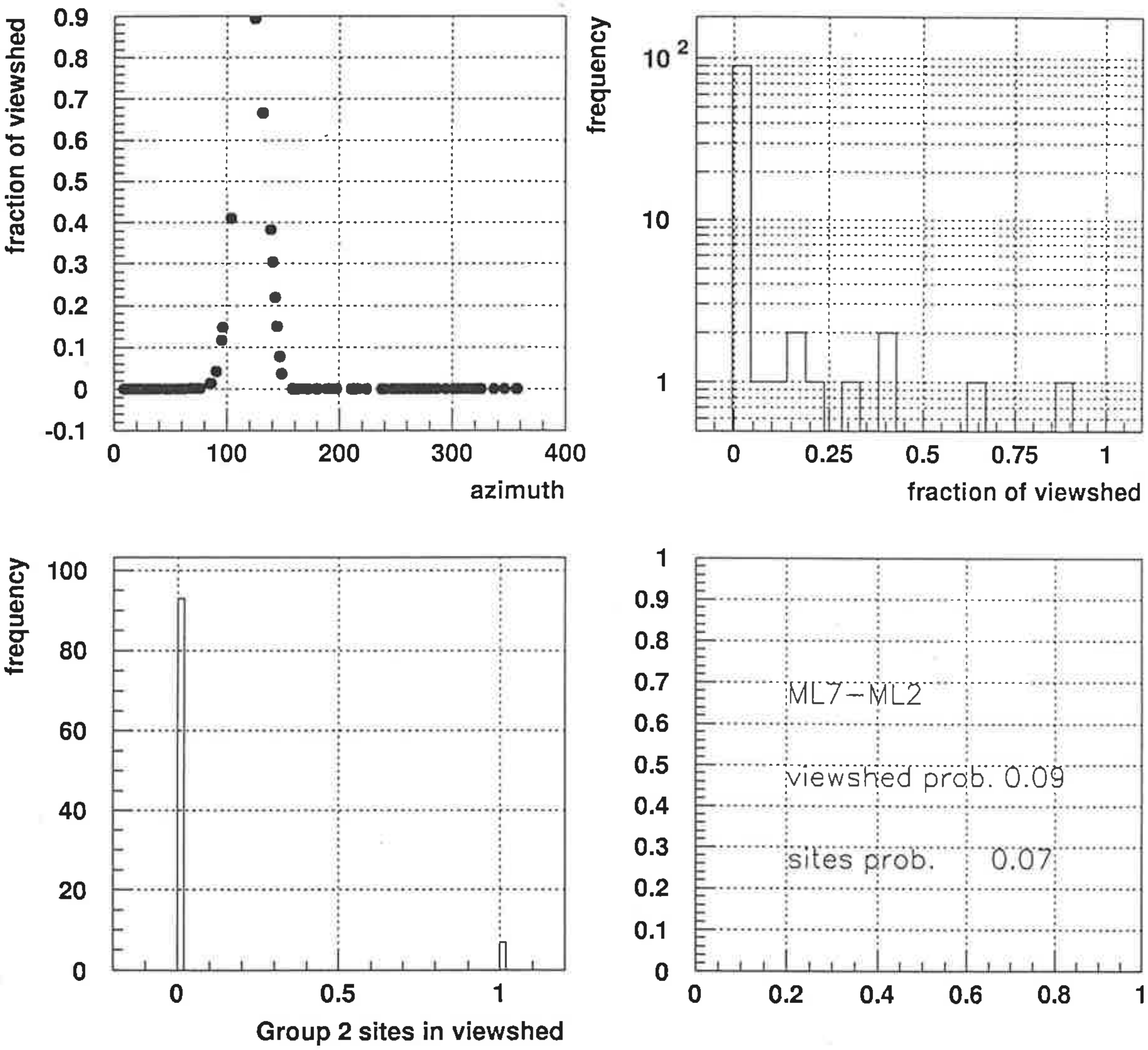
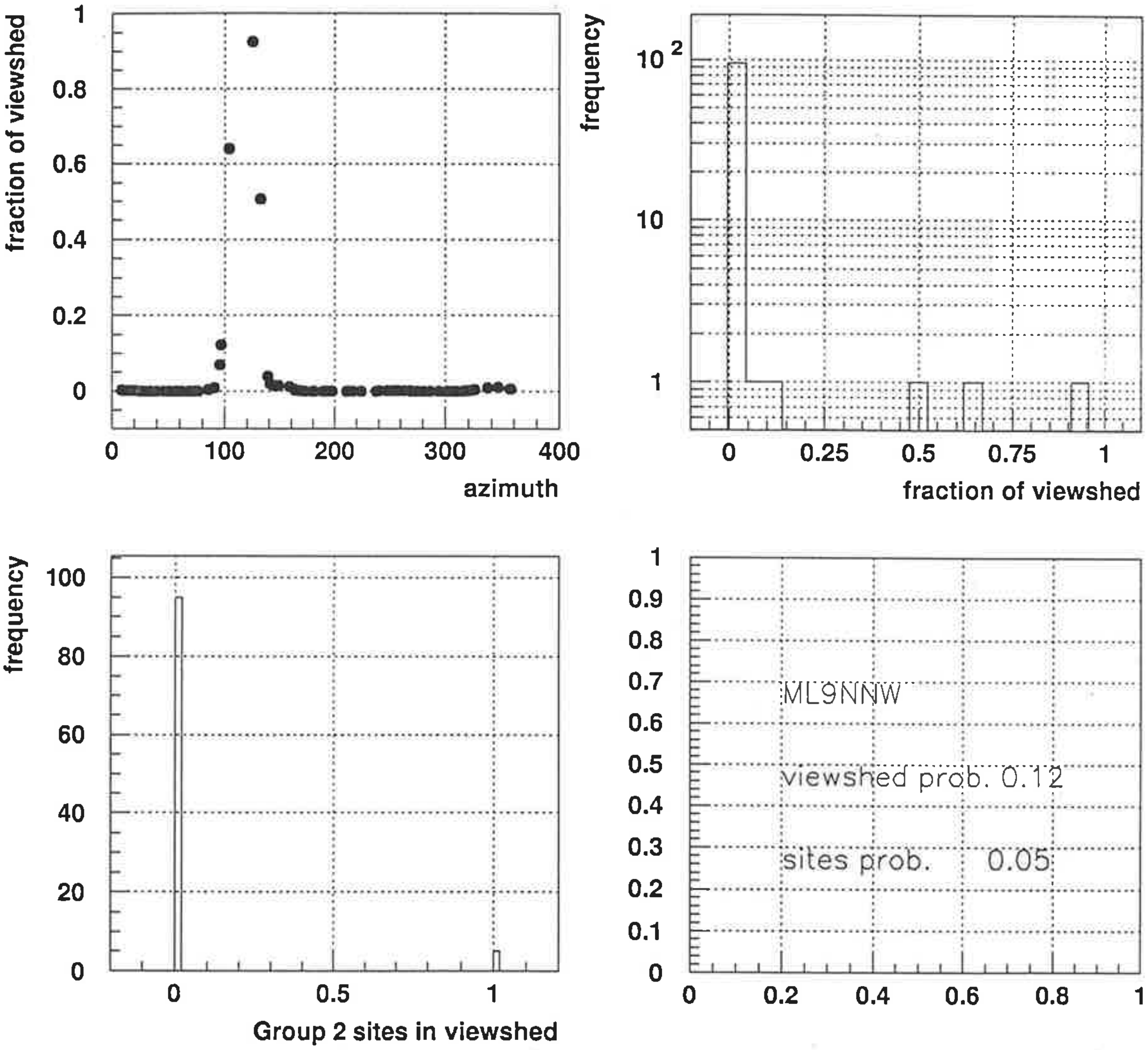

fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML7SE
viewshed prob. 0.07
sites prob. 1

Figure A5.20



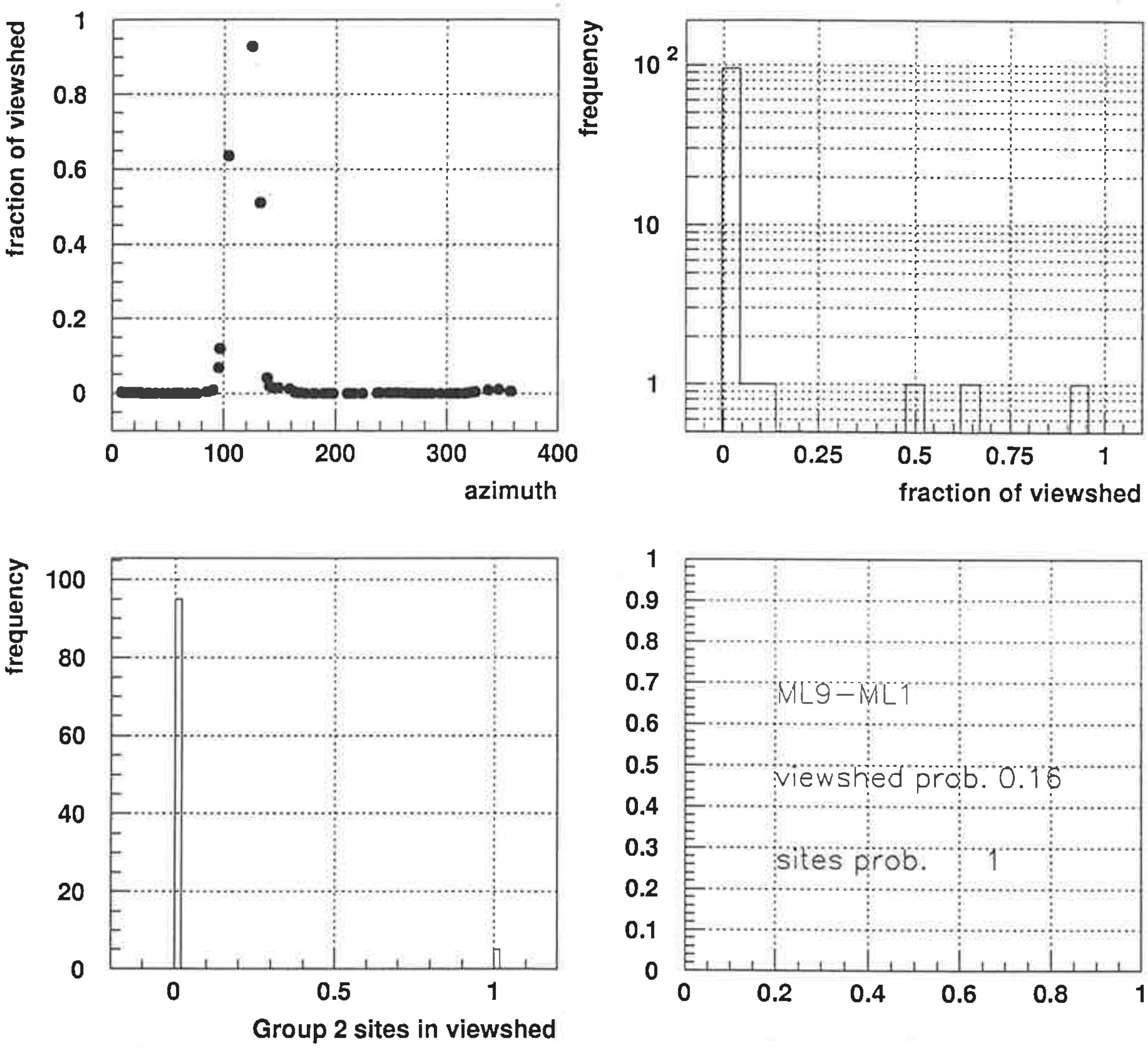
fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML7−ML2
viewshed prob. 0.09
sites prob. 0.07

