VOLUME 2

THE GEOGRAPHY AND ARCHAEOLOGY OF SHETLAND BROCHS

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SECTION 2

GEOGRAPHICAL DISCUSSIONS

Volume 2

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A note on sources

It would be tedious to refer repetitively throughout the following section to general methodological texts in both archaeology and geography. It has therefore been decided to omit references to the more generalised works, and to refer only points of specific detail to their sources. To offset this, a list is given here of the sources of general theories and opinions.

Archaeology

Alcock, L (1975), "The Discipline of Archaeology"
Barker, P (1977), "Techniques of Archaeological Excavation"
Binford, L R (1977), "For Theory Building in Archaeology"
Cherry, J F et al. (1978), "Sampling in Contemporary British Archaeology"
Clarke, D L (1968), "Analytical Archaeology"
Clarke, D L (1972), "Models in Archaeology"
Hodder, I & Orton, C (1976), "Spatial Analysis in Archaeology"
Mueller, J W (ed.) (1975), "Sampling in Archaeology"
Redman, C L (1974), "Archaeological Sampling Strategies"
Watson, P J et al. (1971), "Explanation in Archaeology: an Explicitly Scientific Approach"

Geography

Chisholm, M I (1963), "Rural Settlement and Land Use"
Christaller, W (1933), "Die zentralen Orte in Suddeutschland"
Ebdon, D (1977), "Statistics in Geography" (for example)
Haggett, P (1965), "Locational Analysis in Human Geography"
Harvey, D (1969), " Explanation in Geography"

General

Clark, P J & Evans, F C (1954), "Distance to Nearest Neighbour as a Measure of Spatial Relationships"
Huff, D (1954), "How to Lie with Statistics"
Runyon, R P (1977), "Nonparametric Statistics"

Section 2

Chapter I

Introduction

As originally conceived, the results of this research would have been confined exclusively to the analysis of data concerning geographical aspects of Shetland's brochs, and the methodological implications of these analyses. It was intended to investigate the validity and reliability of methods of interpreting fieldwork data by standardised tests such as those proposed by Hodder and Orton (1976). The archaeologist was to pose questions which the geographer could solve by reference to a large body of data gathered under carefully monitored field conditions. The final interpretation of the results was to be the province of the synthesist, acting to unite the capabilities of geography with the needs of archaeology.

The foregoing Section has amply illustrated the naivety of this intention. There are, in fact, no clearly-defined questions waiting to be answered. Therefore, the following Section has been re-oriented to examine the potential of the available data, and the results are applied to the unresolved research themes outlined in Chapter IV above. In the Section just ended, an attempt has been made to chart the development of current archaeological hypotheses, to examine the areas of doubt still remaining, and to demonstrate the place of Shetland's brochs in the general Scottish scene as regards structural development and artefactual typology.

It has been demonstrated that whatever, in detail, brochs may have been, each can be viewed as an indicator of the former existence of an Iron Age population group. The exact size of these communities cannot be specified. Their economy seems to have been of a diversified subsistence mode. Whether or not these groups actually used the brochs as permanent residences is largely external to the discussions to follow, which use the brochs largely as indicators of economies to be investigated.

In archaeology in general, and in the case of brochs in particular, there are certain aspects of the total body of possible knowledge which are more likely to yield to an excavation approach, and certain where fieldwork is more promising. The former group includes cultural affinities (by artefactual comparison), details of economy (by examination of material remains), detailed architectural studies and, of course, dating. The latter includes site (and hence group) inter-relationships and the broader outlines of economy. But real progress can only result from the co-ordination of the results of both types of approach.

In an ideal world, excavation of all sites to the highest of standards would solve most problems of data-shortage. But in the present (1979) situation of rapidly-escalating costs occasioned by increasing expertise and limited resources of time, labour and finance, it must be clear that broch excavations will be increasingly rare events. Under such circumstances, it becomes essential to consider the potential of low-cost fieldwork as a means of resolving some of the areas of doubt already outlined. Such a resolution would assist excavation-based study by means of defining ranges of inter-site variability and thus aiding the identification of the prime "targets" for the small number of possible excavations, so that these may yield the maximum desired information.

The main intention here is, however, to examine the areas in which fieldwork alone may make the major contribution in understanding the role of the broch in Iron Age society. The positioning of brochs in the landscape is critical in three broad areas of enquiry:

i) the inter-relationships of broch communities one with another,
ii) the nature and functioning of individual communities, and
iii) the precise role of the broch within each community's pattern of daily life.

In each of these cases the position of the broch is the outcome of a location-choosing process which is constrained by the builders' perception of factors which have a spatial dimension. Such factors, being seen as desirable or undesirable in terms of subjective criteria, and ranked according to perceived importance, resulted in a pattern of location which should, if correctly approached, show evidence of the emphasis placed upon individual decision-influencing factors. If the basic postulate, that builders chose the "best" site available, is accepted, one can proceed to analyse the conception of "best", and thus gain insight upon the way in which the economy which produced brochs functioned.

However, it must be noted that there may be numerous factors with spatial expressions which are functions of social, rather than economic, life. The natural desire for exclusive title to a "territory" is perhaps the best example. Therefore a distinction must be drawn in all that follows between factors which can be measured and factors which cannot, but which must nevertheless be considered, since they affect location. All of the models advanced will be based upon factors of the physical environment. Therefore there will remain a great area of uncertainty regarding social questions. If a large body of oral tradition were available, it might be possible to build social factors into these models, and to test these models against field observations. But in the absence /

absence of such a body of evidence, field observations, albeit exclusively of physical factors, must be used as fully as possible.

There are two ways in which an understanding of the principles of location-choosing can be approached. One is by the formulation of a spectrum of alternative location strategies, followed by the testing of each against the observed facts and the identification of the strategy which most closely models the real world. The second method is to take the gathered data and to calculate the degree of interdependence of different factors, so that an "order of precedence" may be established, which will in turn enable a location model to be delineated. The latter approach has been chosen here for a variety of reasons:

i) It is more economical of labour.

ii) It makes use of all available data.

iii) It avoids the possibility of not formulating, and hence not testing, the most acceptable location-choosing model.

Against the proposed method, it must be said that apart from the general framework of study, each case must be approached individually. While this militates against an easy transference of the model-building process to other archaeological situations, it also serves to ensure that the approach adopted is suitable to the available data, and the danger of forcing inappropriate methods upon the data is avoided. Thus the lack of immediate general applicability of the analysis below is a sign of its strength rather than the opposite.

It must be constantly emphasised that spatial and locational analysis can only be of value where space is an important consideration in human activities. More important is the corollary, that if a factor of the physical environment has no spatial variation in quality, then it cannot be an influence on the spatial decisions involved in location.

Variation in the environment is thus the key to the following analysis. The causes of such variation, being essentially geological, climatological, and unimportant to Iron Age man, are not our concern. Rather, we shall concentrate upon the effect of such variations upon man, as observed at second-hand, through his actions.

The environment of Shetland, as of any region, can be split up into factors, each of which has a spatial content. The distribution and location of brochs, and individual sitings, also vary. Correlation of these two sets of variation, at a variety of scales, can be assessed by techniques to be introduced below. But even if a correlation exists, it must be demonstrated that a specific factor should be relevant. Such a demonstration can only be achieved through the use of logical argument. Statistics of correlation measure, but cannot, of themselves, explain. (Harvey, 1969).

The general procedure adopted here has been to build up a model, based upon a framework of scale, for the location-choosing process. This begins with the general (arrival in the region), proceeds to the local (assessment and selection of settlement areas) and concludes with the detailed matter of siting the broch within the chosen area. As will be evident, only towards the end of this process does the archaeological fact of the broch become significant. The broch can only be built if a community of appropriate size and ability has, either itself or through the efforts of its forebears, succeeded in reaching the region, in establishing its hold upon an area of land, and in surviving the vicissitudes of nature and human society. It will also be noted that the broader the scale of examination in this model, the earlier is the choice. This follows inescapably from geography no less than from society. Thus many of the factors examined here, and the decisions which considered these factors, may not have been relevant issues to the generations who built brochs. This depends upon the archaeological fact, as yet unresolved, of whether the broch-builders were first-generation settlers or the descendents of long-established groups.

Essential to the construction of the model are assessments of the significance of specific factors, or groups of factors. The approach is a scaled one, and the conclusion of discussions at each level of scale will be a summary of the relevance, or otherwise, of chosen factors at this scale. Much information will be seen to be generated as a by-product of the analysis involved in the construction of the general model. Some of this information is of itself of interest, even although it does not necessarily contribute directly towards the model of location under construction.

Sampling in Fieldwork ?

The role of sampling in archaeology has recently been much-discussed (Cherry et al., 1978). In essence, sampling theory seeks to produce a picture of reality based upon a small proportion of the data which would be required to produce a complete and perfect picture. The aim is to produce a model of reality which is accurate to known degrees of accuracy by using as small as possible an amount of information, thus achieving economy of effort. A classic example of this is the work of Torrence (1978) on lithic assemblages, in which it was shown that a small sample of flint artefacts, if chosen totally at random from a very large assemblage, could produce figures for proportions of artefact-types which approximated extremely closely to the proportions actually counted. The percentage of accuracy lost was minimal, the percentage of time and effort saved immense.

However /

However, a distinction must be drawn between sampling in situations where it is certain that the whole population of facts is available, and sampling in situations where there is uncertainty as to the size of the original population. If it were known that there were only, at any time, 75 brochs in Shetland, and that the site of each had been located, then it might well be feasible to economise upon the effort involved in field measurement by looking at only a sample of these sites. This sample might be selected totally at random or, if it were desired to investigate the economic aspects, stratified sampling might be utilised to ensure a good range of variety in site-type. However, the sites we have used here are most certainly not all that ever existed, and despite care, some brochs still extant may have been omitted, and some non-brochs included. Since it is not known how many sites once existed, it is totally impossible validly to quantify the reliability of any conclusions based upon the 75 sites which are known, even without further reducing the data, and thus the reliability of any generalisations, by sampling techniques.

Winham (1978), working on Shetland sites of various periods, including the Iron Age, has used the binomial distribution for presence/absence data to calculate the minimum required sample to give predictably reliable results for a wide range of factors. In fact, this approach is invalid in that it merely calculates what percentage of known sites must be visited to produce generalisations valid for the whole known population. It brings us no nearer to any understanding of the original situation. It is the primary contention of the present thesis that in circumstances where the original population cannot be accurately quantified, sampling procedures should not be used unless this is totally unavoidable. Any sampling process must reduce the reliability of the conclusions. In a purely research project there should be no case for deliberately doing this, although in other cases of more urgency there will be reasons for sampling, particularly where time for investigation is limited (Cherry et al., 1978).

A known population of sites is already only a remnant of a formerly larger number of sites, which has been affected by destruction in a way which has probably been non-random in respect to environment. There are also a number of operations essential to the collection and handling of fieldwork data which tend to introduce further bias. These can be summarise thus:

Initial: Selection and definition of study area

Basic: Selection or rejection of sites to be considered (this is conditioned by archaeological criteria which may be either explicit or subconscious)

Field /

Field: Variations in recording standards due to knowledge, skill, equipment or conditions of work.

Analysis: Acceptance or rejection of analytical material and of procedures.

Synthesis: Acceptance or rejection of the results of analyses. Utilisation of hypotheses (preconditioned by preconceptions regarding the operating processes).

With these unquantifiable and unavoidable sources of uncertainty at work in all fieldwork-derived research, there seems to be little case for the use of avoidable sampling procedures.

In the text of Section 1 will be found frequent references to the misinterpretations made possible by treating a small number of examples as typical of all, particularly in the use of Mousa as an exemplar of "normal" broch structure, while the extent of variation among broch economic areas revealed in the present Section will be its own argument. The main aim of discussion in detail of Shetland is to discover how much can be achieved by the analysis of as much data as possible from a restricted area. Obviously, since the results for Shetland alone are presented here, it will be seen that to investigate the whole of Scotland at this level of detail would be a formidable project. Nevertheless, until some attempt has been made to use all available evidence, there can be no background against which sampling can be compared, and its reliability assessed. It may well be that in a few years it will become possible to achieve as detailed a picture of the geography of Iron Age Shetland by the use of sampling techniques, but the harsh fact remains that without studies such as the present example, there would be no way of knowing whether the sampled-based study was accurate in its conclusions. In brief, until there is a solid body of fact to act as a base, extension of archaeological "knowledge" through sampling must remain an unscientific and perhaps undesirable process.

Data-collection and Scale

Having stated the case for using all available data, it remains to outline what data is available, and what the problems of collecting it may be. In Section 1, data regarding structure, defences and artefacts was presented. This was shown to be partial, and open to unknown bias, as it was derived from a situation where individual site conditions often did not permit the measurement of all factors being considered. The limited nature of such data meant that only descriptive, rather than inferential, statistics were appropriate.

In /

In considering geographical factors in the present Section, the quality of the data-set improves dramatically. Regardless of the physical state of the remains of the broch structure itself, the broch's site and environment are always available to measurement. Provided brochs can be located, their setting can always be described in full, and hence strictly comparative, terms. Thus for the 75 sites used in this study, 75 data-sets exist which are complete and completely comparable. More powerful statistical manipulations are thus possible, enabling more precise quantification of the levels of correlation between factors.

The data gathered concerns three broad levels of scale within the environment:

1) Macro-scale: the distribution of sites relative to each other and to the generalised pattern of environmental factors.
2) Meso-scale: the nature of the area within which each broch is set.
3) Micro-scale: the siting of the broch in respect of the nature of each area.

These scales have been taken as basic subdivisions hereafter. The actual environmental factors considered, and the main levels of scale at which each factor might be expected to have significance in location decisions, are as follows:

Distance to next broch site	Macro
Number of other brochs visible	Macro (Micro)
Arable land (presence and extent)	Macro, Meso (Micro)
Geology	Macro
Bioclimate	Macro (Meso)
Landscape unit	Macro, Meso
Distance from coast	Macro, Meso, Micro
Coastal accessibility	Macro, Meso, Micro
Distance from water-supply	Macro, Meso, Micro
Soil quality	Macro, Meso
Drainage	Meso, Micro
Aspect	Meso, Micro
Slope	Meso, Micro
Nature of coast	(Macro) Meso (Micro)
Position relative to best land	Micro
Defensibility	Micro
Convenience for daily life	Micro

Each of these terms will be defined as it is introduced in the text which follows.

Operational Problems

The use of the information gathered under the headings of each of these factors cannot begin until four main limitations have been taken into account. The effect of each of these limitations will be seen to vary with the scale of analysis proposed.

Correct identification of broch sites is essential. Sites which are in fact brochs must not be rejected, nor must sites which are not brochs be classified as such. The effects of errors in this area are most strongly felt at the macro-scale, where a very few sites erroneously omitted or included may serve to distort overall distribution patterns to a very significant extent. Conversely, the establishment of overall patterns may in itself help to highlight areas which appear as "gaps" on the map. This is discussed further in Chapter II below. There is no foolproof technique. The most that can be done, as here, is to gather information of all possible sites, from every available source, and to decide upon a set of criteria for acceptance/rejection, and maintain these. If the results seem wildly improbable, a systematic reconsideration of judging criteria may be in order. As will be demonstrated,in this particular case the results obtained from the 75 accepted sites and the overall pattern of all suggested sites were closely similar, except for tests which would by definition be affected, such as intervisibility.

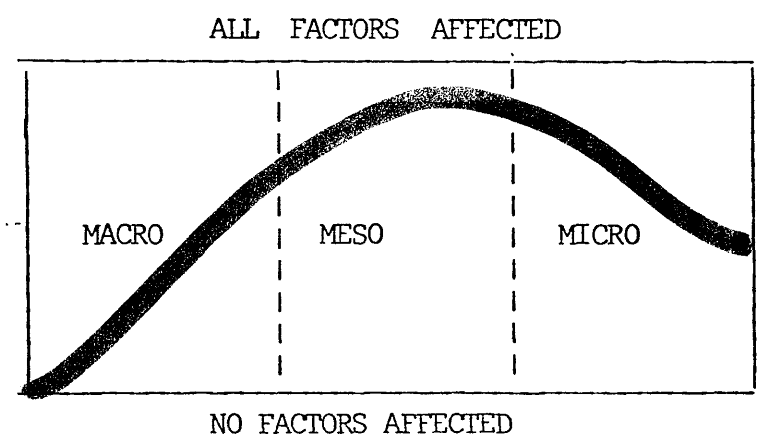
Environmental change since the Iron Age cannot have altered certain factors, such as inter-site distances or subsurface geology. Other regionally-defined factors, such as bioclimate, coastal length or total land area are more susceptible to environmental variations, but at this (macro) scale changes tend to be relatively even overall, and the relative patterns are preserved. Thus with a rise of sea-level, absolute distance to the coast may change, but in most cases brochs retain their relative order of distance from the sea. Similarly, when climatic change is invoked, the most favourable areas remain so, even if they become less or more favourable than before in absolute terms. Thus at the macro-scale the measurement of present quantities provides a valid yardstick, especially if methods of analysis concentrate upon orders rather than values.

At the meso-scale environmental change has a more potent effect. Almost every factor described as an element of the character of the broch's immediate area is susceptible: drainage, soil-cover, sea-level, vegetation, land quality and slope profile to name but a few examples. The worst effects of this can be averted by careful consideration of possible changes since the Iron Age in each individual area, so that the parameters of variation may be established. But once again, in general the relative qualities of the environment have probably changed but little.

At /

At the micro-scale environmental change has had, in most cases, little effect. In two thousand relatively (geomorphically) settled years, hills have remained hills, valleys valleys and cliffs cliffs. Only a few sites (Jarlshof and Eastshore, for example) which lie on low coastal flats have seen significant alterations in their position and relation to nearby land, through loss of substantial areas of low-lying land consequent upon a continuing general rise in sea-level. In the case of Eastshore, loss of land is recorded as recently as 1937. Where sites were built close to sea-level, only a slight rise of water may make an islet of a promontory, while a slight fall may transform a promontory into a rocky ridge rising above salt-marsh. But in such cases, the use of intelligent observation enables allowances to be made for such alterations.

The effect of environmental change on the various scales of data can be summarised schematically thus:

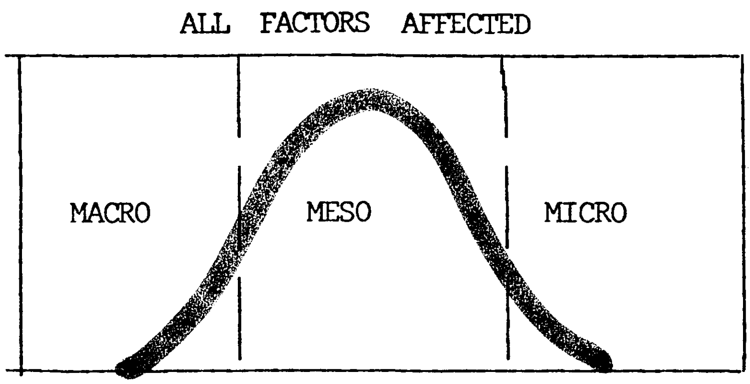


Definition of areas to be considered is the third area in which problems may occur. At the macro-scale there is no difficulty: the area under study is defined as the whole Shetland Islands. Only major geo-tectonic forces would be capable of altering the study area at this scale.

At the meso-scale, the definition of the precise meaning of the "broch locality" or "economic area" is a central element in the collection, analysis and interpretation of data. Before data can be collected in the field, the problem of the extent of areas for which data must be gathered must be resolved. The whole question of "localities", "catchment areas" or "zones of influence" in archaeology in general requires review. The Shetland Iron Age case is discussed in detail in Chapter II, below.

At the micro-scale, the area under study is the broch remnant plus the geomorphic unit upon which it stands. The working definition of "whatever was likely to have been the unit considered by the builders as their working area", if nebulous and subjective, proved easy to apply in the field, although impossible to quantify formally.

Again, a graphical summation serves to show the effect of uncertainty in areal definition relative to scales of data-collection and analysis:



<u>Physical difficulties of data-collection</u> constitute the final problem area. Such problems are varied, at times unexpected, and depend for their resolution upon careful self-monitoring in the field.

The larger the scale of study, the more difficult it is to collect adequate data independently. Ultimately all macro and meso-scale data is displayed upon maps. Much of the original data at the larger scale in fact derives from information published in map form.

For all archaeological purposes, the map-base can be taken as accurate (at least in Britain, where a recent check of the primary triangulation network revealed a cumulative error of a few centimetres over 1400 kilometres). However, even on the most detailed maps, the data displayed upon this base is more limited in reliability. Contours are drawn by interpolation between measured points, although automated air-photographic methods have made the contouring of the new generation of large-scale maps more accurate than formerly. Provided a map of adequate scale is used, slight variations between contour and real heights should not affect achaeological requirements. On the new 1:10 000 Ordnance Survey sheets for Shetland, only water-sources appeared to be significantl mis-represented (too few were shown).

Maps were used in two ways. Firstly, all data recorded in the field was, where appropriate, recorded on a base-map as well as by the noting of raw figures or descriptions. This was done to enable rapid visual checking of detailed analytical results. Secondly, much information which the independent researcher could not hope to gather personally was derived from published and unpublished maps compiled by other workers. Such /

Such information included geology, structure, vegetation, climate and land-use, the last being checked in the field for the broch-vicinities. this data is generally collected at a more detailed scale than that at which it is published, but in most cases the overall pattern was all that concerned the present analysis. In a few cases, however, the scale of detail required for analysis was greater than that published. This was resolved by reference to unpublished data, particularly soil survey information, and in some cases by detailed fieldwork. Specialists in other fields were invariably willing to assist, both by providing access to field data and by discussing general theories and results. In one case, a factor apparently amenable to field-measurement had to be derived from the map-base. This was inter-site visibility, the field measurement of which was rendered difficult by the prevalence of fog in Shetland ! Clearly, this weather-pattern, if representative of Iron Age conditions, may have significance in interpretations of the significance of the factor.

Most of the data used in detailed analyses was of factors at the meso-scale. These factors were recorded at this scale, although general summaries are discussed at the macro-scale. Three types of data were involved:

Type i)	Binomial (presence/absence)
Type ii)	Relative (quality)
Type iii)	Parametric (measurements).

Type i) data is generally unproblematic, except where questions of definition are raised: how far inland is a minimally "inland" site; when does a spring become a seepage, or when is a coastline "accessible" ? Each variable must be examined in turn and criteria established. There are no standard solutions.

Type ii) data was found to make the most important contribution to the forthcoming analyses. A wide variety of factors relating to land quality, aspect, drainage, soil-type and even land-use are only capable of suitable statistical treatment by the application of relative terms. There are formal techniques of soil-classification, for example, but what concerns the archaeologist is not the name or number of the soil, but its fertility, seen against the background of general local soil fertility. The comparative approach in this case is necessitated by the sad fact that in Shetland all soils are poor, even the good ones.

The procedure adopted in such cases was to examine closely the factors concerned, to attempt as full a description as possible, and to form simple classifications based upon natural "breaks" in the data. This produces a classification appropriate to the individual study.

Type iii) data includes all aspects of environment which are capable of direct quantitative assessment. Slopes and distances therefore make up the main elements of this group. The only major difficulties lie in defining what is to be measured. For example, in "distance to coast", a choice must be made between high, low or mean water-mark. Generally, such difficulties are rare. However, one unresolved problem is that of providing a meaningful measurement of distance over differing surfaces. Thus one hundred kilometres over land may be effectively a greater distance, in human terms, than the same distance over the sea, yet one hundred metres over sea is undoubtedly a greater obstacle than over land. This is discussed further below, in the context of nearest-neighbour analysis.

The topic of data-collection cannot be divorced from that of data-classification. Published material is rarely classified to meet exact archaeological requirements, although this may not be apparent without field-checking of the real meaning of classes employed. Thus land-capability bears little relationship to the pattern of arable farming in Shetland, which is the product of many centuries of human labour, often from very unpromising beginnings.Because of this, it would ideally be best to survey each and every aspect of every area in the field. But apart from necessitating a thorough training in each aspect to be observed, this would be prohibitively time-consuming. Again, it is fortunate that a completely detailed picture is not essential, as the achievement of this would be practically impossible.

In fact, it is impossible to collect data in the field unless the purpose to which that data will be put is known. That this is frequently not recognisedcan lead to misunderstanding, especially when data from sources other than personal observation is involved. Thus geologists tend to map structure and history rather than rock-type per se, which latter is usually of more interest to the archaeologist. For the archaeologist concerned with the use of published data there can be no choice between inductive and deductive data, since all data gathered through the use of pre-determined criteria is by its very nature deductive. The most that can be hoped for is that the underlying motives, and hence the limitations, of data collection may be appreciated.

Thus to map Shetland sites as "broch-period" because they yield Type C pottery has been shown to be a case of pre-judgement. (In another period and area, a rather similar situation prevails on Deeside, where an Early Neolithic dwelling exists in close proximity to Late Mesolithic flint-working sites, with little real consideration being accorded to the possibility that the two belong to the same period, and have been divided by terminology rather than chronology. (Reynolds, Ralston, Kenworthy, pers. comm.)).

When /

When mapping environmental data, care must be taken to keep the subjective idea of favourability for settlement as far from the field observations as possible under the circumstances. Thus soils could be mapped as suitable or unsuitable for arable farming, bearing in mind what is known about Iron Age farming technology for the area, but the mapping of an area with arable potential as one suitable for Iron Age settlement would vitiate the whole exercise, as will be clearly demonstrated in Chapter III below. A great effort must be made to record data as observed, without prejudice to later analysis.

Some data will inevitably require to be recorded in the field. As mentioned above, there are two possible approaches. One is to measure each factor as precisely as possible in the field, and to attempt a classification only once all of the data has been gathered. This is extremely time-consuming, can be very tedious, and requires much more time to be spent on site. The second is to prepare a checklist of possible responses for each variable, so that a "yes/no" or "one from n classes" procedure may be used for on-site recording. This involves an amount of preparation, but drastically reduces the time required for fieldwork. The data arrives already semi-classified.

The laborious first alternative has been preferred in this research. To justify this, two numerical examples are given to illustrate the dangers of the checklist approach.

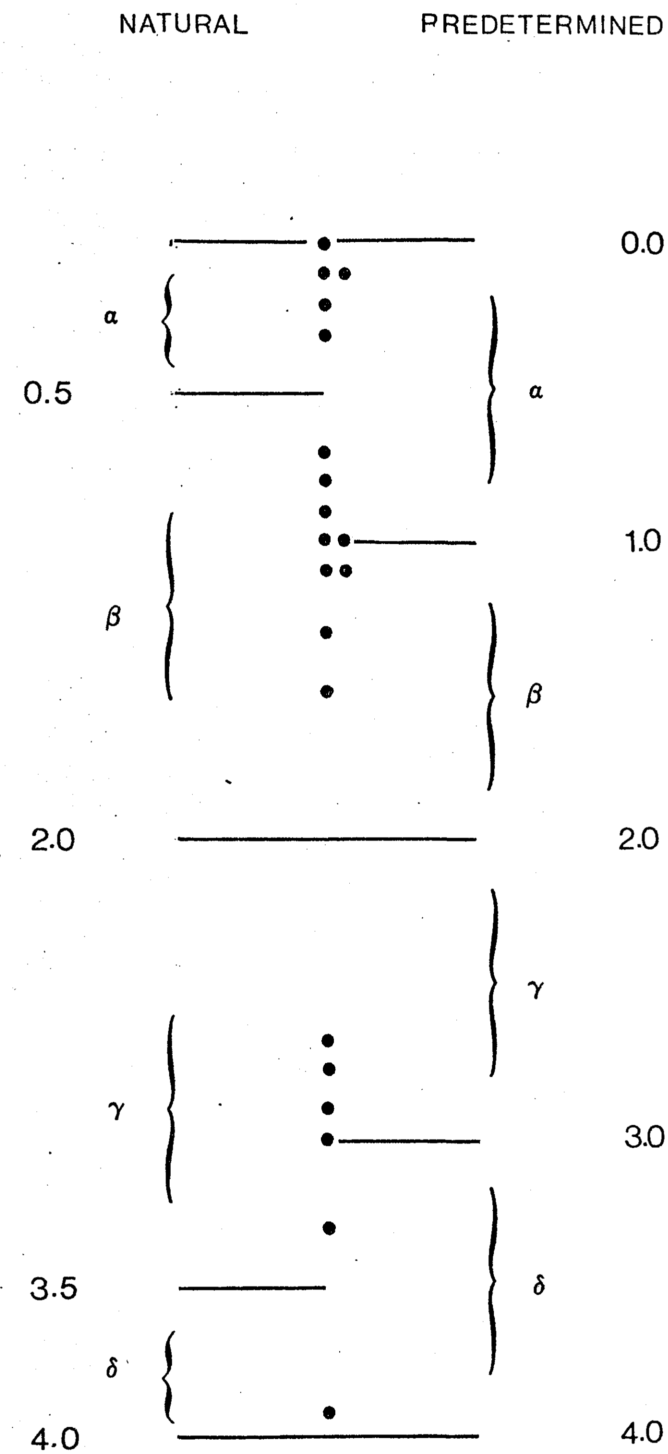
<u>Example 1 : Arable acreage at 30 sites</u>

Observed (actual measurements)

0.4	1.1	2.3	3.1	4.2
0.5	1.4	2.2	3.3	4.5
0.3	1.5	2.6	3.7	
0.2	1.9	2.8	3.5	
0.0	1.3	2.1		
0.7	1.7	2.0		
0.6	1.2			
0.1	1.2		Total = 50.9	
0.1			Average = 1.6967	
0.4				

Observed (classified)

0.0 - 0.99	10	
1.0 - 1.99	8	
2.0 - 2.99	6	Total (calculated from class midpoint)
3.0 - 3.99	4	= 55.00
4.0 - 4.99	2	Average = 1.8333


NATURAL
PREDETERMINED
0.0
α
0.5
α
1.0
β
β
2.0
2.0
γ
γ
3.0
3.5
δ
δ
4.0
4.0

The difference between the averages achieved by the two methods is 7.45 percent.

That is, the pre-classified procedure over-represents the average figure by 7.45 percent. This is because the only "accurate" measure available to analysis is the mid-point of the data-class, and if the data is not randomly or normally distributed, this will not be an adequate representation of the membership of the classes. More critical is the fact that if data is collected in the field in the pre-classed mode, this misrepresentation will never be known. Classified data can only be reclassified by amalgamation, whereas exact measurements can be regrouped until the categories best present natural breaks in the data.

<u>Example 2 : distance from coast (20 sites)</u>

Measured :	0.0	0.2	0.7	0.8	0.9	1.0	3.3	
	0.1	1.1	1.3	2.9	3.0	2.8	3.9	
	1.5	1.0	2.7	1.1	0.1	0.3		kilometres

Pre-classified :	0 - 0.99 km	8
	1 - 1.99 km	6
	2 - 2.99 km	3
	3 - 3.99 km	3

Diagram 2, i, 1 sets out the data in graphical form, and it will be observed that the use of predetermined classes has totally masked the existence of two natural classes in the data-distribution, and has thus concealed a potentially useful fact, that there is a group of coastal and a group of non-coastal sites.

Simply because data is not presented in numerical form does not mean that pre-classification problems can be ignored. A classification "well drained / moderately drained / damp / wet" is of little use if sites persistently fall into a threefold "well drained / average / wet" pattern.

Thus it has been taken as a basic tenet of this research that the classification must post-date the collection of data, to avoid the danger of the use of meaningless classes, and the more subtle temptation to "push" observations into categories when the observation may suggest a marginal position between categories. This seems to accord most faithfully with the overall research aim of attempting to gather as much data as possible as accurately as possible. A checklist was carried into the field, but this was not of the pre-classified type, but a simple list of factors to be measured at each site. Although some of the classes finally used were crude, for reasons to be discussed, they do at least derive from data which has been as accurately quantified and recorded

Summary

Having outlined the major scale divisions in both collection and analysis of data, and dealt with the main sources of difficulty in data-defintion, it is now possible to proceed to the actual analysis and discussion of the data. In three chapters, macro. meso and micro-scale data are presented, discussed in the context of limitations and archaeological questions are posed and attempts made to answer these. The success or failure of the methods adopted is debated before moving on. The aim is to define regularities in the data which will contribute to the "location model" which is gradually built up, and formally set out in the last chapters of this Section.

As has been noted above, data may be of interest at more than one scale-level. When this is the case, the data must be recorded at the greatest level of detail required. Transfer of data from 1:50 000 maps to 1:10 000 maps is not permissible, but the reverse process is. The scale of data-analysis is determined by the archaeological questions. The scale of data-collection is determined by the scale of analysis desired, and by the nature of the variable observed. If these are incompatible, the analytical techniques must be modified to make use of the lower-quality data.

In conclusion, the aim has been to use as much data as possible at as detailed a level as possible. Sampling from among sites has been rejected as an unwarranted reduction of data.

The general principles formulated for use in this study, and recommended for general adoption in such studies, are as follows:

1) Wherever possible, all data, or as much as possible, should be acquired by direct field observation, and recorded as precisely as possible, however tedious this may become.
2) Wherever possible, all sites should be considered in fieldwork. Sampling inevitably reduces the general validity of results.
3) When using pre-collected data, maximum care should be taken to make allowance for bias introduced by the classifications used.

Or, as a general maxim: considering the lack of any proof of the representative nature of the observed set of prehistoric sites, all possible efforts must be made to ensure that the procedures of data-collection do not further bias the already disturbed original regularities which are the evidence surviving to us for logical processes involved in the selection of region, area and site.

Chapter II

Macro-scale considerations

The "broch questions" at the macro-scale are concerned firstly with the relationships of brochs and broch communities one with another, and secondly with the relationships of broch locations to the overall environment of the islands.

In the first case, that of inter-relationships, the formal question under investigation is, "Do the locations of brochs have regard to one another, in a manner which has a spatial expression ?" Alternatively phrased, this becomes a matter of searching for significant order in the spatial distribution of brochs and broch-areas, and attempting to relate any order found in a logical fashion to the nature of brochs and of the communities associated with them.

Analytical methods designed to deal with such data are manifold, but can for convenience be divided into two categories, both derived, ultimately, from the field of ecology. Quadrat methods (Greig-Smith, 1964) depend upon the division of the study area into a grid, or series of grids, composed of equal areas within which the number of points or other phenomena occurring can be counted. The resultant distribution of frequencies of occurrence can be compared with the "random" or Poisson distribution by use of the chi-squared statistic (Davis, 1973). The operational difficulties of the quadrat approach are many, and in the case of Shetland the extreme irregularity of the outline of the study area would mean that, even using a very small grid, many units would contain little but water. This theme, of irregularity of landform, will be found to recur, and is one of the main contributors to the unique character of the Shetland environment. Shetland has an area of some 1440 square kilometres, an area which could, in theory, be bounded by a coastline of 150 kilometres. In fact the coastline is at least ten times this length, with estimates varying from 1500 to 3600 kilometres. This is discussed further below, but its chief effect is to introduce insurmountable operational problems to the use of quadrat methods of distribution analysis.

Fortunately, the more precise method of spatial ordering, nearest-neighbour analysis, seems to be more promising for the case of Shetland's brochs. This technique has been developed by geographers from the work of Clark and Evans (1954). It relates the average separation of sites, as a calculated mean distance, to the total area of the region under study, and /

and compares the resultant statistic to an ideal scale.