Figure A5.21



fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML9NNW
viewshed prob. 0.12
sites prob. 0.05

Figure A5.22



fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML9–ML1
viewshed prob. 0.16
sites prob. 1

Figure A5.23

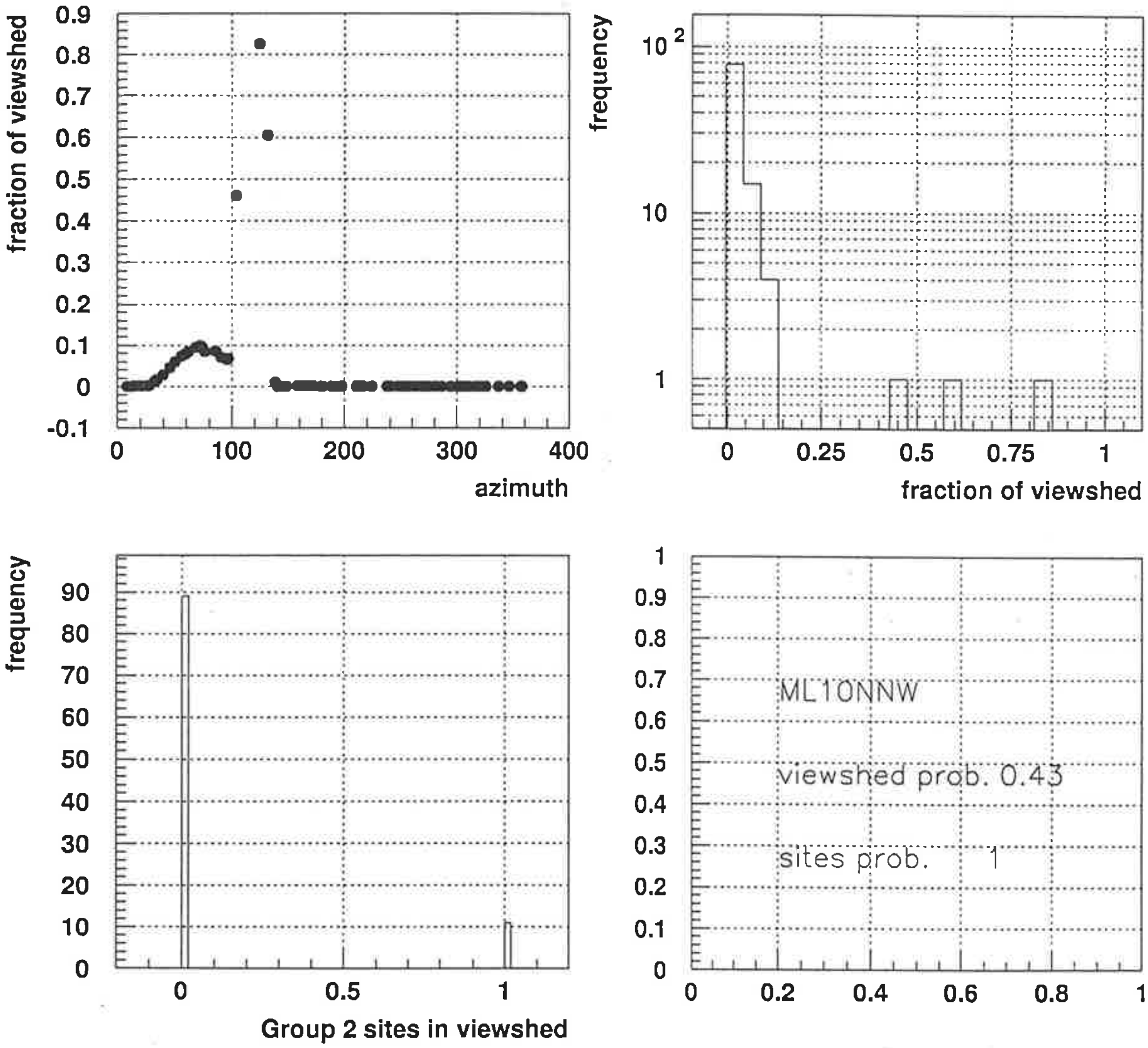

fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML10NNW
viewshed prob. 0.43
sites prob. 1

Figure A5.24

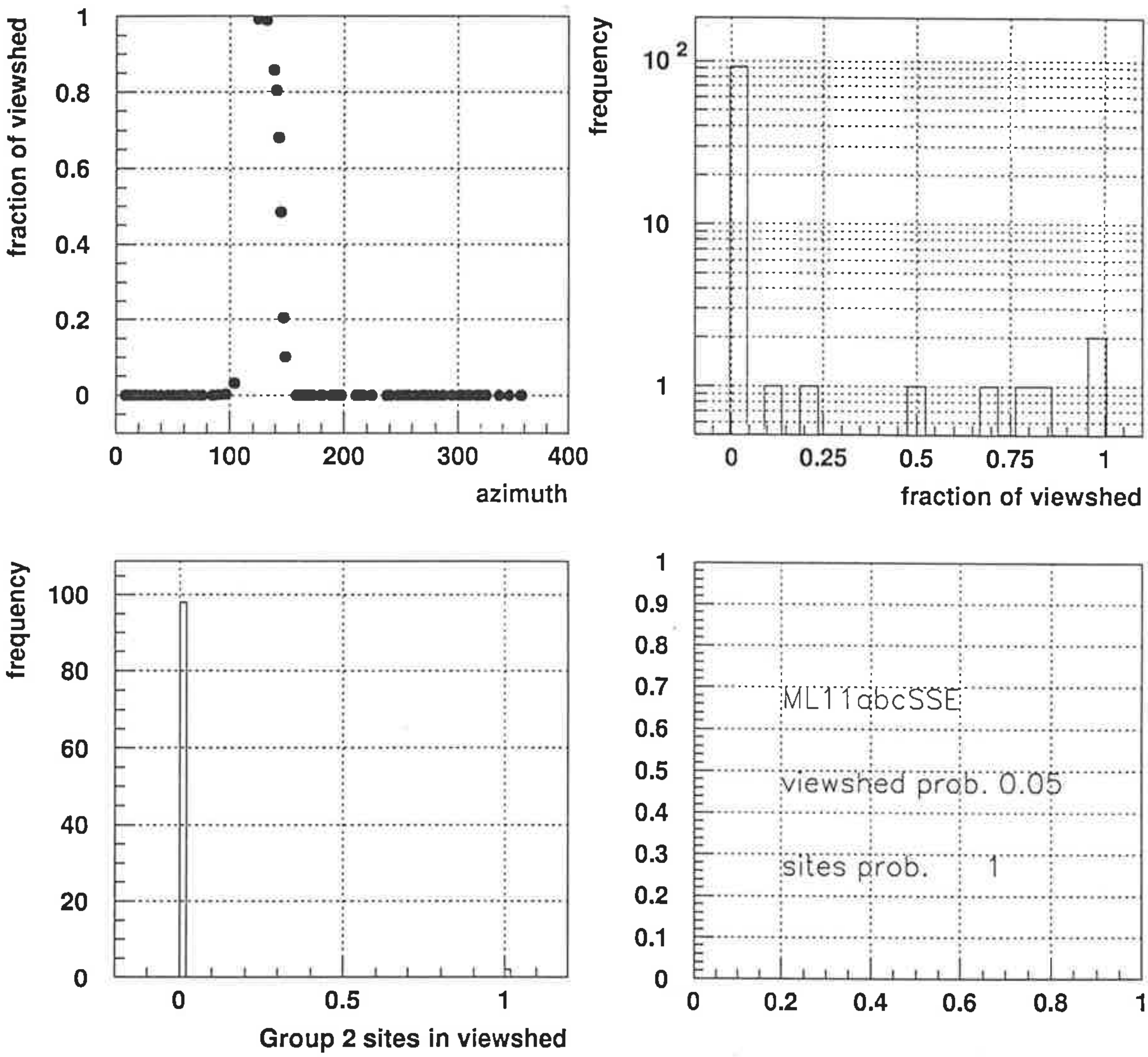

fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML11abcSSE
viewshed prob. 0.05
sites prob. 1