The simplest form of the test, in which each site is connected to its first nearest neighbour (more complex forms use 1st, 2nd, 3rd...nth nearest neighbours) is as follows:

$$R = \frac{\bar{d}_o}{\bar{d}_r}$$

That is :

$$\text{Test statistic} = \frac{\text{Observed average inter-site distance} \quad (\bar{d}_o)}{\text{Expected average inter-site distance} \quad (\bar{d}_r)}$$

The denominator, which represents the random-expectation value (average value if sites are located spatially at random) can be calculated from the number of sites and the total area. The formula for this is:

$$\bar{d}_r = \frac{1}{2 \times \sqrt{\frac{\text{number}}{\text{area}}}}$$

The numerator is simply, though tediously, calculated either by direct measurement from the map, or by the use of the Pythagorean formula, with the sites being represented by their National Grid references. Both methods were tested, but there seems little ground for preference when six-figure grid references were used. Eight-figure refences can be used to give greater precision, and the method is easily prepared for computer operation: standardised programs exist.

The ideal scale against which R is compared ranges from 0.00 (all sites clustered) through 1.00 (random) to 2.1941 (perfectly spaced at maximum possible distance). The normal inference is that with R less than unity, agglomerating forces predominate, while with R greater than this, mutual repulsion is the stronger force. In the present case we have:

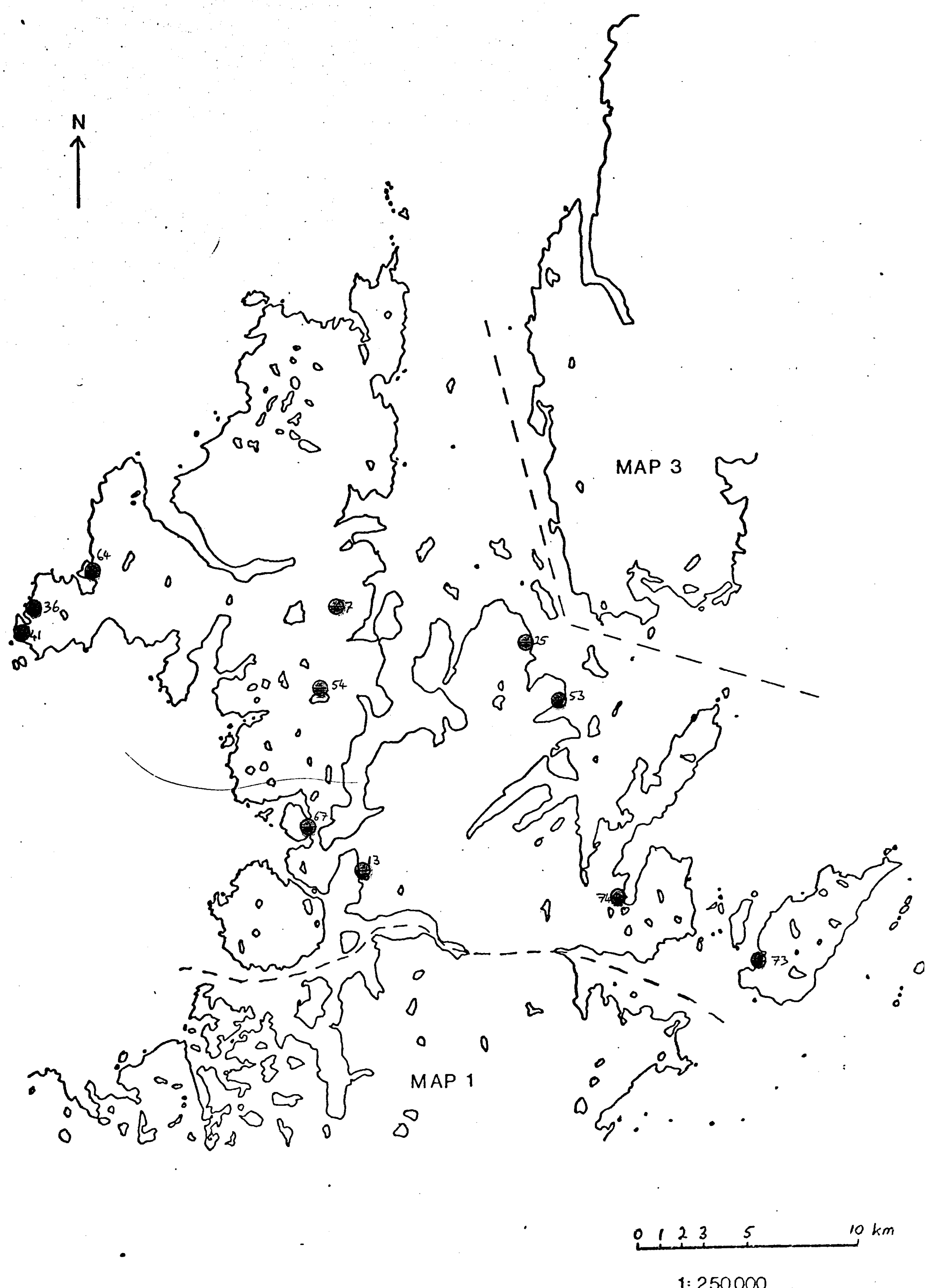
$$R = \frac{\bar{d}_o}{\bar{d}_r} = \frac{2.787}{\frac{1}{2 \times \sqrt{\frac{75}{1440}}}} = \underline{\underline{1.272}}$$

DISTRIBUTION
OF BROCHS

MAP 1

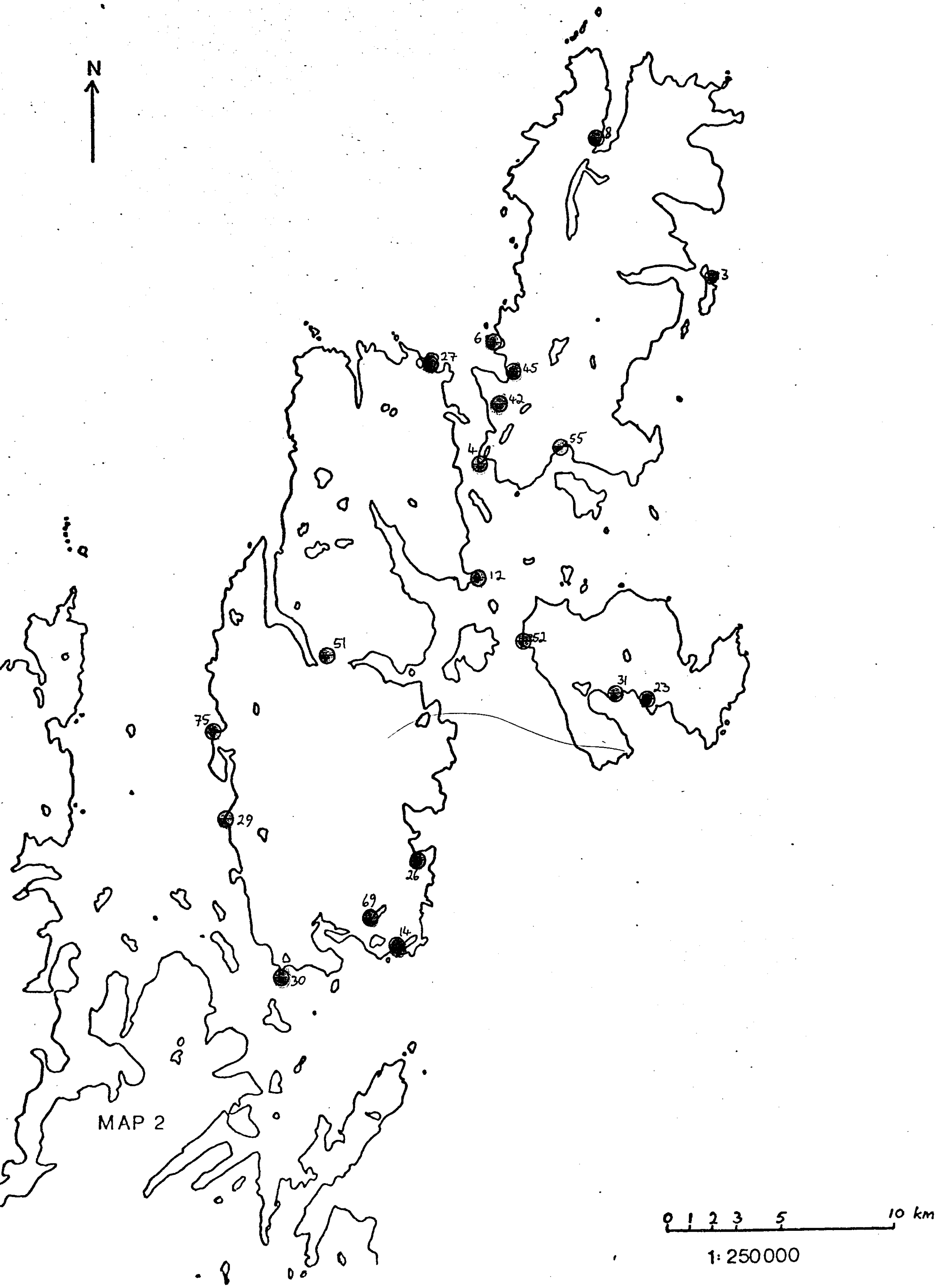
DISTRIBUTION
OF BROCHS

MAP 2



DISTRIBUTION
OF BROCHS

MAP 3



The test statistic, R = 1.272, is statistically significant at the 99 % level of significance. That is, if the true pattern were entirely random, a distribution such as this would have only a one in one hundred chance of occurring. However, even the most cursory glance at the map reveals that a tendency towards an even spacing, as identified by the test, is not readily visible: indeed, the sites seems to group together, in small clusters. Map 2, ii, 1 demonstrates this.

A strongly-marked clustering of sites is observed in Dunrossness, and also around Bluemull Sound, between Unst and Yell. In the West and Central Mainland, a fairly regular spacing seems to obtain. If any tendency appears to the eye, it is towards regional clustering. Hence the anomalous nearest-neighbour statistic requires investigation.

Nearest-neighbour analysis functions, in its ideal form, only on a boundless area, or at least one in which the distance to the edge of the study area, for each site, is less than the distance to the next site. In all other circumstance the "edge effect" operates, and tends to inflate the value of the test statistic, indicating that there is more order in the pattern than is in fact the case. While there is thus a need for a correction factor, this remains at present impossible to calculate, despite much research by geographical theorists. Clearly, the correction must bear some relation to the degree of fragmentation and elongation of the study area. Whatever the size of this corrective factor, it must be sufficiently large in the case of Shetland, where all sites are nearer to the sea than to their nearest neighbour, with one exception, to reduce the true R value to less than unity, that is, to a value which would indicate a clustered distribution pattern.

Hodder and Hassall (1971) have suggested methods of correction based upon eliminating those sites nearest to the edge of the area, but as indicated above, this would leave precisely one site in Shetland ! Thus the nearest-neighbour statistic is an inappropriate measure in this instance, as it is too prone to unquantifiable interference from the fragmentation of the area's outline.

Two modified methods were investigated, sectional and linear nearest-neighbour analysis.

Sectional analysis depends upon the splitting of the area into sub areas in such a fashion that the degree of fragmentation is reduced to a minimum. The only restriction is that each site must have its overall nearest neighbour within the section to which it is allocated. In the case of Shetland, eight subdivisions seemed the appropriate number:

South and Central Mainland	0.789
West Mainland	1.432
North Mainland	0.913
Bressay	0.908
Whalsay	--
Yell	1.387
Unst	1.086
Fetlar	0.895

These figures confirm the visual impression of local clusters of sites separated by areas of lower site density, and also add the suggestion that a significant regularity of spacing may be present in Yell and in West Mainland. As a check on the method, an area-weighted total for this method was produced by the formula:

$$R_{tot} = \frac{\sum R_n A_n}{A_{tot}}$$

Here, R_{tot} = L.258

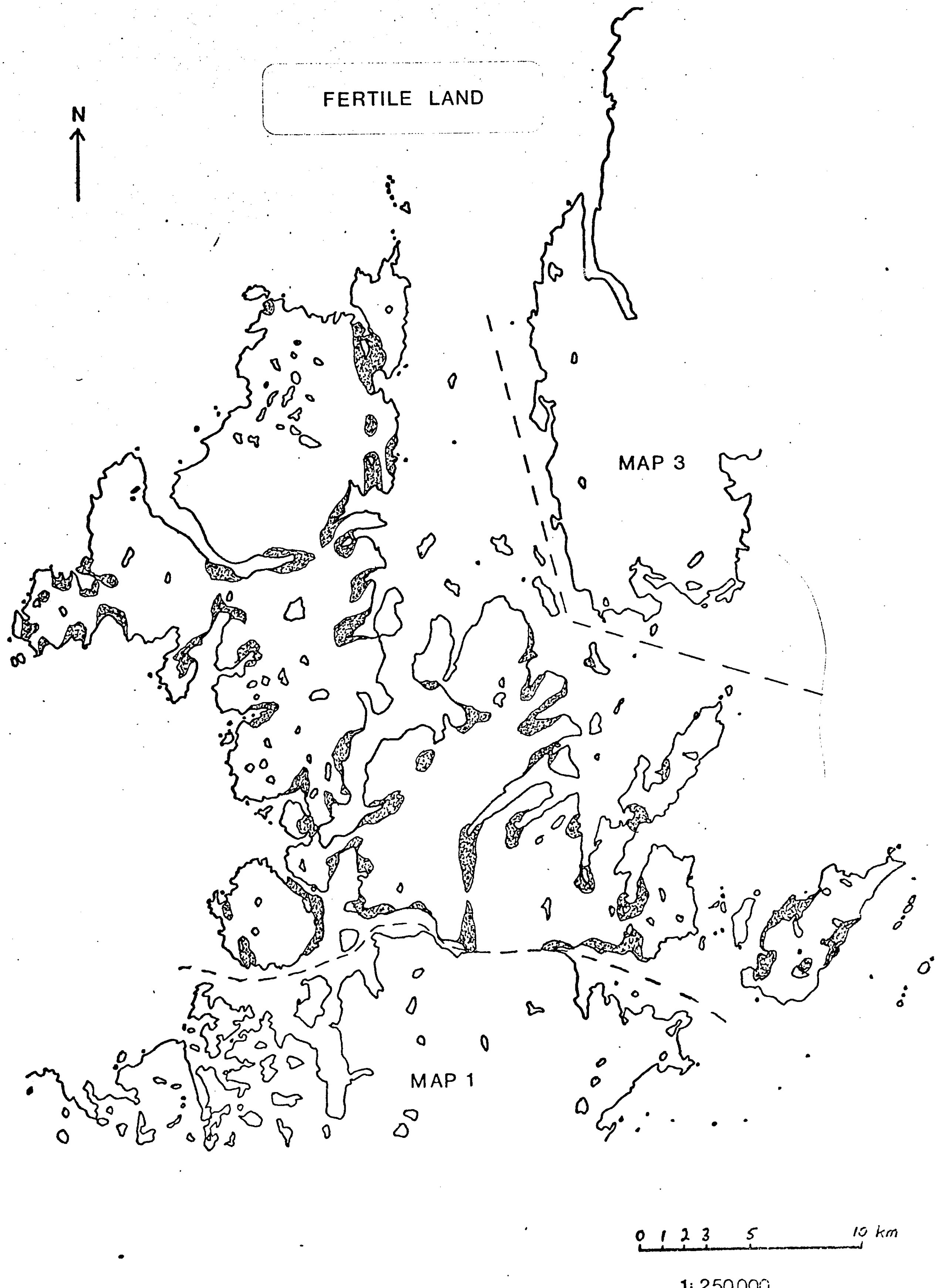
The closeness of this value to that for the single, overall, test (R = 1.272) suggests that the subdivision of Shetland has not served to distort the patterns in any of the areas by a significant amount. This form of the nearest-neighbour test seems to offer a useful tool, as it clearly indicates differences between areal patterns which can be detected visually.

The suggestion that there is a regular spacing of sites in Yell and West Mainland was borne out by visual inspection of the map. The broch sites in these areas are nearly all coastal, and are scattered around the coast at roughly equal intervals. This is presumably because of a lack of good land further from the sea, an overall Shetland problem which is particularly acute in these districts. In Dunrossness, on the other hand, a strong clustering of sites occurs, with a mean inter-site distance of 1.3 kilometres. In this region, arable land comes closer to ubiquity than elsewhere in Shetland (see following chapter).