Figure A5.25

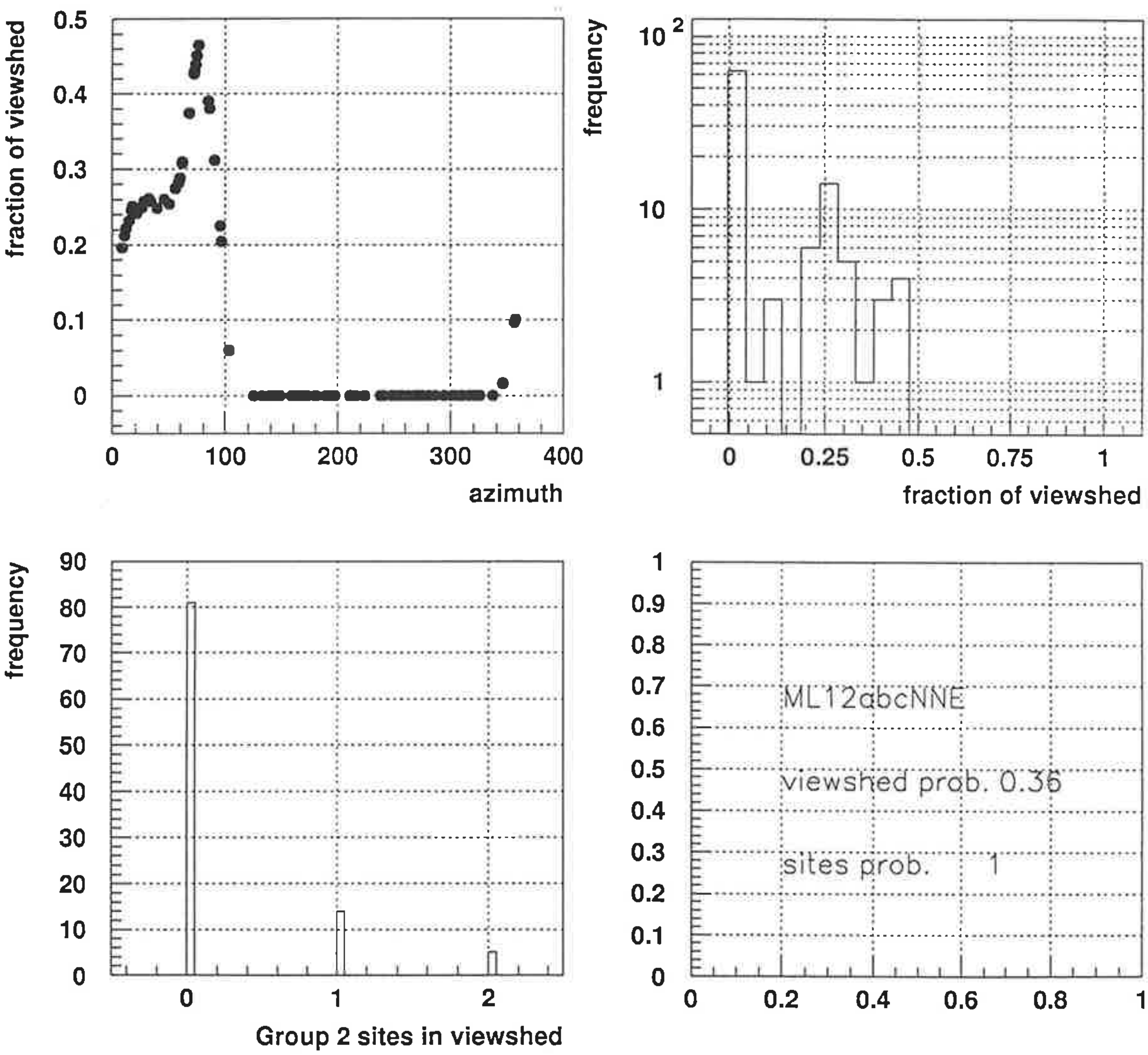
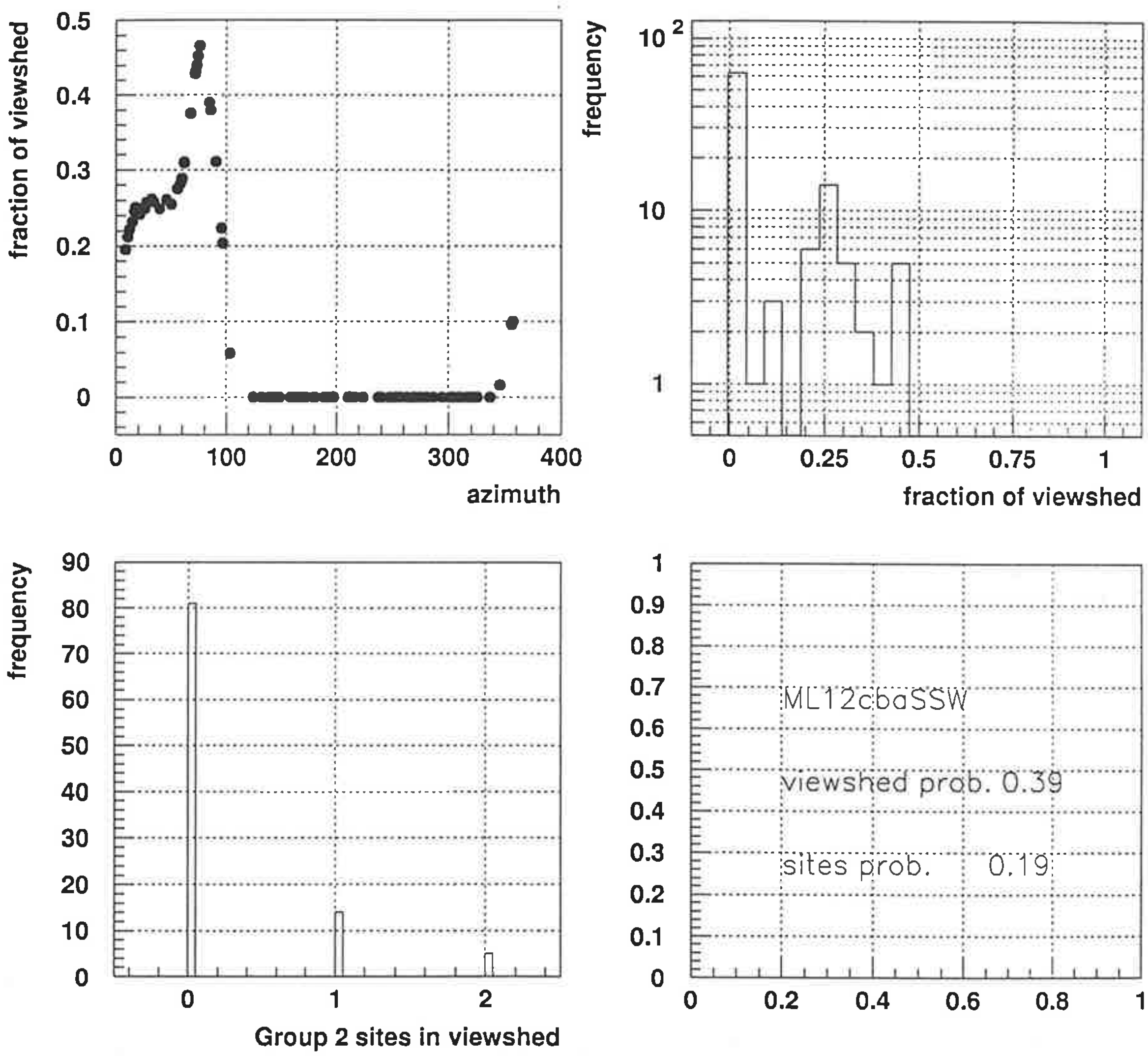
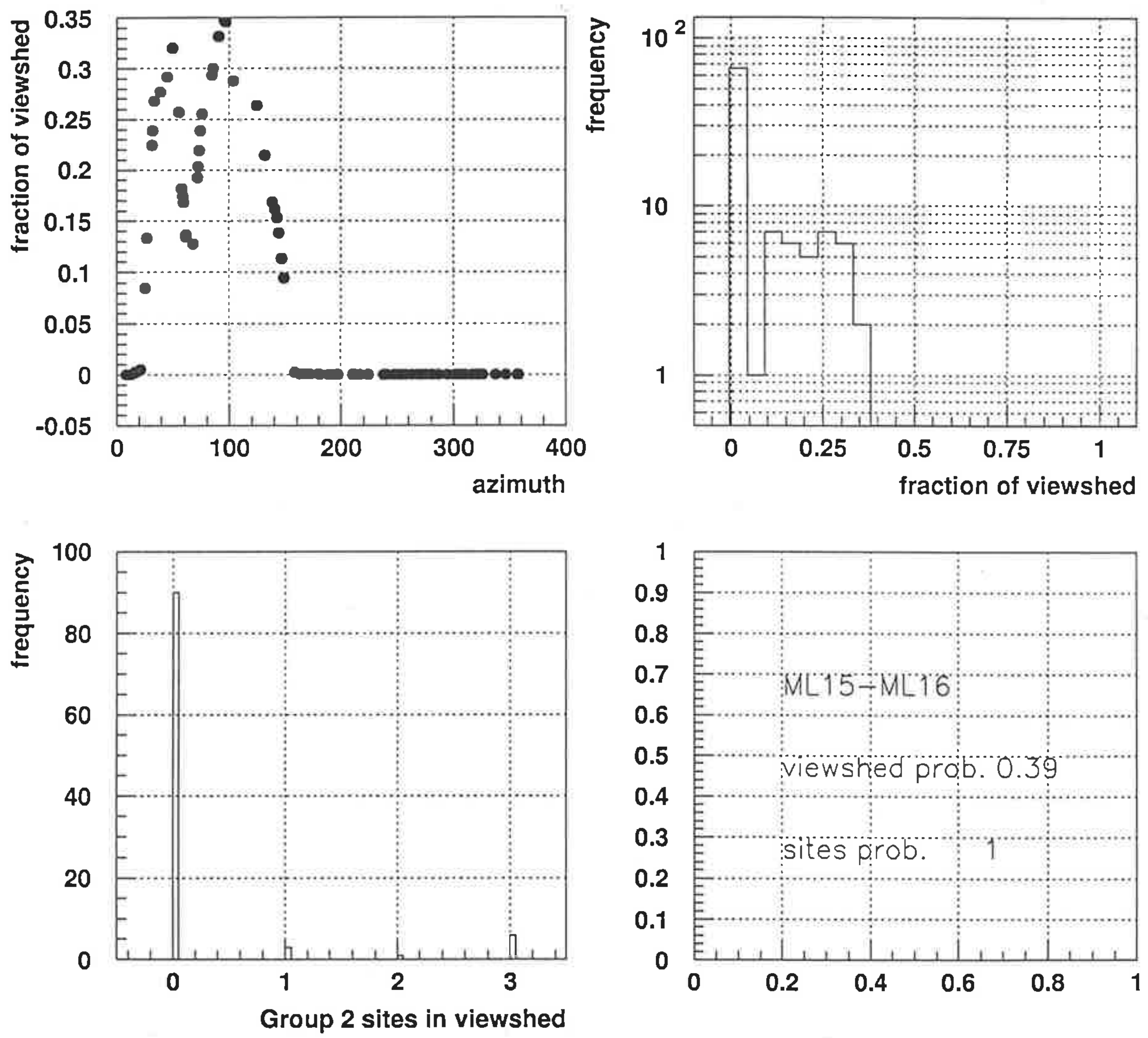

fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML12abcNNE
viewshed prob. 0.36
sites prob. 1

Figure A5.26



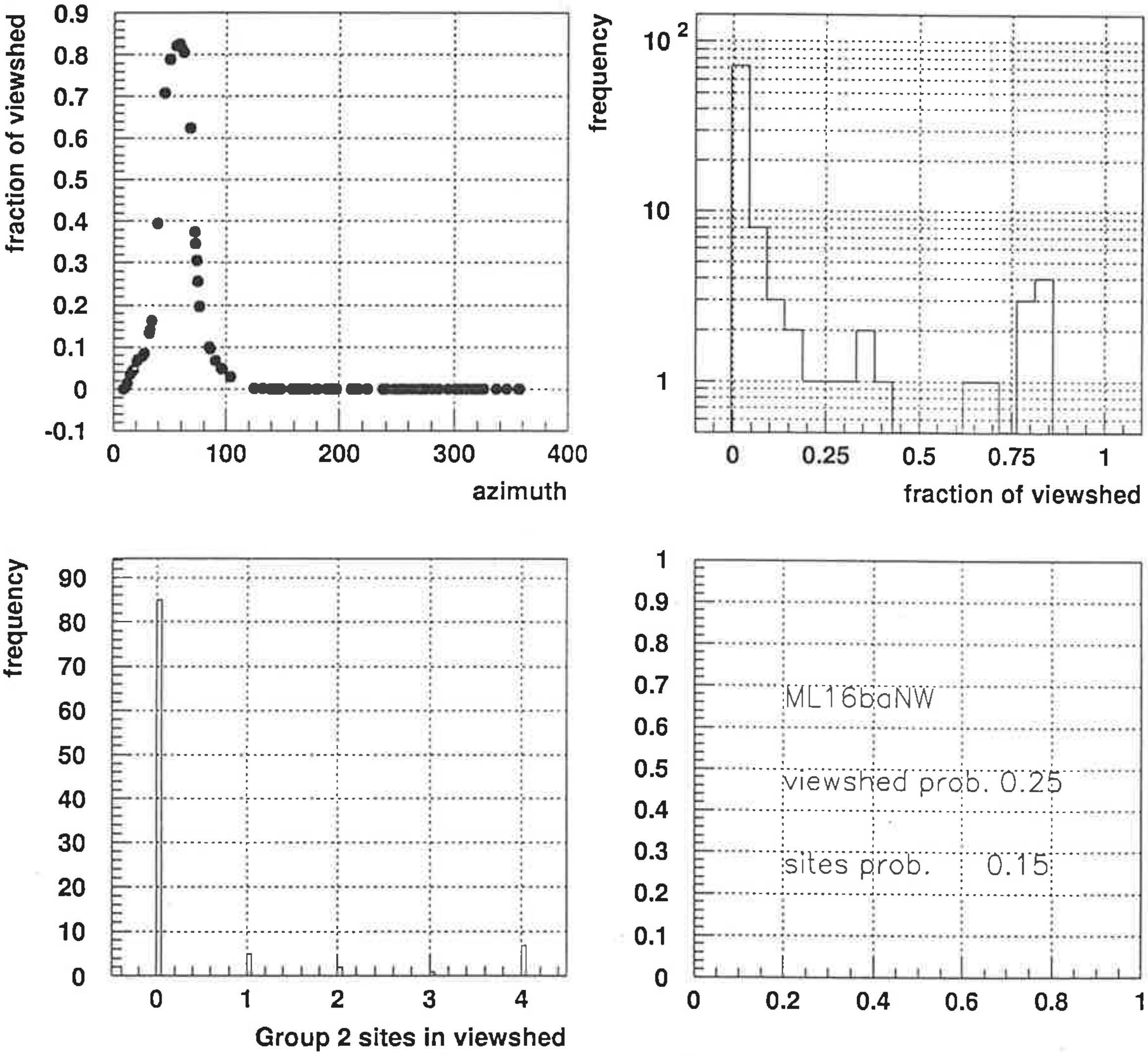
fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML12cbaSSW
viewshed prob. 0.39
sites prob. 0.19

Figure A5.27



fraction of viewshed
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
100
200
300
400
azimuth
frequency
10 2
10
1
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
100
80
60
40
20
0
0
1
2
3
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
ML15-ML16
viewshed prob. 0.39
sites prob. 1

Figure A5.28



fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML16baNW
viewshed prob. 0.25
sites prob. 0.15

Figure A5.29

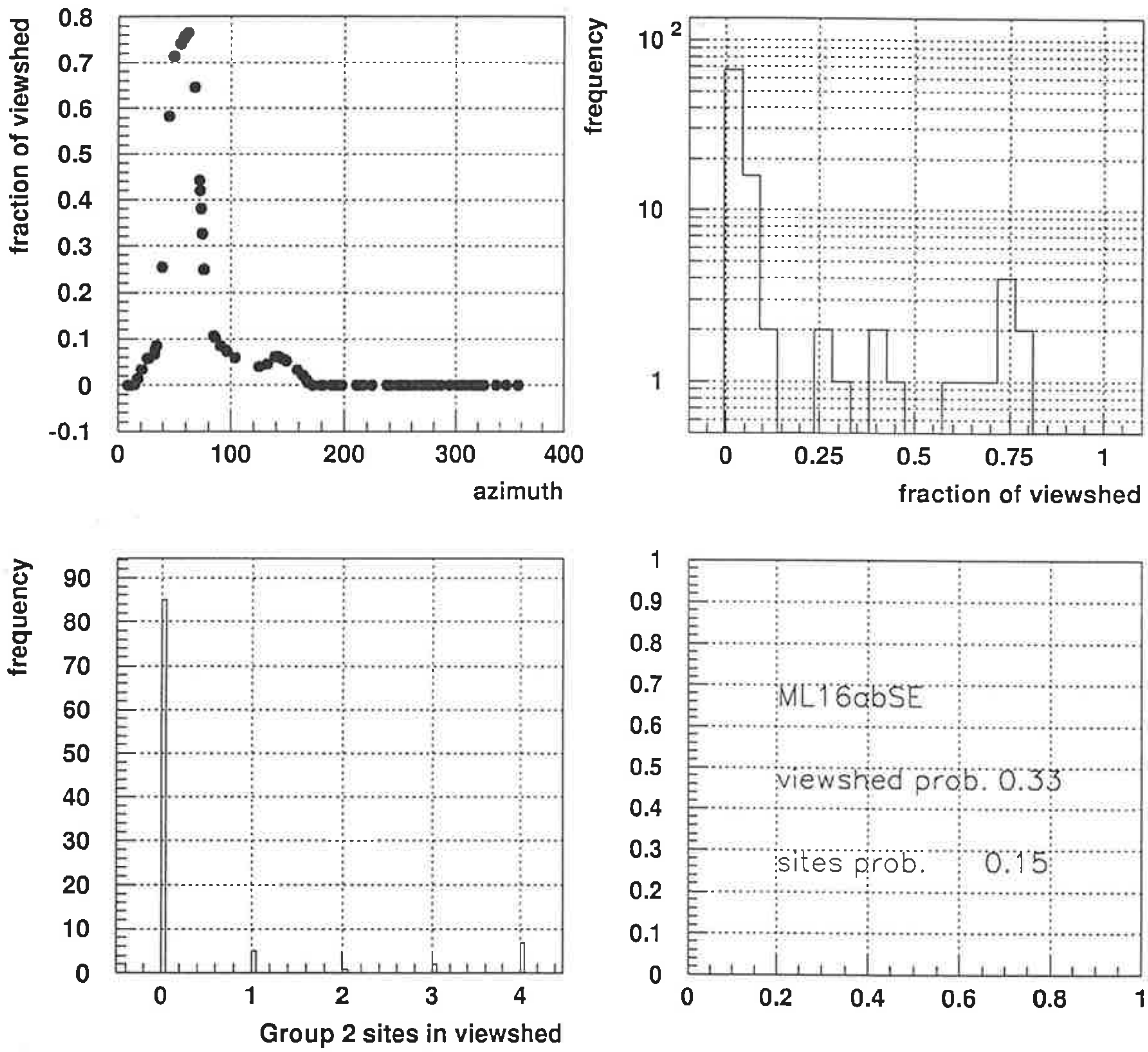

fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML16abSE
viewshed prob. 0.33
sites prob. 0.15