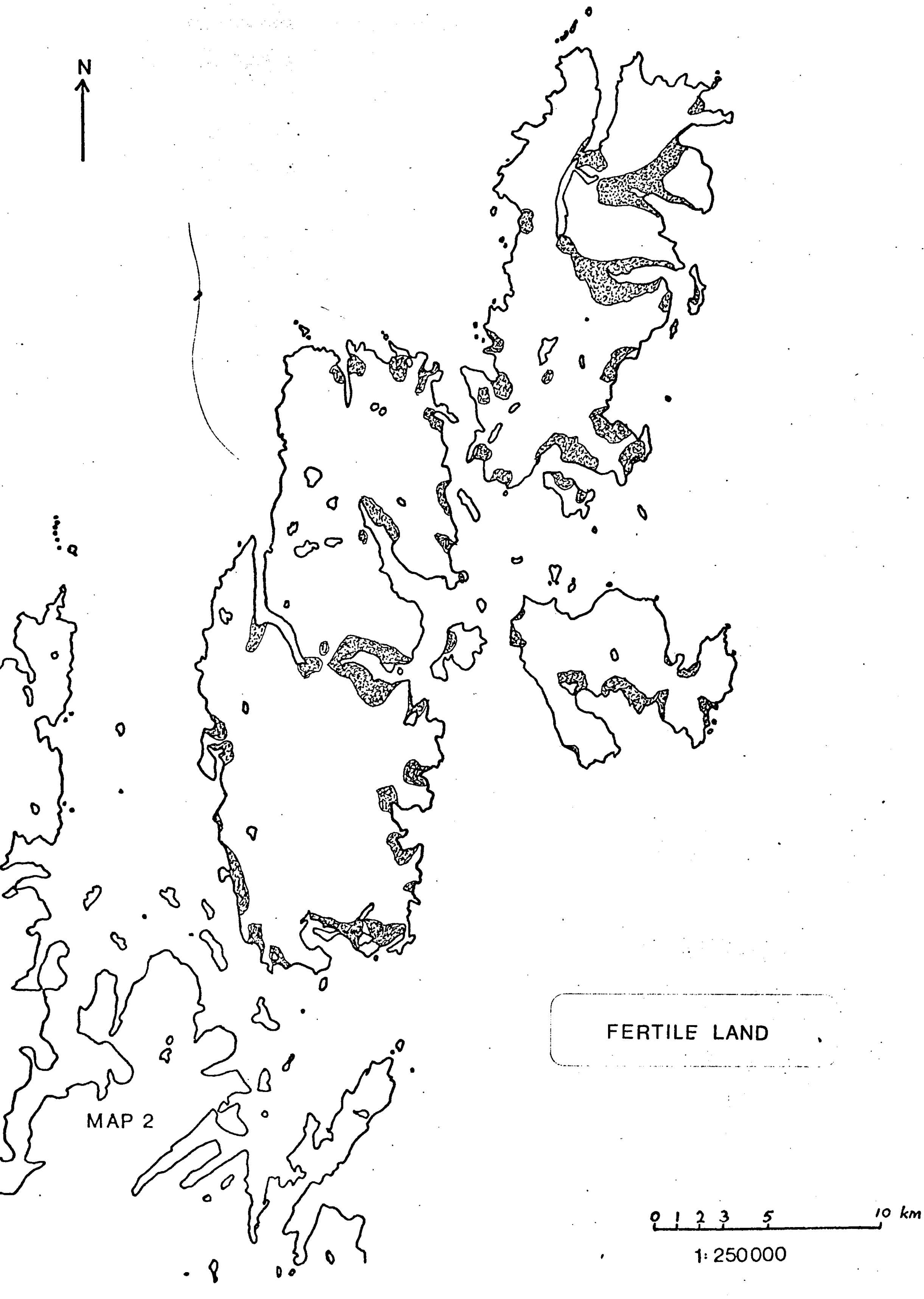
This theme of arable availability was pursued, and a nearest-neighbour statistic was calculated, based upon the distances between the centres of all patches of arable land large enough to feature on Map 2, ii, 2. The R statistic was 1.205, similar to that for brochs of 1.272. Two conclusions derive from this test: firstly that the order observed in broch-spacing may be dictated by the natural order in the spacing of arable land, or secondly, that arable land may in fact have been created around broch sites. It will be remarked /

MAP 1

MAP 2



MAP 3



remarked that while the single nearest-neighbour test is to a great degree vitiated by the edge effect, this effect can be ignored where two or more tests carried out on the same area are compared.

A second alternative, that of linear nearest-neighbour analysis, was investigated. The aim was to establish if there was a general tendency to a regular spacing around the coast, on which most brochs in Shetland are located. However, this technique requires a precise measurement of the length of the inter-site coastal segments (having been originally developed for use on inter-city road distances). It is an unfortunate fact that even coastal geomorphologists have to date failed to find an acceptable method of defining coastlines (Baugh, 1975; Maling, 1968; Mandelbrot, 1967). Because of this practical obstacle, the attempt to modify this technique from Pinder and Witherick's (1975) research had to be reluctantly abandoned.

A basic problem in all attempts to identify spatial patterning is the need to remember that in many cases there is no reason for such a pattern to exist. It has been noted in many archaeological cases that, even where conditions seem ideal, there is not regularity of distribution. So although quadrat or numerical methods may identify order, or fail to do so, it is as well to consider if there might be expected to be an order. As an aide-memoire, the following tabulation is worth noting:

1) Pattern detected:
   - a) This is a remnant of original regularity
   - b) This is a product of non-random destruction
   - c) This is a product of non-random fieldwork
   - d) This is a spurious product of the analytical technique

2) Pattern not detected:
   - a) There was no original order
   - b) An original order has been destroyed by selective erosion (random destruction can destroy an ordered pattern; Haggett, 1965)
   - c) The technique is not suited to detecting order present.

It is as well to remember that site-site interaction may not have been particularly common in prehistoric times, so that spatial order, which results from adjustment to contacts with neighbouring groups, may not be generally to be expected. Even where spatial interaction between groups is suspected, the determining role of patterns in the distribution of environmental factors, particularly strong in marginal settlement areas, will often over-ride the inter-site forces of agglomeration or repulsion. It might be suggested that this is to a great degree the case for the Shetland Iron Age.

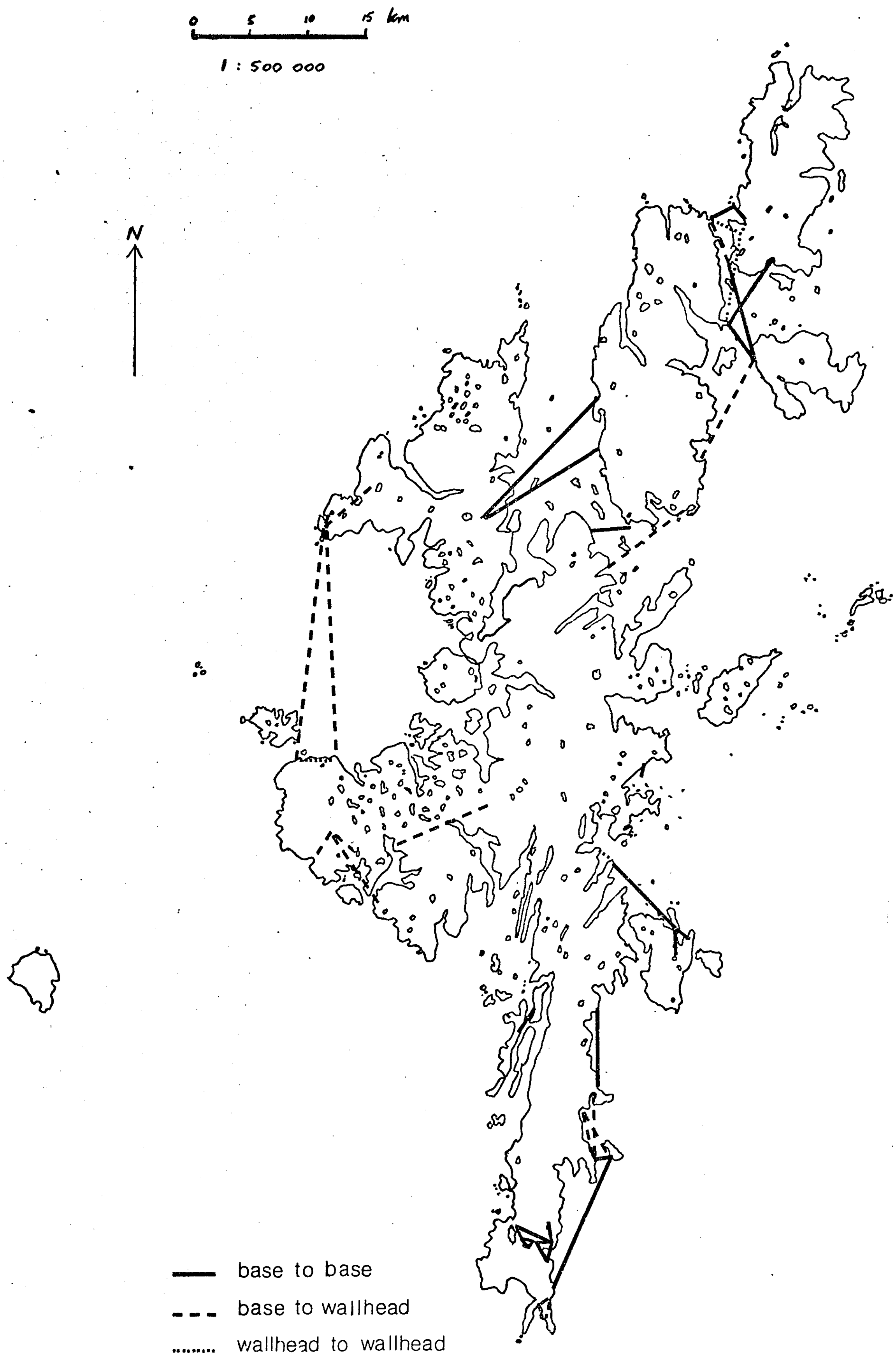
The other consideration to be taken into account while concentrating on the relationships among sites is intervisibility. This does not seem to have been considered systematically in recent years, although Rudie (1976) has dealt informally with this aspect of the brochs of Strathnaver, Sutherland. Intervisibility might well be of importance in any relationships hypothesised to have existed among broch groups, whether mutually co-operative or antagonistic. In the case of mutual assistance, brochs would reasonably be expected to have been situated with at least the wallheads intervisible, to facilitate the interchange of signals. In a situation of mutual hostility, the entrance of one broch would require to be visible from the wallhead of the next, and vice versa, so that watch could be kept for threatening movements of men.

A map of intervisibility was compiled (2, ii, 3) with three contingencies in mind. A base-to-wallhead height of 10 metres was assumed for the sake of argument. The three types of intervisibility are:

1) Base-to-base
2) Base-to-wallhead
3) Wallhead-to-wallhead.

The object of this was to determine whether the brochs of which we have evidence could be shown to have been situated so that they were in view one from another, and if so, whether this degree of intervisibility could be attributed to a deliberate series of siting decisions.

In only two regions were sizeable groups of intervisible brochs identified: Dunrossness and around Bluemull Sound. These are the parts of Shetland where brochs are thickest on the ground, and it would in fact be exceptionally difficult not to site the observed numbers of brochs so that they were not visible one from the other. Many other small groups and pairs occur, and it does seem probable that small rather than large groupings might be expected, as the idea of an integrated defence network seems rather far-fetched, as does the picture of a large number of groups simultaneously calculating the optimum location to watch their neighbours. However, an objective assessment of the siting evidence does not suggest that any broch was deliberately placed in a location awkward for daily life just so that the next broch was visible. No satisfactory statistical test could be devised to substantiate the visual impression, especially as so many imponderables would be involved, such as the use of lookout points on intervening hills. So far as the general outward view is concerned, most /



INTERVISIBILITY

most brochs have a wide view over their immediate areas, but many have more restricted distant views. This local effect is discussed further in chapter IV below.

To summarise the evidence for interaction, as provided by the distribution of brochs, it can be said categorically that the factors normally claimed as promoting spatial order in site-location are so heavily influenced by the character of the Shetland environment that their effect is totally masked. The location of brochs may, indeed, relate closely to theoretical models, but these are so distorted by the irregular base of the physical landscape as to make the observation of any regularity something not to be expected.

The second group of factors to be considered at the macro-scale also play a major role at the meso-scale. Most of the elements of the physical environment capable of on-site recording, such as soil-type or land-quality, would have been central considerations to the broch-builders, or their ancestral groups, in their search for areas of settlement at whatever period of prehistory these people arrived. Thus the overall pattern of such factors has an important effect in relation to the overall patterns of human settlement, just as the detailed pattern of these factors has a strong effect on the way in which each local area could have been exploited. The latter, more detailed aspect, is discussed in the next chapter.

In considering the general relationships of the distribution of brochs to environmental factors, two critical caveats must be borne in mind:

1) The locational choice may have been made long before the broch-phase. In three excavated sites in Shetland, there was considerably-earlier occupation on the same site at two localities (at Jarlshof and at Clickhimin, but not at Sae Breck). Alternatively, there may have been occupation at or near the broch site which has escaped detection. As ever, the precise dating of the broch-building phase remains elusive.
2) A high correlation factor between broch sites and the distribution of a factor does not mean that the factor was necessarily a critical consideration, but merely indicates a regularity to be explained.

The factors to be considered here, in their overall effects on the broch distribution in Shetland, are:

Intervisibility : The brochs of Mousa and Burraland
face each other across the Sound of Mousa

1) Arable or former arable land
2) Sub-surface geology
3) Bioclimate
4) Landscape Unit
5) Distance from coast
6) Coastal accessibility
7) Distance from water-supply

These factors are of differing types. The first three are areal, a quality partially shared by the fourth, which is also to some extent nominal. Items 5 and 7 are linear measurements, while 6, which is closely tied to 5, is in essence a non-linear distance measurement in its relation to brochs.

The chi-squared technique, which is described in detail in a note following this chapter, was found useful in discussing factors 1 to 4, but for the factors 5 to 7, less-standardised techniques had to be employed.

Arable land, sub-surface geology and bioclimatic zones are all areally-classified variables. That is, the whole area of Shetland can be attributed, in varying proportions, to one of the constituent classes of the classification, and the individual site will lie either within the area of one particular class, or on the boundary between two classes. To establish whether or not broch sites are more strongly associated with any particular class of a variable, for example arable rather than non-arable land, is in theory very simple. The relative proportions of each class are established, and the number of sites falling in each class is counted. If the statistical indicator used (here the chi-squared test) indicates a significant difference between the distribution of total land and total numbers of sites among the classes of the factor, this points to a situation which requires further investigation.

The main operational difficulty is, perhaps surprisingly, not due to the statistical methods, but to the simple practical problem of the accurate measurement of area. There are mechanical methods of area-measurement, but these are heavily influenced by the accuracy of the operator of the machine. It is normal, rule-of-thumb practice to measure areas by covering the map with a fine grid ruled on film or tracing paper and counting the grid-squares which are dominated by each class. The small amounts of other classes in some squares counted should be offset by the small areas of the class which lie in squares dominated by other classes. The drawback of this approach is that it requires the making of subjective judgements in regard to the percentage of squares occupied by the main classes. This can be overcome by using the intersections of the grid-lines as sample points, with two great advantages /

advantages; firstly the need to inspect each square closely is removed, and secondly it becomes easier to record classifications for several factors simultaneously. The only real constraint on the use of what is essentially a systematic sampling procedure is that the size of the grid must be kept small, so that there are many more sample-points than classes.

Using this technique, and the 1 km National Grid as a sampling frame (intersections of 1 km grid lines), a test count gave a total land area of 1495 intersections = 1495 square kilometres, which compares very favourably with published estimates of from 1440 to 1480 square kilometres for Shetland's area. The difference, which at maximum is less than 4 percent, can be attributed to the rather indistinct coast representation on the 1:50 000 map base.

With this high degree of accuracy is still associated a considerable amount of tedious, repetitive, labour, and it was desired to reduce this essentially routine procedure to a minimum. To this end an experiment was conducted to ascertain the smallest number of points which could be taken at random from the grid and would represent to a close degree of reliability the actual proportions of different classes. As the arable/non-arable ratio for Shetland had been calculated for all 1495 grid intersection points, this data was used as a basis for experiment. Samples of 50, 100, 200 and 500 points were drawn at random, four of each size. The results are tabulated overleaf.

Sample Size	Arable	Non-Arable	Percentage	Discrepancy
1495	202	1293	13.5	0 (0%)
50	10	40	20.0	6.5 (48%)
50	8	42	16.0	2.5 (19%)
50	6	44	12.0	-1.5 (11%)
50	4	46	8.0	-5.5 (41%)
Mean 50	7	43	14.0	0.5 (3.7%)
100	18	82	18.0	4.5 (33%)
100	10	90	10.0	-3.5 (26%)
100	15	85	15.0	1.5 (11%)
100	11	89	11.0	-2.5 (19%)
Mean 100	13.5	86.5	13.5	0.0 (0%)
200	30	170	15.0	1.5 (11%)
200	22	178	11.0	-2.5 (19%)
200	26	174	13.0	-0.5 (4%)
200	28	172	14.0	0.5 (4%)
Mean 200	26.5	173.5	13.25	0.25 (2%)
500	68	432	13.6	0.1 (1%)
500	66	434	13.2	0.3 (2%)
500	69	431	13.8	-0.3 (2%)
500	67	433	13.4	0.1 (1%)
Mean 500	67.5	432.5	13.5	0.2 (1.6%)

As will be readily seen from the tables, a sample size of 500 would have produced a figure reliable to within 2.5% (a result which gains support from the summation of the four samples of size fifty). Even allowing for the maximum 4% relaxation due to the difference between the accepted area and the 1495 of the grid-intersection count, the sampling results for samples of size 500 have a maximum error product of less than 7%. That is, the estimates based upon samples of 500 are accurate to 93 percent or better.

So /

So some economy appears to be possible through the use of random sampling from the grid-base. While there is some effort involved in actually selecting and locating the sample points, this is marginally outweighed by the saving in time spent on actual observation of the classes. The saving on time in the manual operation of this procedure is slight, but in a situation where data for all grid-squares or intersections was already held by a computer data-bank, the savings in time and therefore cost would be both real and tangible. It is hoped to integrate some of the environmental data held by the I.T.E. (Institute of Terrestrial Ecology) on this basis (Molineux, 1978), but this is a long-term project, as the data is not yet available for general use.

It must be emphasised that this type of sampling is radically different from that discussed in Chapter I, the crucial difference being the fact that in the case of areal measurement by sampling the whole facts could be obtained if required, while in the former case, that of sampling from among archaeological sites, the original case cannot be known in toto.

In the remainder of this chapter, all areas have been calculated by the use of the above methods, except for arable land, where all 1495 points were taken (this simply constitutes a larger sample than the rest). The levels of sampling used are stated as appropriate.

Arable land may be derived from two published sources which cover most of Great Britain, including Shetland: the Soil Survey's Land Capability map series and (with more effort) the Royal Air Force's 1946 coverage of Britain by air photography at approximately 1:10 000. In addition more recent air cover is available for some districts, especially the coastal areas, but this is in general non-standardised as regards scale and film type.

The chief disadvantage of the Land Capability series, for the archaeologist, is that the governing criteria behind the classification are those of modern agricultural requirements, with the result that flat land is rated highly (for mechanical cultivation) whereas in pre-mechanical times such land, particularly in highland areas, would have tended to be rather damp for cultivation, with most farming taking place on valley-side slopes. This defect can be observed at work in Shetland, where much Grade 1 land is not, and has not been, used because of waterlogging which is theoretically remediable. Conversely, some areas of /

of low capability have arable crops because small fields have been built up over years of effort from completely unpromising foundations on shingle or peat-moor. Aerial photographs have the simple disadvantage that since the measurement of arable land is a lengthy optical process, it is usually more economical of time and effort to map the land-use patterns in the field. Air photograph interpretation was tested (see below) and is reliable, but cumbersome, and not to be recommended for the non-specialist when field observation is possible.

As it was the (achieved) intention to cover the whole of Shetland on foot, arable land, and land formerly used as arable, were recorded direct from the landscape onto the base-map (in this case the Ordnance Survey 1:50 000 series). Local residents were able and willing to give much valuable guidance as to present and former conditions, and were especially helpful in distinguishing improved pasture from grassed-over disused arable. Such information must obviously be treated with care, but generally was in accordance with such documentary evidence as was available.

As a test of the reliability of air photograph interpretation the island of Unst was surveyed both on foot and through the use of air photographs. The resulting figures for land of good quality agreed to within 1.5 percent. The exact value of this figure is suspect, since it is less than the cumulative scale distortion to be expected from the photographs, but serves to indicate that such an approach would be of value if field time is limited for some reason. Great care would be required over the establishment of field-checking procedures to ensure that print tones were accurately interpreted. The actual field results are used below for all of Shetland, including Unst.

13.5 percent of Shetland's map area is composed of good quality land, adjudged to be capable of supporting Iron Age arable farming. This is rather less is calculated as a percentage of total surface area as the latter, which allows for slope factors, shows a proportionately lower excess value for more gently-sloping surfaces, on which most good land lies. The dimensions of this difference are small enough to be negligible for Shetland as a whole, but might be significant in some local areas. A table of map and corresponding true areas is given:

Slope angle	Map area	Surface area
10°	100	101.5
20°	100	106.4
30°	100	115.5
45°	100	141.4

For practical purposes the map area will suffice for Shetland, where average slopes are below 10 degrees, but the slope-factor has been raised here as a possible consideration in more rugged terrain, and is in fact large enough to be significant in certain areas of Shetland, particularly the North Mainland and parts of Unst.

Using Map 2, ii, 2, as seen above, it will be observed that 13.5 percent of Shetland's area is good quality land, this group comprising all land which is, has been, or might be, capable of arable cultivation. Of this portion, 37 percent is presently used as arable (that is, 5 percent of the islands' area), and of this most is under sown grass. The present-day cropland represents between one and two percent of the total land area of the Shetlands.

While it might prove to be an inevitable over-estimate, the total of good land has been used here, as there is no way of knowing how much was used in the Iron Age. What evidence is available, in the form of clearance cairns around some remote broch sites, such as Burra Ness and Belmont, would suggest that the land near to brochs, at least, was cleared for cultivation, but again, whether all of the clearance cairns are of the same age, or represent a periodical shift in arable land, is not known. The amount of environmental work carried out in Iron Age Shetland is minimal, but inference from earlier periods (Whittle, 1979) and later times (Bigelow, 1979) argue for a crop to fallow ratio much higher than the present.

Of the 75 sites used in this study, 47 were found to lie on, or within 50 metres of, good quality land, while of the remaining 28, half are within two minutes' walk of such land (approximately 150 metres). Most of the remnant are on small islets lying offshore from areas of better land.

The construction of a chi-squared contingency table from this data is straightforward (the basis of the method is explained in the note on techniques which concludes this chapter). The expected values are for the hypothesis that there is no spatial correlation between the distribution of brochs and the distribution of good land:

	On arable land	Not on arable	
Observed	47	28	75
Expected	10	65	75

$$X^2 = \text{Sum} \frac{(O - E)^2}{E} = \underline{\underline{157.96}} \quad (\text{D.F.} = 1)$$

This result is statistically significant at well over 99 percent, that is, if brochs really were distributed randomly, such a pattern of observed association would have a less than one hundred to one chance of occurrence. Even allowing for the inevitable over-estimate of the area of arable land for this period, an exceptionally strong correlation exists, and must be explained.

Logically, there are three possible conclusions:

1) The result is spurious (the one in a hundred chance) and brochs are located in space with no correlation to good land. In more familiar archaeological terms, this is equivalent to a single radiocarbon date lying more than three standard deviations away from the true core date.

2) Brochs are directly linked to arable land distributions by some causal link, in this case presumably that the builders chose to construct brochs close to actual or potential farmland. However, the strong likelihood that the association has been exaggerated must be borne in mind. The reason for this suggestion is that once centres of activity are established, the surrounding land tends to receive more attention than peripheral land, so will be manured and gradually improved. Thus the establishment of settlement nuclei will have tended to polarise the pattern of land use.

3) Both the distribution of brochs and the pattern of arable land are in fact linked causally to some third factor which has not been considered here, but there is no direct causal link between the broch and arable distributions.

The first possibility is the reason for using confidence limits. The remote chance cannot be ignored, but as it is ever-present, it requires to be set in perspective. At least the statistical method, through the assignment of percentage reliabilities, can provide this perspective. While the direct causal explanation is most attractive, it is very difficult to assess the likelihood of the third effect, that of common cause. There are a number of other factors which are capable of influencing land quality and may also have been location considerations in the minds of Iron Age inhabitants, so judgement will be suspended until these have been examined.

These factors are : Geology
Bioclimate
Landscape Unit.

Subsurface Geology was considered to be a potentially influential factor, with a bearing on ease of construction (affecting original distribution) and survival of structures (affecting remnant, observed, distribution). Clearly, geology may have a strong bearing on soil-type and quality, and this is also discussed below.

A simple division can be made between rocks which are readily split and those which are not. The basis of this division is the Institute of Geological Sciences Regional Handbook (Mykura, 1976) and the works cited therein. The two classes comprise:

Fissile :
- Sandstones and flagstones
- Limestones
- Phyllites and spillites
- Gneisses (except heavily-veined types)
- Gritstones
- Shales

Non-fissile :
- Granite and granophyre
- Serpentines
- Diorites
- Andesites and allied tufaceous rocks
- Gabbroic rocks

These are displayed in Map 2, ii, 4.

This crude division is generally effective, the main exceptions to the classification being blocky sandstones and grits of greywacke type, and serpentines of extremely fractured nature. These are however so scarce as to have little effect upon the scale studied here.

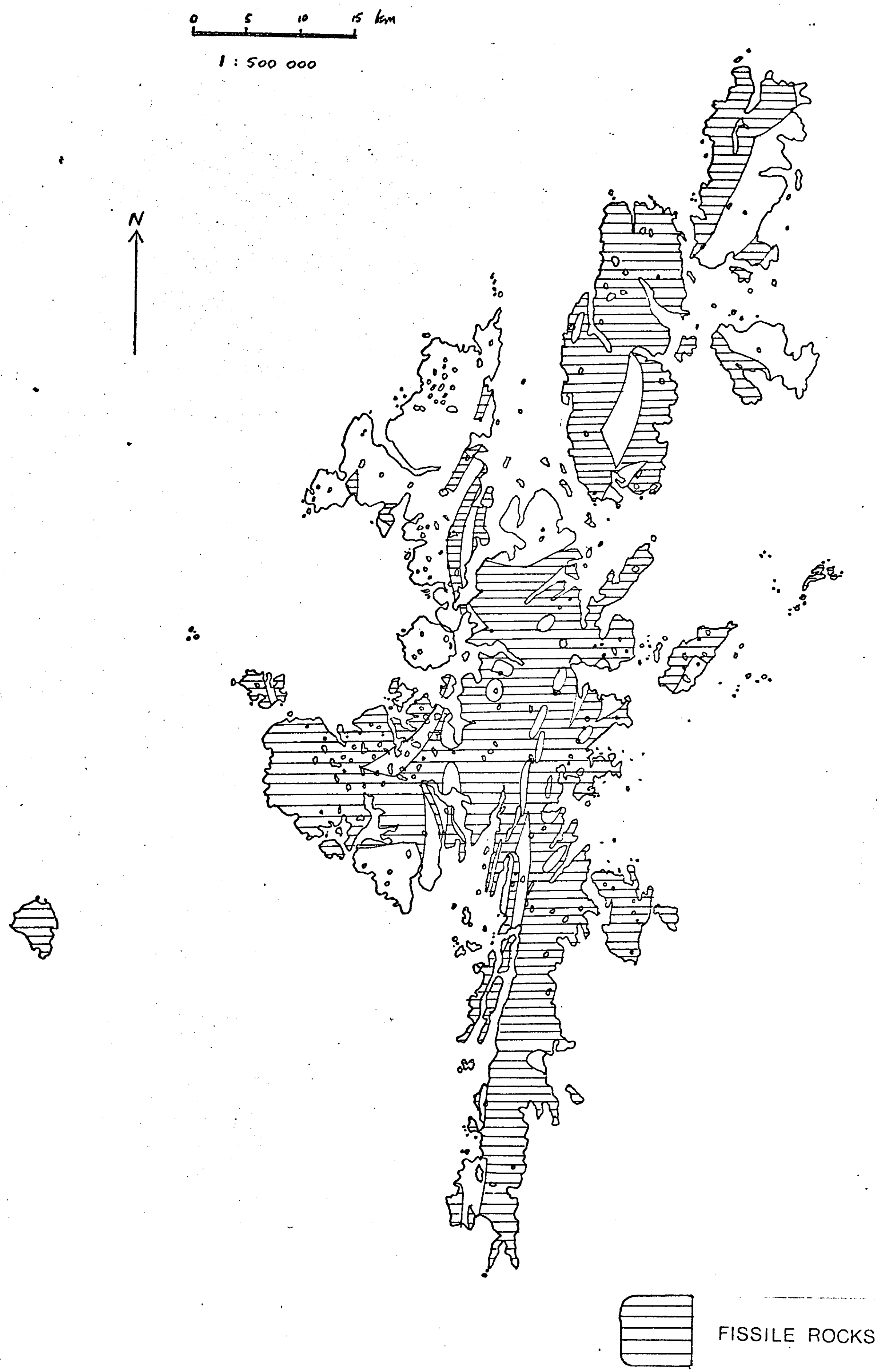
The chi-squared test was used, with the null hypothesis being that no spatial correlation exists between the fissility of rocks and the distribution of brochs. The results were as follows:

	Fissile	Non-fissile	
Observed	63	12	75
Expected	$52\frac{1}{2}$	$22\frac{1}{2}$	75

$$X^2 = 7.00 \quad (D.F. = 1)$$

This is significant at 99 percent. That is, there is a very strong positive correlation between the distribution of fissile rocks and the distribution of the broch sites used in this study.

The /


0
5
10
15 km
1 : 500 000
N
FISSILE ROCKS

The same three interpretations exist as for arable land: spurious result, true correlation, or covariation.

If brochs were originally built with greater frequency on areas of good building stone, in preference to other areas, this would explain the observed pattern. But to demonstrate this dominance of the quality of the stone would require positive proof, such as the building of brochs on non-fissile substrata with "imported" stone of more amenable type. In fact the only case observed in which a broch is not built of the type of rock directly subjacent is at Burgan, which is built of a "difficult" granite, transported some distance from a hillside outcrop. This broch stands on an outcrop of more-readily worked gneiss, and the use of the granite can in this case be explained by the likelihood that a good outcrop of frost-shattered granite blocks was available on the hillside, removing the need to actively quarry building material.

Culswick, also built of granite, is as well-built as many brochs of more tractable stone, if a trifle less refined to the aesthetic eye. In general, the availability of the rock, in terms of quarry-sites, seems to have some importance. There is little good evidence for laborious quarrying, although many of the coastal brochs lying on flagstone outcrops seem to have been built by stripping ready-freed blocks from the shore. Field-gathered rock seems to be little used, probably because of the great disparity of size and angularity, much of Shetland's glacial and fluvioglacial deposits being of a well-rolled nature not conducive to dry-stone construction. The exception to this is the broch of Clevigarth, around which a broad area of land does appear to have been cleared, partly no doubt for agricultural reasons, but partly at least to provide building materials, as attested by the make-up of the tumbled ruins. In most cases outcrops are favoured as sources, and especially outcrops which have been loosened by the action of frost or sea, as at Culswick or Levenwick respectively.

The absence of evidence for the importation of good stone to areas poor in such material may be to some extent spurious, since as good building material would be at a premium in such areas, stone-robbing might be expected to have been more severe there than in areas where good building-stone formed the bedrock. This matter of robbing from broch sites is discussed further below.

From the list of rock-types, it is apparent that there is a marked association between the distributions of better soils and more amenable rock-types. Visual comparison of Maps 2, ii, 2 and 2, ii, 4 will confirm this, but to confirm the impression a random sample of 200 points, from the sampling grid, was tested by the chi-squared test, which confirmed a very strong correlation between fissile rock and arable land.

This may be compared with the observation by Chapelhow (1965) that the constituents of most Shetland tills do not seem to be far removed from their parent outcrops. Solid geology is, then, a reasonable guide to the mineral contents of soils. However, the actual mineral contents of the rocks must be treated with care. The base-rich serpentines of the Unst-Fetlar block do not break down in such a fashion as to render their potentially-beneficial mineral constituents available to plant-growth, and are in fact characterised by a plant assemblage world-famed for its poverty. But the crude generalisation that not only are the fissile rocks of better soil-forming potential, but that this potential is in fact fulfilled, holds for most of Shetland. The harder rocks, which are also the less-fissile, tend to promote peat-growth. This is partly due to the inherent acidity of the main hard-rock types, but is also attributable to differential erosion. During the last glacial period, all of Shetland was covered by a considerable depth of slowly-moving ice. On the softer rocks, the effect of this was to mould gentle linear landscapes, which by and large allow regular drainage. On the more resistant blocks, the erosion was of a more irregular type, heavily influenced by faults and zones of weakness, and resulted in large tracts of "knock and lochan" topography, whose disturbed and inefficient drainage has since led to peat-growth. This has served to reinforce the effect of the rock-soil correlation, as the mantling of thick peat is an effective inhibition to cultivation.

If better soils are found to be associated with better building-stone, then differential survival might be expected to have operated, with higher post Iron Age population densities resulting in more stone-robbing for later structures, and hence most surviving brochs being on poor soils overlying unfavourable bedrock. As shown above, the reverse of this is true, with brochs concentrated on areas of good soil and good rock, even where outcrops, as sources for later buildings, are scarce, such as central Dunrossness, between Boddam and Spiggie. Brochs might be expected to have survived best in non-arable areas, but the stong broch-arable correlation denies this.

If stone-robbing has been concentrated as might be expected, the original distribution of brochs must have been even more strongly biased towards good farmland than is the case for the remnant examples. Any quantitative conclusion is made impossible by the undoubted difference in the extent of disturbance at different sites. Some brochs in areas with plenty of natural stone have been totally removed (Islesburgh, for example), whereas Clickhimin, hard beside the growing town of Lerwick, has survived remarkably well. Another factor here may be the actual ownership of ruined structures, as these were recognised as assets to

the /

the crofter in Orkney, if not in Shetland (Fenton, 1978).

In summary, the observed strong association between the distribution of brochs and that of fissile rocks is likely to have been at least as strong in the past as it is today, and may even have been more marked in former times.

Bioclimate, the third factor, is a convenient summary of vegetation groups and climatic criteria. The most convenient (and accessible) approach is that developed by Birse, Dry and Robertson (1970, 1971) for the Soil Survey of Scotland. The index of classification is composed of:

Accumulated temperature	(total of mean daily temperatures)
Potential water deficit	(difference between evaporation and precipitation)
Thermal zonation	(dependent upon latitude and altitude)
Oceanicity	(extent to which water surrounds area).

It is fortunate that this data is readily available to the archaeologist, as the calculation of such data for the whole of Shetland would be prohibitively expensive of time and effort. The regions of Shetland are displayed in Map 2, ii, 5 (Birse, 1974). All of Shetland falls, as might be expected, into the Hyperoceanic sector, and the classes within this bear a close relation to vegetation types, with only two of the eight classes being favourable for general farming activity. The classes, and their distribution in percentage land area, are:

H_3B_2	Humid southern boreal and lower oroboreal (Damp, moderate temperature)	45.5 %
H_3B_1	Humid upper oroboreal (Damp, cool temperature)	6.7 %
H_2B_2	Very humid southern boreal and lower oroboreal (Very damp, moderate temperature)	5.8 %
H_2B_1	Very humid upper oroboreal (Very damp, cool temperature)	38.5 %
H_2A_3	Very humid orohemiarctic (Very damp, very cool temperature)	1.7 %
H_1A_3	Extremely humid orohemiarctic (Wet, very cool temperature)	1.0 %
H_2A_2	Very humid lower orohemiarctic (Very damp, cool temperature)	0.2 %
H_1A_2	Extremely humid lower orohemiarctic (Wet, cool temperature)	0.6 %
	Total	100.0 %


0 5 10 15 km
1 : 500 000
N
MILDEST
ZONE

This data was used to prepare a contingency table for the chi-squared test, the "expected" data being generated from the null hypothesis that the 75 brochs displayed no spatial correlation with any specific climatic type or group of types, but are spread at random around the climatic landscape.

	H_2B_3	H_3B_1	H_2B_2	H_2B_1	H_2A_3	H_1A_3	H_2A_2	H_1A_2	Total
Observed:	55	1½	5	13½	0	0	0	0	75
Expected:	34	5	4	29	1	1	0	1	75

$X^2 = 26.955$ (D.F. = 7) *

The result is significant to over 99 percent. That is, for a group of 75 randomly selected points such a marked pattern of association with the mildest climatic zones would occur with a probability less than one in one hundred, if the sites were in fact randomly distributed among the different classes. (In fact, the correlation is significant to 99.9 percent, or one in one thousand.) There is a very clear and very strong tendency for broch sites to lie in one of the two classes which represent the mildest of the eight climatic types found in Shetland.