Figure A5.30

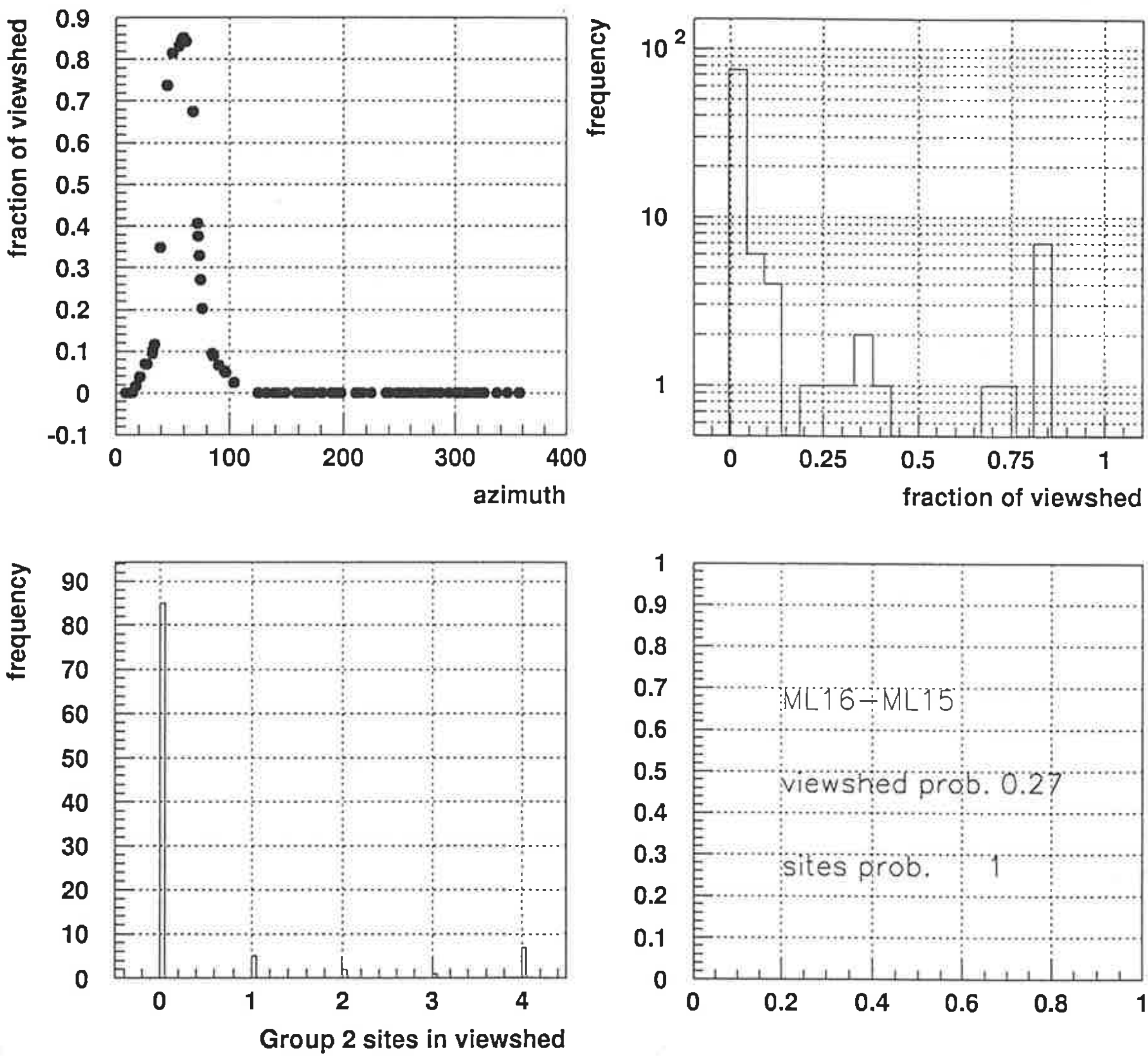
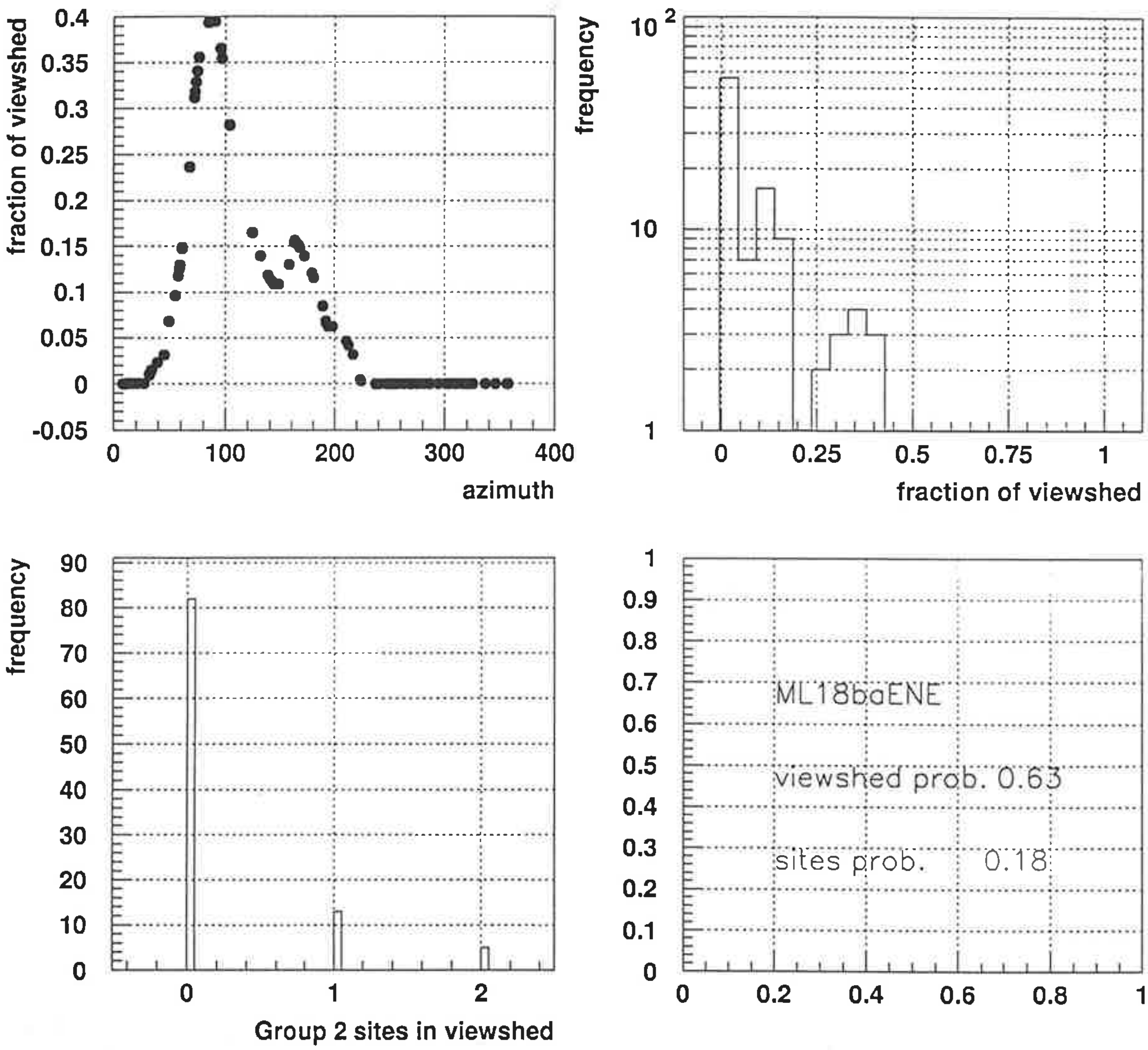

fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML16-ML15
viewshed prob. 0.27
sites prob. 1

Figure A5.31



fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML18baENE
viewshed prob. 0.63
sites prob. 0.18