This leads to the suggestion that climate may have played a significant role in location choice, particularly in the choice of area, rather than site. However, since one of the factors influencing both soil-formation and land capability, it would be expected that climate bears a strong relationship to arable land and land of potential arable quality. Looking at the 75 broch sites, we have:

Arable land + mild climate (H_2B_3 or H_2B_2)		45 sites
Arable land + poor climate		2 sites
Non-arable land + mild climate		15 sites
Non-arable land + poor climate		13 sites
	Total	75 sites

Thus, even if a broch has little or no arable land in the vicinity, it will tend to be sited in a mild climatic zone. However, this must be treated with care, for the definition of "broch on arable land" used above was quite restrictive: in actuality, most brochs are near some arable land, and those that have no access to any such land are, in fact, almost all in the last group, in areas with little arable and poor climates.

N.B. The X^2 test is invalid if many E values are less than 5. A corrected result, by amalgamation, is $X^2 = 25.818$, D.F. = 1. The conclusions remain valid.

Localised weather patterns and micro-climates of site areas fall below the resolution of this approach, but in general it was remarked that broch sites are frequently not in particularly sheltered spots, probably for three reasons; 1) such spots are often overlooked by the slopes which give shelter, 2) they are often sites with less than good outward visibility, 3) the broch itself was probably sufficient proof against the weather.

Cunliffe has discussed the above correlation between mild climate and broch sites in very generalised terms (Cunliffe, 1978).

Landscape Unit is a term used to describe the type of location of the likely area of agricultural land associated with each broch. It was noted during fieldwork that there are in Shetland sizeable arable areas which are apparently not associated with brochs, and it appeared to be worthwhile to attempt a measure of whether one particular type of area was favoured above others in terms of the likelihood of its having a broch. Five broad classes of arable area were defined in landscape-unit terms:

1) Bay head or coastal valley
2) Open coastal strip
3) Isthmus
4) Inland basin or valley
5) Promontory

An operational difficulty was deciding how small an arable area should be considered as significant. Historical geography and field observation were invoked, and only areas larger than those associated with single crofts were included. In practice this meant the exclusion of a sizeable number of small arable patches which were predominantly coastal.

The figures for distribution among the five landscape units were correlated to three classes of relationship to the broch sites. These are :

1) Not near any known broch
2) Near a broch which does not itself stand on arable
3) Containing, or immediately adjacent to, a broch.

These can be set out in a tabulation thus:

	Broch	Near-broch	Non-broch	Total
Bayhead	16	11	77	104
Open coast	13	11	11	35
Isthmus	3	1	15	19
Inland basin	12	5	5	22
Promontory	3	0	6	9
Total	47	28	114	189

Summing broch and near-broch figures to give a value for all areas of arable or arable-quality land possibly associated with brochs, and using as the null hypothesis the suggestion that brochs are located at random with regard to the differing types of landscape unit, a chi-squared table can be constructed to investigate any preference for specific types of area location:

	BH	OC	I	IB	P	
Observed:	27	24	4	17	3	75
Expected:	41	14	$7\frac{1}{2}$	9	$3\frac{1}{2}$	75

$X^2 = 20.739$ (D.F. = 4)

That is, brochs appear to be associated preferentially with areas of arable located on open coasts and in inland basins, while the number of brochs associated with arable areas in bayheads is less than might have been expected. The observed pattern is significantly different from the expected, to the extent of more than 99.9 percent, and requires some investigation.

The observed pattern is very difficult to explain. Two possibilities present themselves, either a true preference for open coasts and inland basins, or else a deliberate avoidance of bayhead situations. If the latter are avoided, presumably because of lack of open visibility to seaward and access to the open sea, why should inland basins, usually with very poor outward vantage and by definition no marine access, be so favoured ? The brochs seem to be either completely divorced from the sea or else in full view on the open coast, although it should not be forgotten that bayhead locations are still the most numerous for broch areas.

Perhaps the better explanation is a preference for open coasts, perhaps linked with fishing and fowling, and inland basins, associated with extensive pasture and small but sheltered arable patches. In any case, the absolute abundance of available bayhead locations means that while /

while this type is not as common as might be expected, it is still the dominant one, and the "type" of broch area is the small, moorland-locked, coastal valley running down to a small bay or inlet.

The four factors considered so far at this macro-scale, and analysed relative to broch-location by means of the chi-squared test, have shown a complex inter-relationship among geology, land quality and climate, while certain types of landscape unit (whose frequency is a product of geology) have been shown to be more likely to contain a broch than are others.

It should be noted that had any of the first three factors, of land quality, subsurface geology or bioclimate, been analysed in isolation (as here) there would have been a strong correlation with the distribution of brochs. However, had only one of these factors been taken as the explanation, a grave error would have been perpetrated. Further analysis has shown that covariation among these three elements of the physical environment is so strong that all must be treated as a single composite variable, rather than as individual causes with separately-identifiable effects upon location.

The fourth factor will be considered again below, as the three remaining macro-scale factors have some role to play in its proper interpretation.

Three factors remain to be considered here. These are:

5) Distance from coast

6) Accessibility of coast

7) Distance from water-supply.

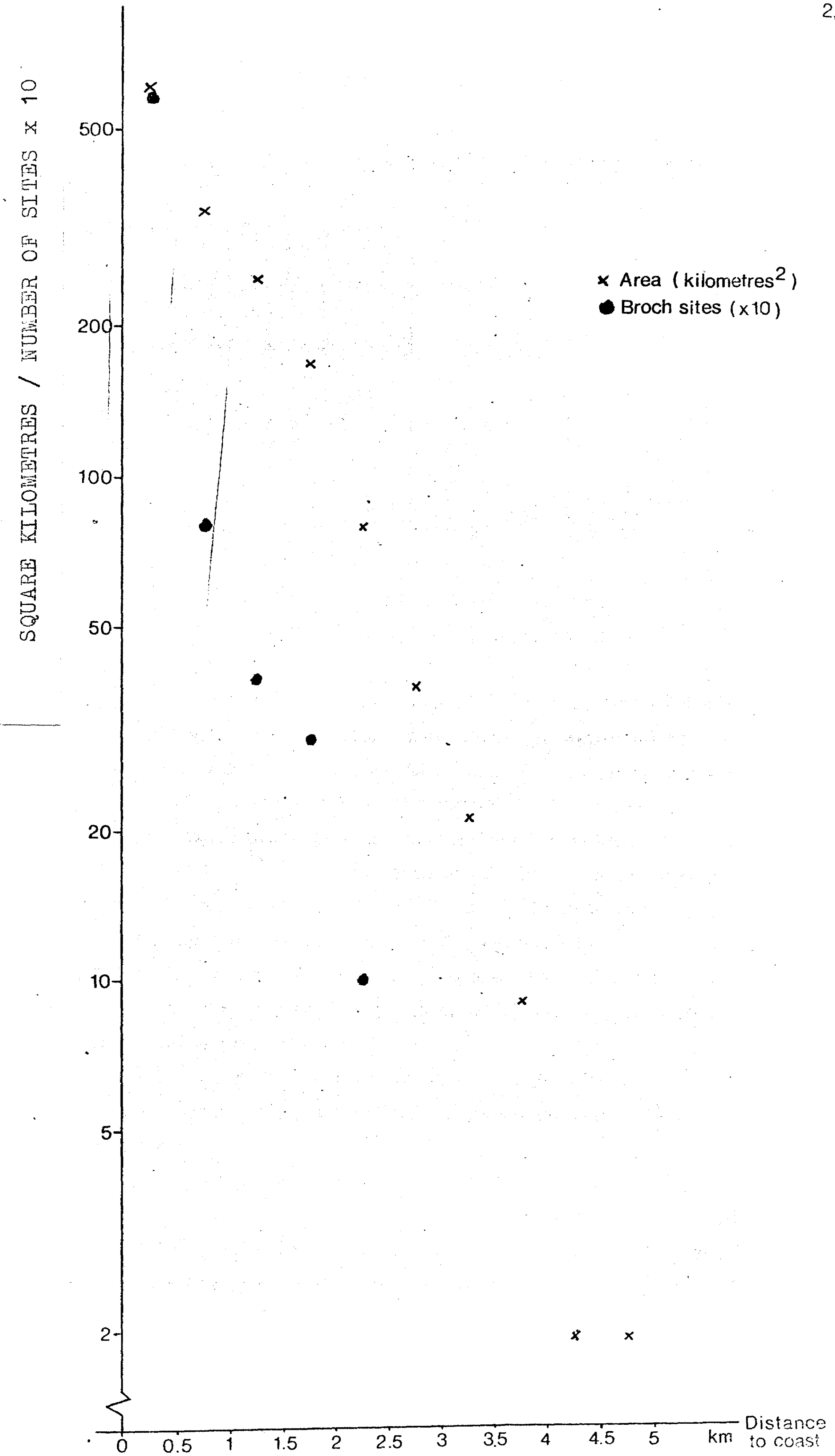
These cannot be analysed so readily as the factors considered above. The difficulty lies in the fact that the chi-squared test depends upon the calculation of expected values for classes of the variable, against which observed values are compared. Ideally, the chi-squared test is to be reserved to data which is pre-classified, as was the case above. Distances, however, are continuous spectra of relatively precise values. Simply to split these measurements into arbitary length classes so that they may be analysed using the same test is to waste most of the precision of data available. The alternative is to use some method of comparing distribution curves, as is attempted here.

Unlike /

Unlike the geology and climate, and to some extent the land-quality and landscape-unit, data, there are no pre-existing map or numerical data bases from which to operate. Thus the general pattern of distance measurements had to be established ab initio.

A non-random grid was placed over the map of Shetland, with points on a square framework at one kilometre distances apart. As it had been demonstrated that a measure of careful sampling was useful, such an approach could have been used, but in practice all 1495 points were taken as data-sources. For each of these points three measurements were taken : distance to nearest coastline, distance to the nearest accessible part of the coastline, and distance to the nearest perennial freshwater supply. These three sets of figures, which can reasonably be taken as representative of the "average environment" were used as a datum for the analysis of similar figures for the locations of the 75 brochs under investigation.

Coastal Distance was studied by means of the construction of a "curve of littorality". The technicalities of this new approach have been relegated to the note on techniques which closes this chapter, and a brief resume will suffice here. The curve is a graphical expression of the percentage (or absolute) area within a given distance of the coast. For any island, there is a steady fall-off in area with distance from the sea. (To visualise this, it is helpful to imagine lines drawn on a map of the island, each line at a constant distance from the sea.) This approach has in fact proved unexpectedly useful, in providing a new measure of insular fragmentation which may be of value to purely geographical studies (Author, forthcoming). As a reference point, the value of Mean Coastal Distance (MCD) can be calculated. This is defined as the distance from the sea at which a line drawn on the map will enclose (and therefore also exclude) exactly half of the land area. Having calculated these figures for the 1495-point sample, they can be compared with the corresponding values for broch-locations. The curves for the general environment and for the 75 broch sites are displayed in Diagram 2, ii, 6, and are as follows:


SQUARE KILOMETRES / NUMBER OF SITES x 10
500
200
100
50
20
10
5
2
× Area (kilometres²)
● Broch sites (x10)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
km
Distance to coast

Distance to coast	Figures for overall case		Figures for brochs	
	Basic Percentage	Cumulative Percentage	Basic Percentage	Cumulative Percentage
0.0 to 0.49 km	39.33 (29)	39.33	78.67 (59)	78.67
0.5 to 0.99 km	22.54 (17)	61.87	10.67 (8)	89.34
1.0 to 1.49 km	16.59 (12)	78.46	5.33 (4)	94.67
1.5 to 1.99 km	11.37 (9)	89.83	4.00 (3)	98.67
2.0 to 2.49 km	5.35	95.18	1.33 (1)	100.00
2.5 to 2.99 km	2.54	97.72	0.00 (0)	100.00
3.0 to 3.49 km	1.40 (8)	99.12	0.00 (0)	100.00
3.5 to 3.99 km	0.60	99.72	0.00 (0)	100.00
4.0 to 4.49 km	0.13	99.85	0.00 (0)	100.00
4.5 to 4.99 km	0.13	99.98	0.00 (0)	100.00
	99.98	99.98	100.00 (75)	100.00

Mean Coastal Distance (overall) = 0.896 kilometres
Mean Coastal Distance (brochs) = 0.277 kilometres

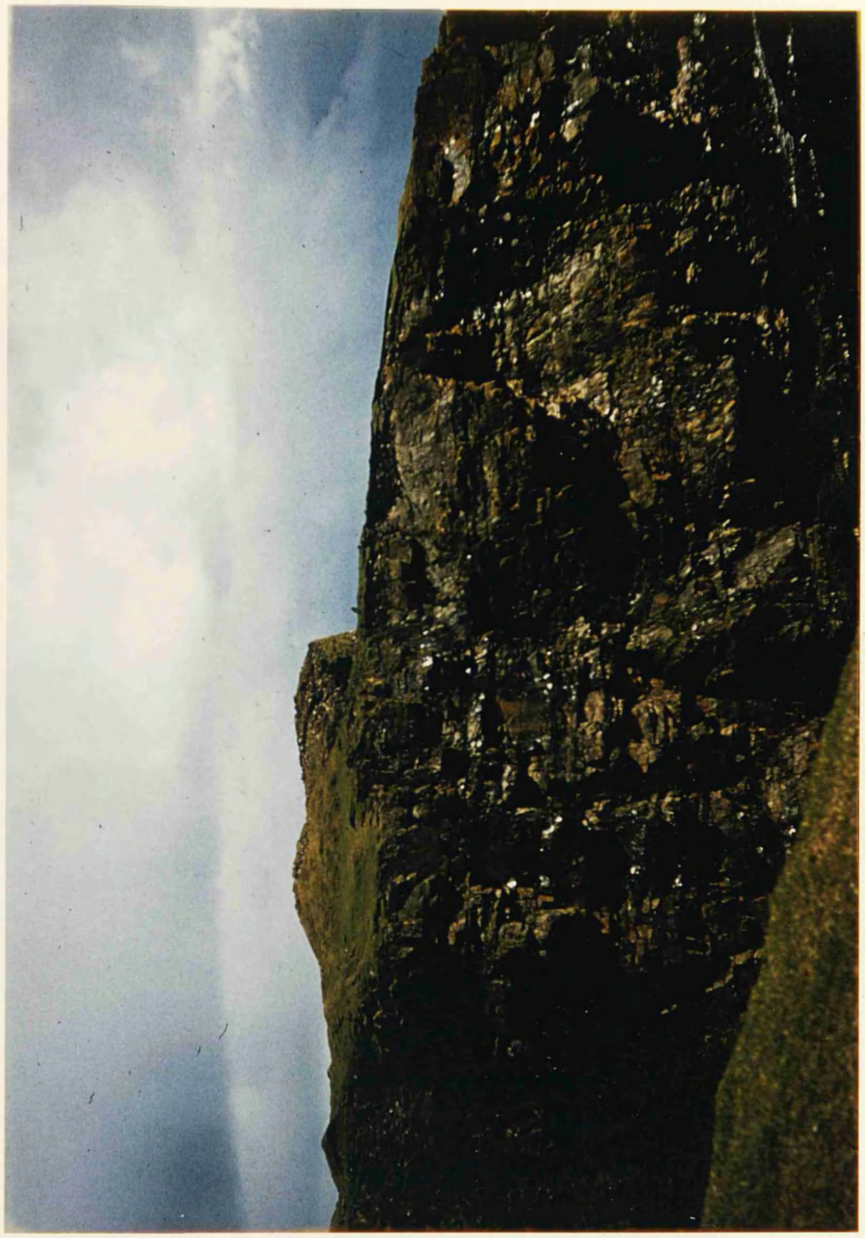
Visual comparison of curves and figures shows a much faster fall-off in numbers from the coast than would be expected if brochs had no spatial association with coastal areas. It can in fact be shown (see note at end of chapter) that the ratio of the gradients of the two curves is an accurate measure of how much more coastal the sites are than the mean case, and that this ratio is approximately equal to the ratio of mean coastal distances, when the curves on the graph are linear. Here both ratios equal 3, approximately, and it can be said that brochs are three times more coastal than would have been the case if they had been located at random, with no regard to the distance of each location from the coast.

As a matter of interest, a chi-squared test was carried out on the above data, using the overall figures as expected values, and the result was:

$$X^2 = 51.257 \quad (D.F. = 5)$$

However, while this indicates a very strong likelihood that brochs are not located at random with respect to the coast, it does not quantify this difference from the expected, merely stating that it is significant with a given percentage likelihood of error (here, 0.1 percent). Thus the above approach is to be preferred over the chi-squared test as it gives a real answer, rather than acting as an indicator.

Two /



Coastal accessibility : Burland broch perches high upon the cliffs, within metres of the sea, and cut off from it in practical terms.

Two possible lines of explanation can be offered. Firstly, there may have been a real preference for the coast. Since later settlement has also concentrated around the coast, the pattern cannot be the result of any normal process of selective destruction, as this would be greatest in such areas. Secondly, the correlation may in fact be a product of covariation, with brochs preferring arable areas, which are by the nature of the Shetland landscape predominantly coastal.

It is of considerable interest that neither the tabulation above, nor the curve on diagram 2, ii, 6, identifies the group of "inland basin" areas noted when considering landscape units. The chief reason for this apparent omission is that for many such areas the actual distance to the coast may be small compared with the effective distance, as a significant number of these inland basins stand on the backslope of coastal cliffs.

<u>Coastal Accessibility</u> was therefore considered to be worth investigating. Many brochs are situated on cliff edges, perhaps only a few metres from the sea in terms of direct ground distance. But often the nearest access to the sea, via a creek, beach or gentle slope such as would be suitable for launching a small boat, is more distant. Tables 54, 55 and 56 of Appendix 2 show this, and can be summarised thus:

Nearest coast is accessible:	45 sites
Nearest coast is inaccessible:	30 sites
	75 sites.