Figure A5.32

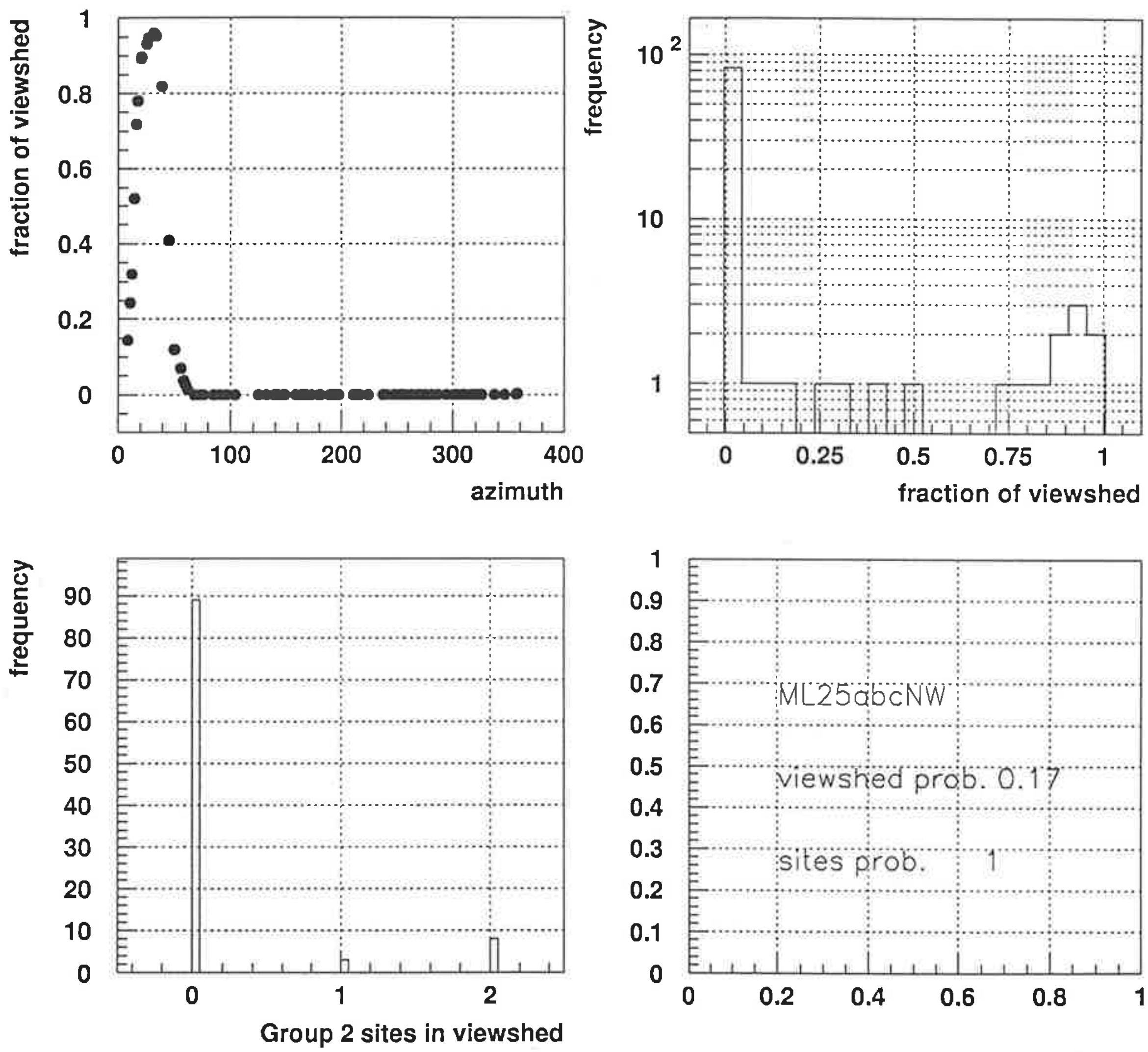
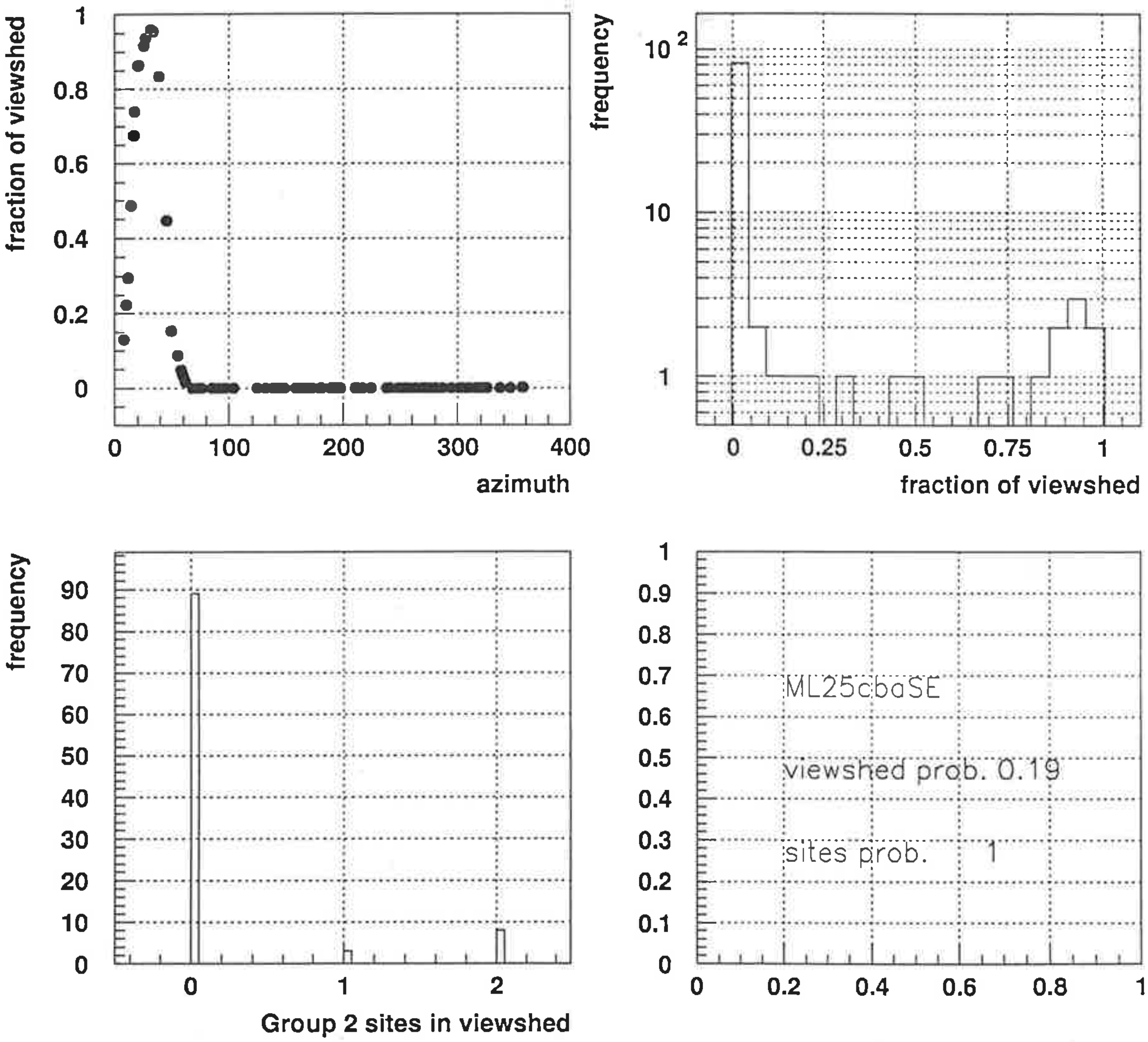
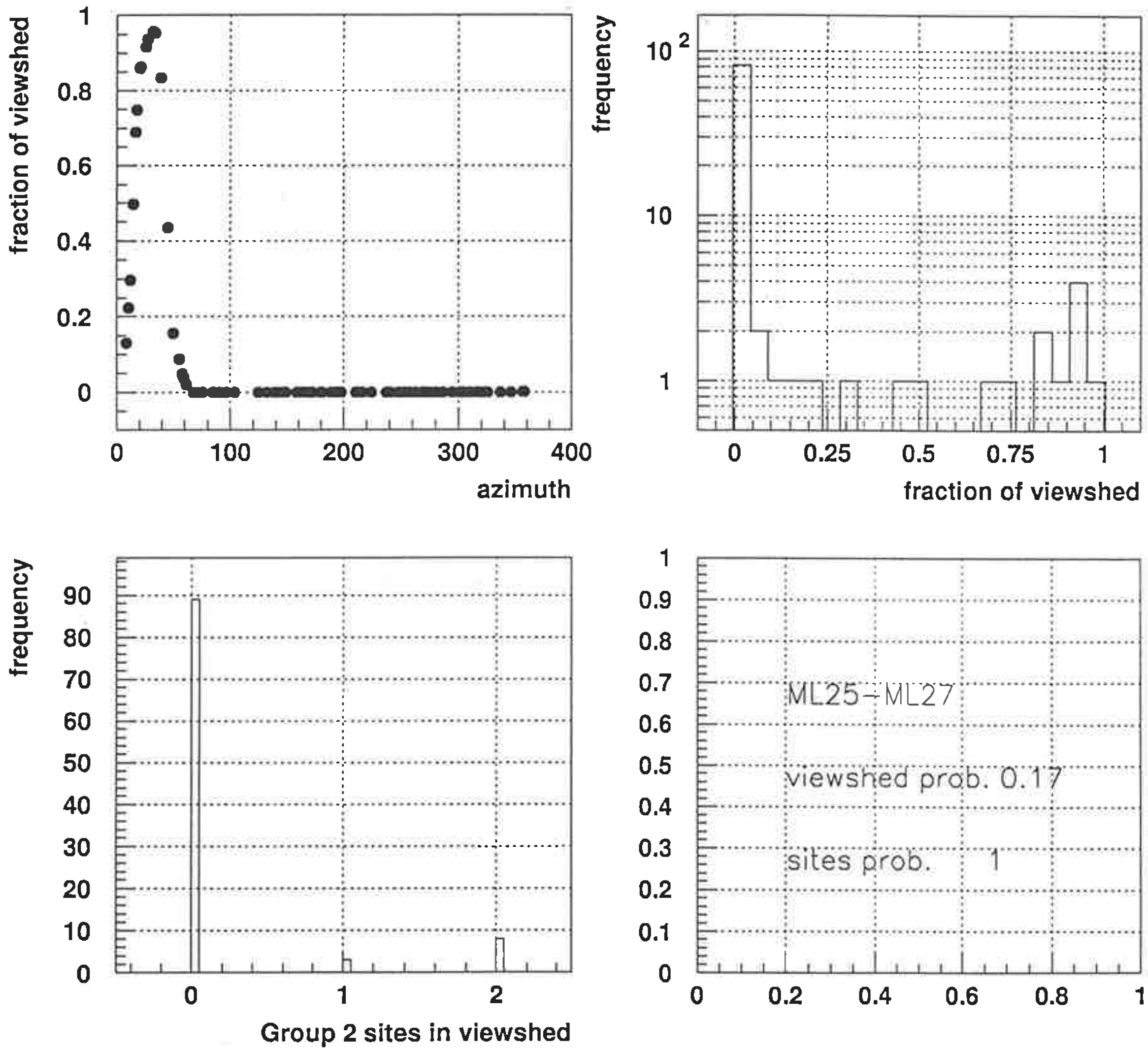

fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML25abcNW
viewshed prob. 0.17
sites prob. 1