Even this is an over-simplification. Frequently the coast nearest to the site is accessible, but a better landing-place is available at a slightly greater distance. Mean broch to coast distance is 0.277 kilometres, but mean distance of brochs to nearest landing place is 0.360 kilometres. The actual additional distance may vary from a few metres to one kilometre. The distribution of excess distances is:

0 to 49 m	50 to 99 m	100 to 199 m	200 to 499 m	over 500 m
51	5	8	6	5

Most brochs are coastal (see above), but some coastal brochs are not on access points. Such is the nature of the Shetland terrain that the further a broch is from the sea, the more likely it is that the nearest coast will be accessible. This is because the land is deeply penetrated /

penetrated by long drowned valleys, called locally "voes", which have gently-sloping heads.

Clearly, change in the relative sea-level will be of great significance here. While the precise level of the sea would seem to have risen an average of two metres since the broch period (Hoppe, 1965, Flinn, 1973), in general no cliffs have become low shores, or _vice versa_. Any change has been towards encroachment of the sea over low shores, as at Eastshore and Jarlshof. The most severe effects of this marine transgression are generally restricted as low shores are quite scarce in Shetland. Only around Virkie, in Dunrossness, does loss of land in the last two thousand years appear at all severe in extent.

Looking again at the landscape-unit results, it is noticeable that most of the "open-coast" class of broch locations are placed with the broch some distance from the best landing place, perhaps signifying an exchange of convenience for increased defensibility. Bayhead areas, on the other hand, frequently have their brochs close to the beaches. To some extent this may be due to differences in the shape of arable area within each unit. This is discussed further in Chapter IV, below, as the effect is greatest at the micro-scale.

Water Supply is the last factor to be considered at this general level, and has the distinction of being one of the few archaeologically-considered environmental factors (Fergusson, 1877, for example). This interest centres around the necessity for a good water-supply if a broch is to be capable of withstanding a prolonged siege. The general absence of internal sources within Shetland brochs (one definite and two doubtful) other than relatively small tanks, has led to the suggestion that any form of warfare involving lengthy investment of brochs must be rejected from the set of possible methods of action. This is discussed in Chapter IV of Section 1.

Nevertheless, it was considered worthwhile to know whether brochs do in general tend to be built close to good water-supplies, to the extent that this may have been one of the considerations in the mind of the builders. Water-supply for a broch is not easy of definition, as the rate of flow, and indeed the location, of springs and streams can change quite rapidly, both in a cyclic and in a permanent, fashion (Gregory and Walling, 1975, give examples). But in general, for the Shetland case, such changes do not appear to have been frequent, and it /

it seems reasonable to assume that perennial sources will have changed little since the Iron Age. The main exception to this will be the small seepage sources often noted at the head of the arable land, which are in effect a springline around the edge of the peat. As the location of the edge of peat-cover is not known for the broch-period, this introduces some uncertainty into measurements. It can be assumed that the peat blanket has not extended areally since the Iron Age, and that continued clearance will mean that on average, such springs will have been closer to brochs then than now.

Distance used in this analysis is measured map distance, which is usually approximately equal to walking time, except where the broch is on an islet and the nearest source of a regular supply is on the shore of the mainland opposite. These islet cases, nine in number, have been excluded from the table below. The background pattern of the normal environment has been acquired by the use of the sampling methods outlined above, and a random sample of 200 points was used. This seemed quite adequate for the present purpose.

Distance to supply	Sample points	Brochs
0 to 49 metres	23	14
50 to 99 metres	28	9
100 to 149 metres	41	10
150 to 199 metres	48	11
200 to 299 metres	32	14
300 to 399 metres	19	4
400 to 499 metres	7	3
500 to 999 metres	2	1
	200	(75-9) = 66 (less 9 islets)

These results can be used to construct a contingency table as follows:

	0-49	50-99	100-149	150-199	200-299	300-399	400-499	500+
Observed	14	9	10	11	14	4	3	1
Expected	8	9	14	16	$10\frac{1}{2}$	6	2	$\frac{1}{2}$

$X^2 = 10.039$ (D.F. = 7)

This fails to be statistically significant, even at the 90 percent level of confidence.

In other words, the pattern of distances from brochs to their most likely source of fresh water does not differ markedly from the pattern which would be observed if brochs were sited without any regard to the presence of water-sources. While it would be safe to conclude that the desire to have a good water supply close at hand seems not to have been a major locational constraint, it must be observed that the actual distances involved are relatively slight: 700 metres was the greatest broch-water distance observed, while 750 metres was the greatest of the sample distances. Thus fresh water may well be so nearly ubiquitous in the Shetland landscape as to fail to be a limiting factor in the spatial sense. The actual importance of water is, of course, attested by the tanks in broch courtyards, and the few wells found in and near brochs. But overall, the crude conclusion is that it is impossible <u>not</u> to be close to fresh water in Shetland.

Discussion

At this, the macro-scale, two types of data have been utilised. One is derived from the measurement of linear distances from standard map bases, the other from the allocation of sites and areas to classes which are based on areal distribtuion maps. The latter may have been either already in existence, or compiled for the purpose of this study from field-gathered data. Wherever data was gathered in the field, the recording was at a greater level of resolution than that at which the analysis above has been undertaken.

The measurement of linear distance posed few problems, except in regard to nearest neighbour analysis. The longer a straight line drawn upon the map of Shetland, or anywhere else, for that matter, the greater the likelihood is that it will cross water which is too deep or wide to leap or ford. It is possible, although time-consuming, to construct NNA statistics which are based upon minimum land travel distances. However, this would involve a new measure of area, as the effect would be to expand the more fragmented, coastal regions of the map. A travel-time map cannot be constructed for more than one centre and still remain in only two dimensions (Findlay, pers. comm.). In short, recalculation of the nearest neighbour statistic for shortest travel time would make the whole approach unviable, as the technique is based upon both distance and area, and the latter can no longer be measured in any meaningful units. A less theoretical, but equally potent, objection is that where true travel distance (on land) most exceeds linear (map) distance in Shetland is where the lines of travel bend around the heads of the voes, and it is precisely these locations which are the most mobile element of the Shetland coastline (Mather and Smith, 1974), and their Iron Age position cannot be satisfactorily estimated. Further, there must come a point at which the traveller will cease to walk round the voe-head and will instead take to the water in some form of boat.

For these reasons, no adjustment was carried out, but it can be observed by inspection of the map that the effect of such an adjustment would be generally to preserve clusters but to further disperse parts of the distribution which are already scattered. This is simply a fact of the Shetland landscape. The larger broch clusters are in areas with plenty of good quality land, and such areas tend to be less fragmented by the sea than in the areas such as the West Mainland, where a succession of voes and headlands had led to a pattern of scattered and partially-isolated communities, at least by the Bronze Age, when the onset of the climatic deterioration, a fact here, even if in dispute for southern Britain, had forced the abandonment of the upper slopes between /

between the coastal patches of farmland which survive to the present day (Whittle, 1979; Winham, pers. comm.).

The general picture of location derived by the use of nearest neighbour analysis was that only in Dunrossness was it likely that broch groups may have found themselves competing for land, even when it is assumed that all brochs were in use simulataneously (see Section One). As spatial competition is essential for the establishment of any observable regularity of spacing (Haggett, 1965) it may be suggested that the overall lack of any such regularity points to a series of communities which were not under such a great pressure from their environment, in terms of resource-requirement, that they contested the ownership of land to any marked degree. Similarly, the absence of any consistent pattern of clustering would argue against the practice of co-operation in resource-exploitation (see also next chapter). In brief, broch-groups appear not to have exploited the land to its full capacity, and indeed may not have exploited all of the land which was available to them.

To a great measure, this isolation of individual groups is a function of the physiography of Shetland. Even today, the numbers of people supported by the land alone are strictly limited, and other sources of food are employed. This was even more the case in relatively recent times. It is perhaps significant that the apparent economic area associated with a broch (see below) is often almost identical to the area of land associated with a small community, or township, of three to six crofts. This may in itself have implications for estimation of Iron Age population levels.

The complex interaction of land-quality, geology and bioclimate has already been discussed, and provides a good example of the interdependence, or covariation, of numerous variables. It is hardly surprising that height above sea-level varies with distance from the coast, and this explains why the former has been omitted from analysis here. The difficulty is in deciding which is the independent variable. Other grouped variables are common, but may be less obvious to the archaeologist: soil depth and slope angle, soil depth and altitude, slope angle and altitude; these are all examples. At the level of manual analysis, the best protection against the identification of spurious correlations is to consider, continually, the possibility of the variable under study being itself controlled by other factors.

These /

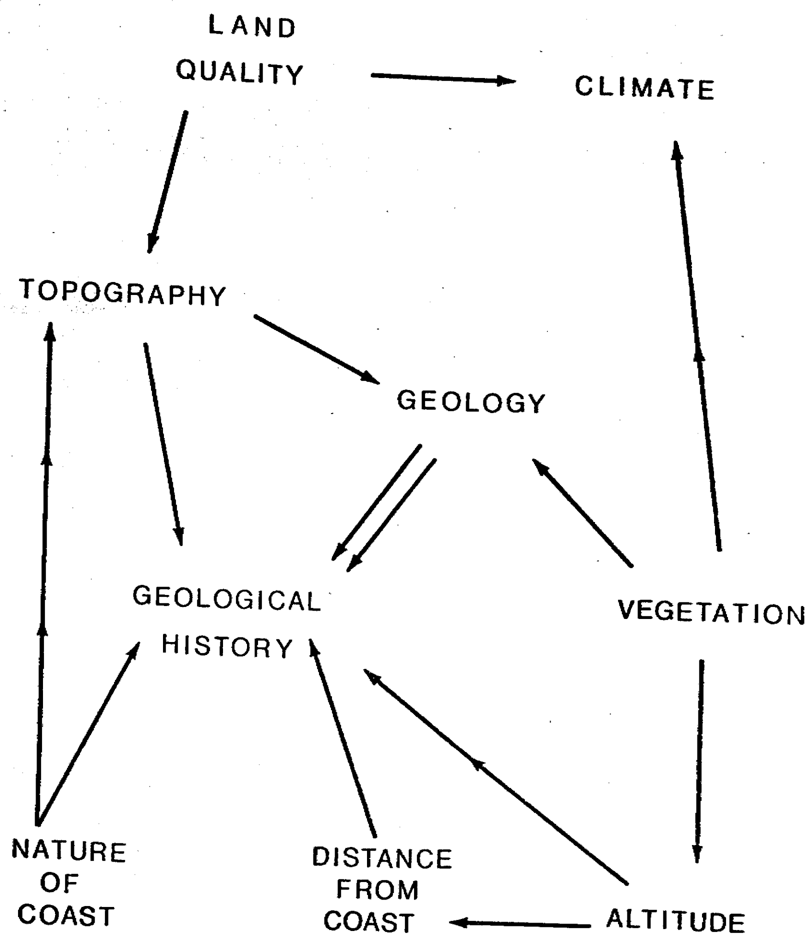
These problems can be eliminated by computerising the data and performing a principal components analysis (or factorial analysis), (Lawley and Maxwell, 1963). This will isolate the major composite variables in the observed patterns of association. This was not undertaken here for three reasons. Firstly, the process is costly in terms of computer time. Secondly, the data available to analysis is of different types and is expressed in a variety of units of varied precision. Thirdly, and most important archaeologically, the manual methods have been sufficient to show that the closely-interlinked "basic environment" factors account for most of the pattern of distribution of Shetland brochs. That is, there is only one principal component of variation. This is displayed in its complex composition, in Diagram 2, ii, 7. As can be seen from this schematic expression, the only truely independent variables in the environment seem to be climate and geological history.

Attempts to analyse the significance of the coastline in relation to broch location have resulted in the development of a measure which is apparently unknown to archaeologists and, indeed, to geographers. The more general aspects, which are discussed in the note below, suggest that Mean Coastal Distance may have a useful role to play as a member of the family of measures of shape discussed by Taylor (1971).

The overall trend is demonstrably of a coastal location, with brochs lying toward the coastal end of their assumed farming areas. The exceptions to this rule, such as Stoura, or Brough on Bressay, are usually where the more inland location allows the broch better to overlook likely approach routes. This is discussed in detail in Chapter IV, below. A class of location in relatively landlocked basins and valleys contrasts strongly with the more normal coastal location, and the coastal sites themselves seem to prefer open coastlines which can overlook wide expanses of water. The significance of location within the broch area is discussed further in Chapter IV.

Fresh water supply did not appear to be a locational constraint, probably because of the ubiquitous availability of this element, in the form of springs, streams, or lochs.

In brief, the survey at the macro-scale has revealed little identifiable spatial interaction among broch-groups, but a very strong and complex relationship between individual sites and the generalised pattern of environmental factors. It might be expected that these two observations would occur thus linked, as would their converses.



→ = DEPENDS UPON

SCHEMATIC INTER-RELATIONSHIPS
OF
ENVIRONMENTAL FACTORS

Note to Chapter II : Analytical Techniques

The standard test of spatial correlation used throughout the discussions of this Section is the chi-squared test. The reasons for choosing this test from the number available are its flexibility and relatively high level of reliability, linked to its ease of operation. In addition, since it is already widely used and understood, the results of analysis can be widely read and appreciated, and this is essential if the research undertaken here is to be of any general use to the progress of archaeology. Although this test can be used in a wide variety of circumstances, two particular forms of question have been answered here. The first concerns the correlation between sites and their environment, and the second the relationship between factors of that environment:

1) "If n points had been selected at random from the landscape, instead of the n archaeological sites, how likely is it that the random sample would have shown the same correlation with this factor as did the archaeological sites ?"
2) "If at all points on the map there were no spatial correlation between these factors, what is the likelihood that the observed strength of correlation would have occurred in a random sample of points ?"

The test compares real data against "expected" data. The latter represents the "null hypothesis". If arable land is in question, the procedure is to divide the number of sites into the proportions of the arable/non-arable classes (75 sites, 13.3 percent arable, so 10 sites should be on arable land), and to state the null hypothesis thus: "The observed pattern does not differ significantly from the expected pattern." This is given precision by adding a level of confidence, in percentage terms. Usually 90, 95 or 99 percent is selected, and this represents the likelihood that the test will not reject a null hypothesis which is, in fact, true. Published tables allow the X^2 statistic to be assessed, and if its value exceeds the critical value for the chosen level of significance, a statistically-demonstrable correlation has been identified, and the null hypothesis is rejected.

For most purposes in archaeology, the null hypothesis will be that the sites should match the background pattern of the natural environment. However, the test can be used to test specific theories which are couched in quantitative terms. If, for example, it is felt that /

that sites are twice as likely to occur on arable land as on non-arable land, this can easily be used as the null hypothesis, and the expected figures calculated accordingly. It is immaterial to the operation of the technique how the expected figures are generated, since the test is a purely objective test of the extent to which the observed pattern differs from that expected. Examples of this test based upon "natural" expected values have already been given, while examples based upon "hypothetical" figures will be found in Chapter IV, below.

Having carried out the test and (for the sake of argument) having obtained a value for chi-squared which indicates a statistically-significant spatial association, it remains to decide what the result means. Clearly, this will be phrased in terms of the specific situation, but formally there are only five possible types of explanation.

1) Reject the result as spurious.
2) The association is real, but entirely coincidental.
3) The association is the result of a dependent relationship, sites tending to be located according to the pattern of the factor.
4) The association is the result of a dependent relationship in which both the site-distribution and the pattern of the factor are not dependent upon one another, but upon another factor which has not been considered.
5) The distribution of the sites is in fact the pre-condition for the pattern of the associated factor (this is the converse of 3)).

Now, responses 1) and 2) simply mean that there was no point in carrying out the statistical test. Once the parameters are set, and the test has been conducted, the results should be explained, not the test rejected, even if the results are not what was expected. In fact, the situation of pure coincidence (2) is so rare in nature as to be omitted, and the likely explanation of apparently unlikely correlations should be sought in explanation 4), that of covariation. Normally explanation type 3) will be the most likely when environmental factors show a correlation with archaeological site distributions, although type 5) situations, in which the presence of the site determines the pattern of the factor, may be much more common than is realised. Thus in Shetland arable land seems to be at least partially dependent for its existence upon the presence of long-established farming communities, who have cared for, and indeed extended, the naturally-available land. This, indeed, may be the case for most of the Atlantic Province.

There /

There are many more powerful techniques available, but the more powerful a technique is, the better must be the data, and the more complex the calculations. Thus less scrutiny can be maintained of the procedure at work. Because the chi-squared test was simple, and well-known, at least in name, to most archaeologists (Reid, 1972) it has been preferred here. However, it should be noted that a series of tests of increasing complexity exists, culminating in factorial analysis, in which every factor is correlated with every other to produce "axes" which identify the principal components "causing" the variation between the observed distribution of sites and the random expectation.

While the results of such tests can be fascinating, the tests did not seem necessary in the present case, since the main causes of variation were clearly shown, by simple methods, to be environmental aspects relevant to the agricultural and littoral exploitation of resources. The result of factorial analysis would have been to reveal what was already known, and it must be added that in situations where all of the factors are related to the environment, it is not surprising that the principal component of variation is found to be the natural environment (Winham, 1978).

However, there is a very real role for this approach in the archaeology of Shetland, since a series of such tests, based upon data from sites of different periods, would, by the gradual variation in the relative importance of the principal components, reveal long-term trends in changing man-environment relationships. The publication of the multi-period, sample-based, approach undertaken by P. Winham is awaited with interest, although it is felt that a non sample-based approach would have had more precision, and more direct comparability to the present study.

The measure of Mean Coastal Distance adopted above is, strictly speaking, a specialised form of nearest neighbour analysis, and is a member of a larger group of indices based upon distributions of random line-lengths within finite areas (Taylor, 1971).