Figure A5.33



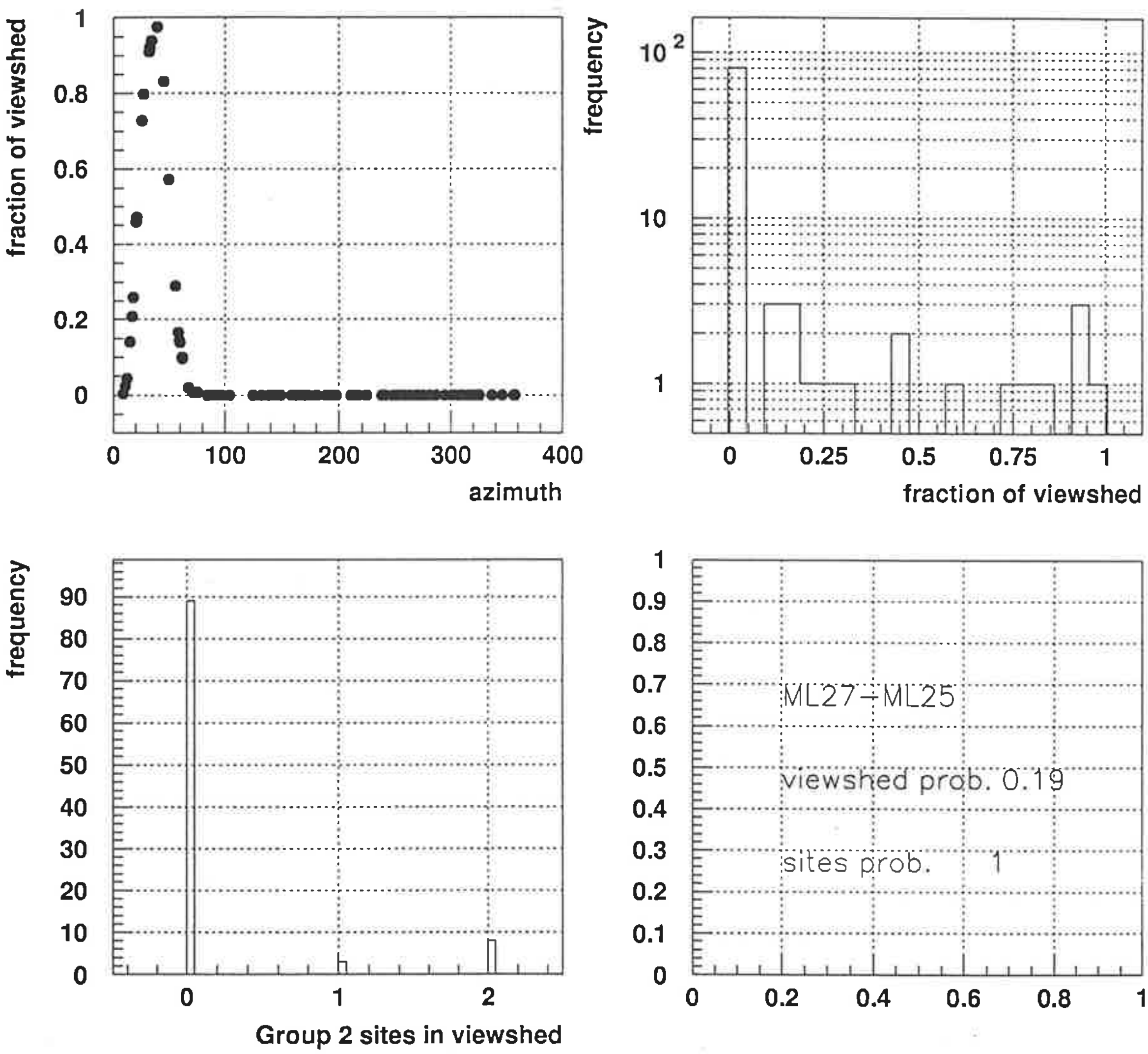
fraction of viewshed
azimuth
0
100
200
300
400
0.2
0.4
0.6
0.8
1
frequency
fraction of viewshed
10
1
0.25
0.5
0.75
Group 2 sites in viewshed
10
20
30
40
50
60
70
80
90
2
ML25cbaSE
viewshed prob. 0.19
sites prob. 1

Figure A5.34



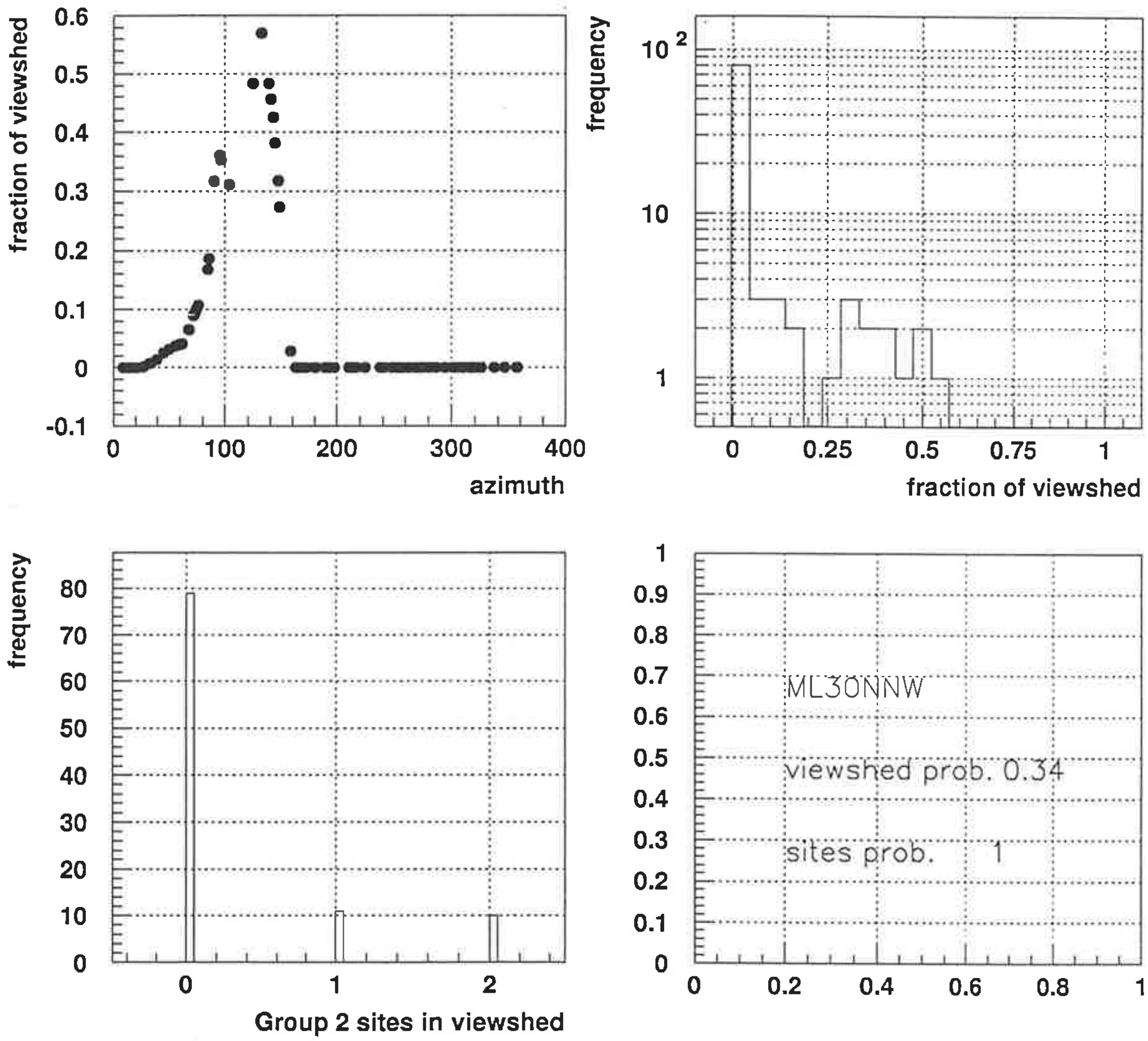
fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML25→ML27
viewshed prob. 0.17
sites prob. 1

Figure A5.35



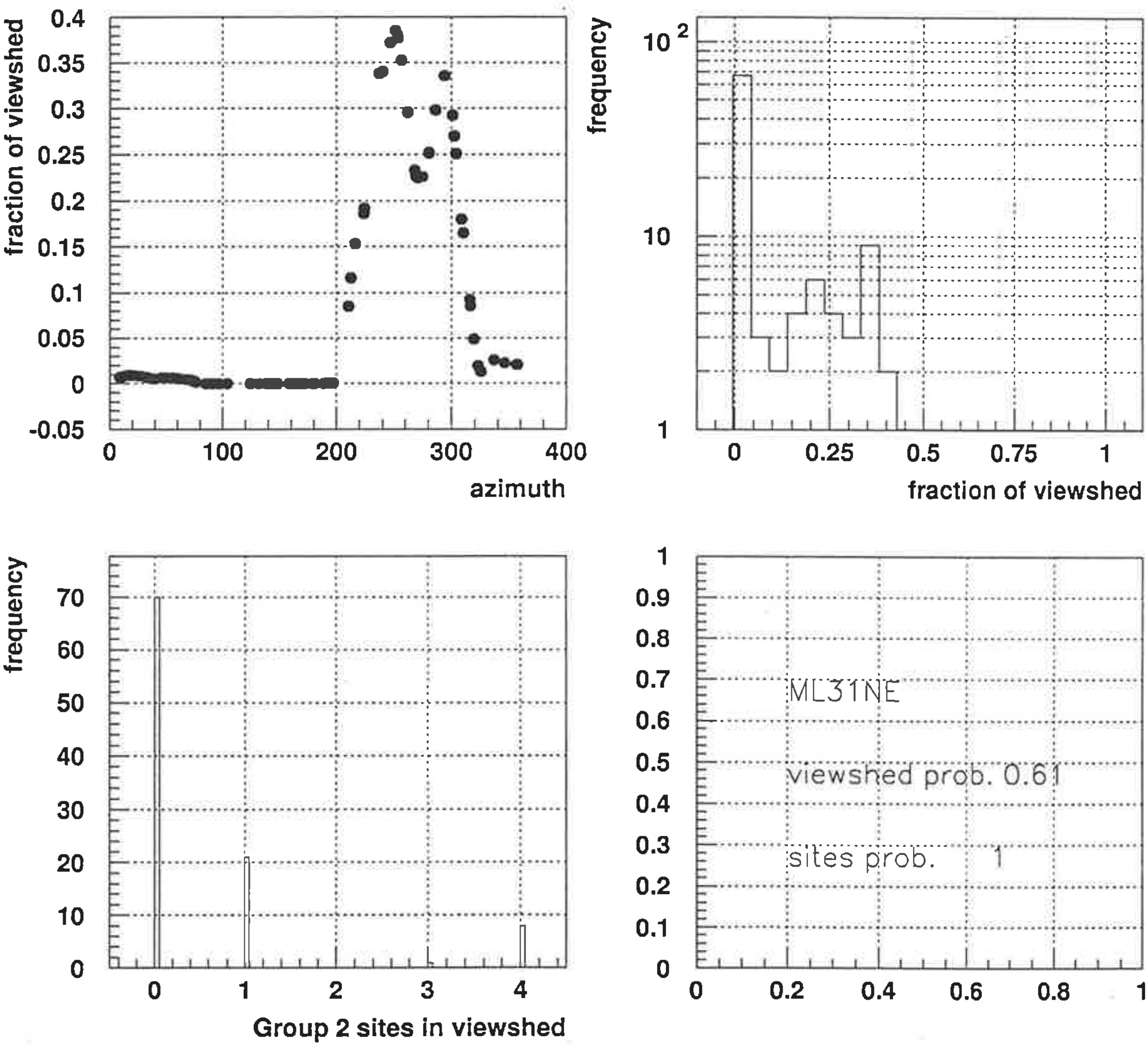
fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML27–ML25
viewshed prob. 0.19
sites prob. 1

Figure A5.36



fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML30NNW
viewshed prob. 0.34
sites prob. 1

Figure A5.37



fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML31NE
viewshed prob. 0.61
sites prob. 1

Figure A5.38

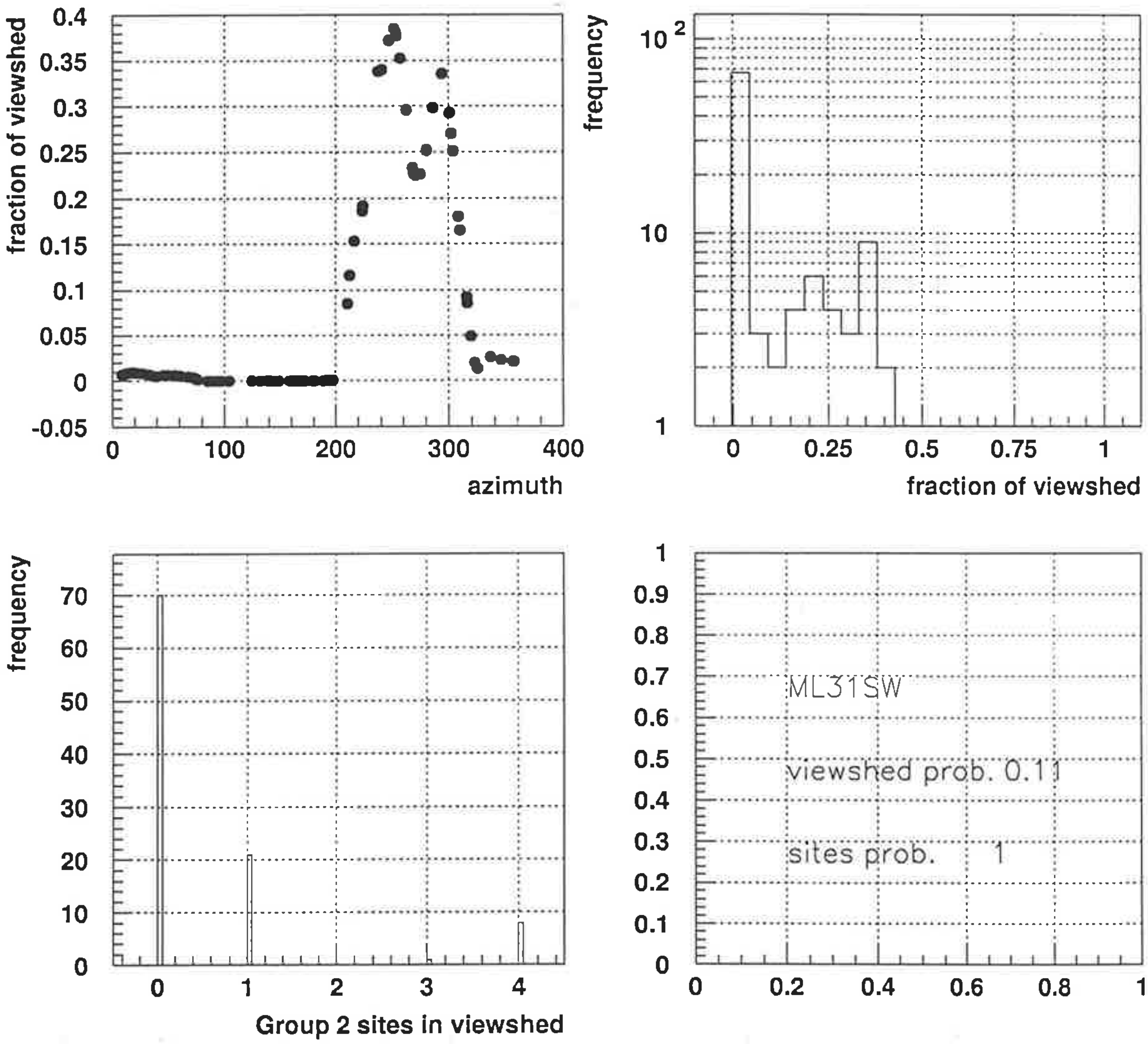
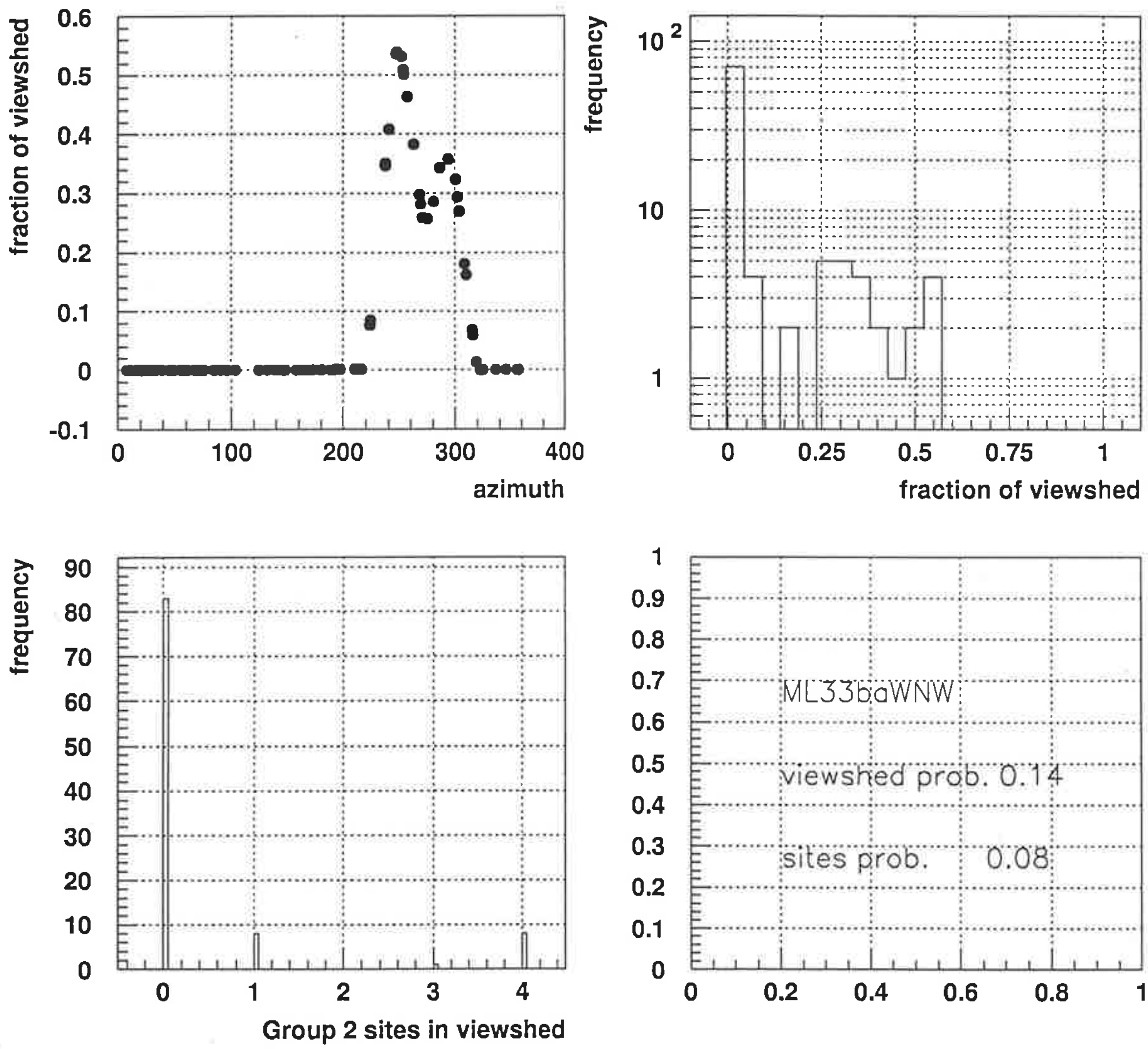

fraction of viewshed
azimuth
frequency
fraction of viewshed
frequency
Group 2 sites in viewshed
ML31SW
viewshed prob. 0.11
sites prob. 1

Figure A5.39



fraction of viewshed
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
100
200
300
400
azimuth
frequency
10 2
10
1
0
0.25
0.5
0.75
1
fraction of viewshed
frequency
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
Group 2 sites in viewshed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
ML33baWNW
viewshed prob. 0.14
sites prob. 0.08

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