It can be theoretically demonstrated that the curve produced by measuring areas at specific distance intervals from the edge of a finite, single, area is an inverse square function. This explains why Diagram 2, ii, 6, which is plotted on log-normal paper, is almost a straight line. The slope of the line is proportional to the compactness of the area, which can be represented as a function of the perimeter and the area. The less the gradient, the less fragmented is the area. Thus for the /

visual comparison of 2, ii, 6 a statistical treatment is possible. Using the least-squares method the regression equations for the two lines can be calculated, and the two line gradients determined. The ratio of the gradients then forms an index of just how much more coastal brochs are than might be expected. The equations are:

Overall: $\log_n y = 18.9 - 2.240\ x$
Brochs: $\log_n y = 15.0 - 3.056\ x$

The gradients, which are in logarithmic form, must be translated into real numbers, and are, respectively, 9.393 and 21.242, and their ratio is therefore 2.261. That is, brochs are two-and-a-quarter times more coastal than is the average set of seventy-five points on the map of Shetland. Formally, this ratio is

$$\frac{\text{Gradient (observed)}}{\text{Gradient (expected)}}.$$

This measure seems capable of useful extension, as it is a very common occurrence to read that a group of sites is "coastal" or "non-coastal" in distribution, without any quantification of the trend. This test now makes it possible to say not only "how coastal" a group of sites is, but to compare the "coastalness" of several series of sites, perhaps of different function or period, within one area.

Thus it will be seen that the actual analysis of data for the purposes of this study has produced some advance in the actual techniques available to the analyst.

Chapter III

Meso-scale considerations

Attention at this level of scale was concentrated upon the definition of the basic economic structure possessed by the Iron Age broch-owning communities of Shetland. In order to achieve this, it was first necessary to define the economic sphere of action of each group, and then to establish the range of variation among areas, so as to produce a more detailed picture than that which could be achieved by the study of the overall patterns described in the last chapter.

Data

Much of the data of the foregoing chapter was in fact collected at the meso-scale by field measurement and observation, and although this data proved useful for the analysis of overall correlations with facets of the environment, it was originally intended for the purpose of providing a detailed view of the different economic options suggested by the nature of the areas around different broch sites. Although the concept of economic areas is central to the following discussions, care was taken in the field to gather data impartially, so that the lack of a known broch site did not result in non-recording. Therefore all good land was mapped, and many other measurements and observations were carried out. This necessitated the coverage of the whole of Shetland on foot, and over three thousand kilometres were walked in four field-seasons, in addition to substantial vehicle mileage. Because the ruins of each site were to be visited, it was deemed economical to gather environmental data in the field. However, had the archaeological facts been sufficiently well-documented, it might have proved possible to carry out most of the measurements of the physical and biological character of the environment through the use of aerial photographs, with a supporting programme of field-checking. However, this approach would have had some drawbacks.

Firstly, the only nation-wide coverage is at 1:10 000, dates from the 1940's, and is in black and white. The scale is rather small, and the monochromatic image is difficult to use without experience, although skilled operators find little difficulty in the classification of vegetation by tone and texture. A more recent survey is available, at a larger scale and in colour, and this is ideal for the present purpose. However, only the coastal areas of Britain are covered, and even these not completely.

Given good air-photographic coverage, a survey similar to that carried out on foot could be approached in the following manner:

1) Check archaeological and local sources for all possible sites.
2) Take a few sample sites, and using air photographs classify the surrounding area on each of the environmental factors thought to be significant.
3) Visit each site, and at the same time check the reliability of the photographic interpretation.
4) Define the list of sites to be considered in the analysis.
5) Complete the classification of each area by the interpretation of the photographs, ideally with repeated field-checking of the classification to ensure reliable results.

The advantages of this type of approach are that field operator error is reduced to a minimum, and every area receives equally careful attention. It is remarkable how difficult it is, in the field, to remain unaffected by the transient working conditions, be they weather changes or more exotic distractions, such as the attacks of enraged skuas. The disadvantages of this approach are due to the fact that reduced time in the field tends to work towards a lowered comprehension of the general nature of the study-area's environment, that all-important "sense of place" which aids understanding of human activities and motivation. By the same reduction of exposure to the region, many sites may remain undiscovered which might have been located while moving from one known site to another. It would not be facetious to observe that had the excavator of the Clickhimin blockhouse spent some days camped beside the loch, his reconstruction might have been more convincing. The main problem in fieldwork is the avoidance of the impression that all of the situation can be grasped at once. Acclimatisation to a different environment can be a lengthy process, for which there is no adequate substitute, and until it is completed, observations cannot be fully trusted.

Because the economic areas defined below were delimited only after fieldwork was completed, it seems reasonable to suggest that each part of these areas has been given relatively fair attention. Although the eventual classification of factors into "good" and "poor" is much used, this does not mean that fieldwork was wasted. By the end of the survey it was apparent that "good" land in Shetland was a rather different quantity from good land in most of the remainder of Scotland. Also, although a crude division has been used here, the recording of data at more detailed levels has kept open the option of more refined analysis.

It was noted that over the last two millenia the quality of land in Shetland has polarised, with the good improving and the poor becoming even poorer.

Part 2 : Defining Economic Areas

The aim of analysis at the meso-scale is simply to determine the nature of the economic unit represented by the inhabitants of each broch. The economic details of life would doubtless have varied from area to area, so any answer will be in terms of ranges of potential, rather than in absolute figures. But before any analysis can take place it is essential that the areas under discussion be clearly defined.

Definition of "tributary" or "dependent" areas is a major current theme in geographical research, where it is by now generally accepted that the boundary of any area will depend upon the function under investigation. Around any central focus of human activity, there exists an area more strongly linked to that focus, in terms of economic activity, than to any other focus, but for any one facet of that relationship the detailed boundary with neighbouring centres may vary in position. At the present day, one township may graze sheep on land which provides the peat for a different community.Most geographical research has been carried out in modern, urban, situations (Ray, 1967, for example). The major constraint upon such an approach is that areas of influence must be in mutual contact : the model cannot cope with unexploited territory, and has difficulty in dealing with the exploitation of territory which is not contiguous to the main area, as may be the case with transhumance activities.

A different, and explicitly archaeological approach, has been taken by Higgs and Vita-Finzi (1972). The area around a centre of settlement is viewed, at least initially, in isolation, without allowing for the interference of neighbouring sites. The conceptual diffrence between this and the previous approach is that in this the site is seen as "exploiting the territory", while in the previous the site is seen as "servicing the area". As both may apply to the broch, in that the people must have exploited resources to survive, while the broch provided a defensive service to the inhabitants of the area, both are considered here. The Higgs and Vita-Finzi approach has been extended, notably by Dennell and Webley (1975) and Barker (1975), and has come to bear the title of site-catchment analysis.

It is apparent in the case of the Shetland Iron Age that, as for many archaeological studies, the main problem in defining past economies is in fact the difficulty of defining the areas of operation of these economies. The details of economic activity depend upon the way in which economic areas are defined, and once this definition has been achieved, the actual economy can be approximated with relative ease. Consequently, an /

an investigation was carried out into various methods of territorial delimitation, commencing with the purely theoretical imposition of rigorously-defined patterns and gradually relaxing the parameters until a reasonably convincing pattern of territories could be established.

Polygons of various forms are popular tools of the spatial analyst, after the pioneering work of Christaller (1933) and Losch (1954). These have been applied in archaeology, both wisely (Hodder and Hassall, 1975) and with less circumspection (Cottam and Small, 1974). In theory, the ultimate expression of uniform-sized settlements competing for space in a uniform environment is a hexagonal lattice with a regularly hexagonal territory/service-area surrounding each central settlement point. However, reality is seldom so perfect. Distortions will occur in the ideal pattern due to:

1) Unequal group size
2) Uneven environment
3) Human variables ("group character")
4) Uneven original spacing of centres

1) will partly determine, and be determined partly by, the extent and quality of the resources controlled by each group.
2) is the normal case, and if all other variables could be equalised, the distortion of territory-size would be an efficient measure of the variation in environmental quality.
3) cannot, as yet, be adequately allowed for by geographers or archaeologists. The emergence of a strong group-leader may outweigh all apparent disavantages.
4) In the real world, the activities of a group, particularly one practising agriculture, will tend to tie that group to a single location, while the ideal model situation is one in which groups are free to relocate their settlement until they have achieved the optimum site for their economic activities.

Certain elements of the above can be applied to the case of the Shetland Iron Age. As archaeology cannot contradict this, it seems a reasonable assumption to take broch-groups as being equal-sized. Clearly, "equal" is not meant in the pedantic sense of identicality, but in the more general sense of broad comparability of numbers, abilities, and demographic structure. Populations associated with brochs will be treated as being in the same order of size. The human factor (3) must be ignored, as it cannot be handled competently. In a society composed of roughly equal units, the effect of this factor may be more social and political, and less economic.

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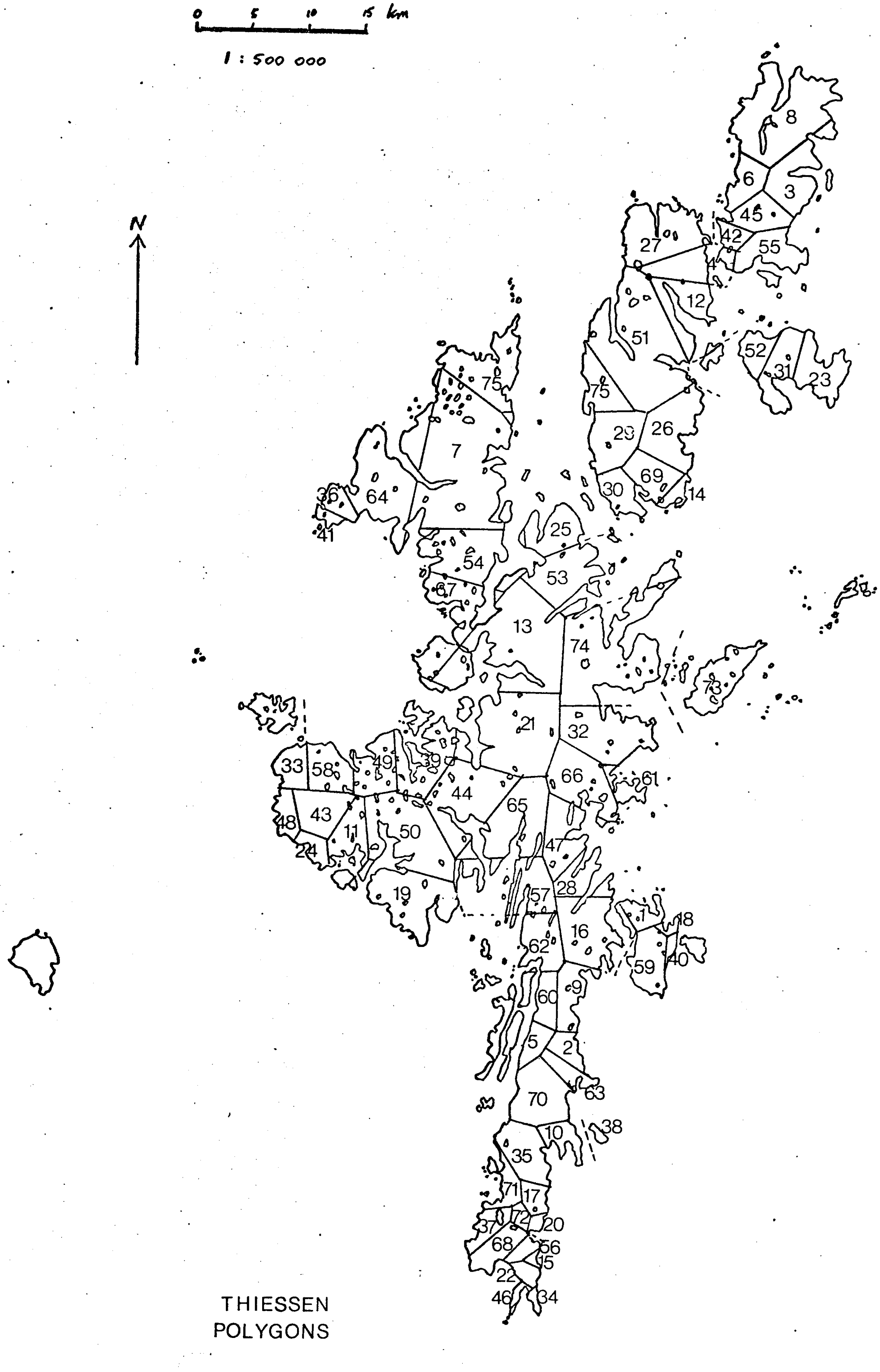


THIESSEN
POLYGONS

75 brochs

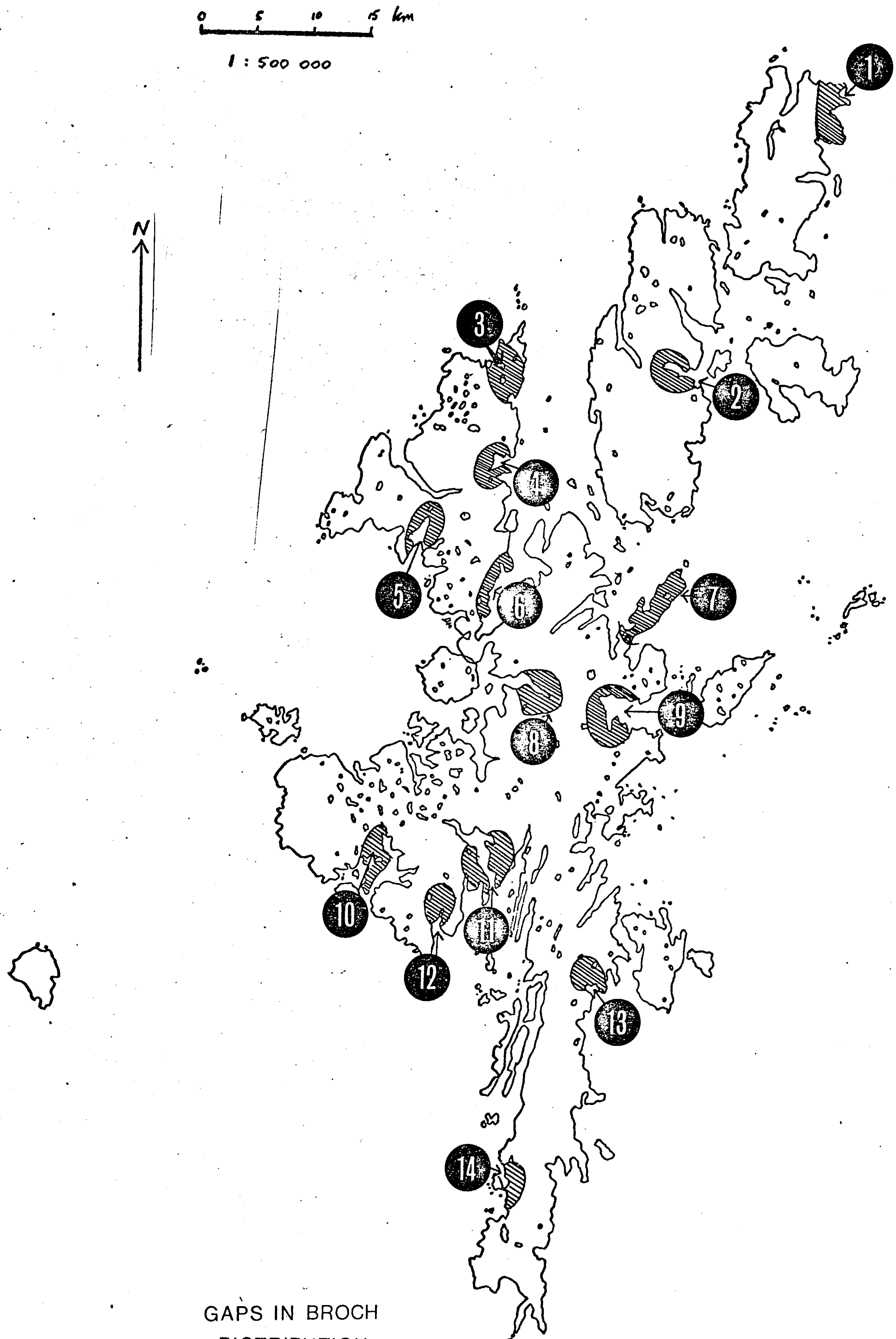
The unevenness of the environment must be closely related to the unequal spacing of actual sites, and this has been investigated through the use of Thiessen polygons (Bogue, 1949, for theory).

The hexagonal areas of the ideal world sketched above are special cases of the Thiessen polygon, which simply defines the locus of points nearer to a given centre than to any other centre. Mechanically, the boundaries of polygons consist of the linked sections of the perpendicular bisectors of lines linking all centres to one another. The effect of using this technique on the 75 Shetland broch sites is shown in Map 2, iii, 1.

The territorial areas thus defined vary greatly in size and shape. The immediate visual reaction is towards disbelief in any underlying order, but it was essential to find an objective means of testing the pattern to assess its value as a means of defining economic areas. In the present case, three possibilities are available on the positive side and one on the negative. These are:

1) The size of areas is inversely proportional to land quality. (That is, areas with poorer land must be larger to provide the same resources in total.)
2) The size and shape of areas varies due to the removal (in antiquity) of brochs from an originally more regular pattern.
3) Some contemporary sites which are not brochs have not been taken into account, but are in fact equivalent, in terms of population size, to brochs.
4) The method is inappropriate, either because broch-groups did not compete for land, or because their economy was not sufficiently land-based for this method to provide an adequate estimate of the territory exploited.

Reason 1), that the size of areas is related to the quality of land within them, was tested by the Spearman Rank correlation method. The 75 areas defined by the polygons were ranked in order of size, from 1 to 75, and these areas were also given a ranking for total relative fertility. This latter measure was based upon land quality, total arable extent, and present agricultural population. The ranking is not presented here for reasons of space, but the end result was a coefficient of +0.4638. At the 99 percent significance level (Ebdon, 1978) there is a positive correlation between area size and total relative fertility. This is exactly the opposite of what would be expected if the large area /



GAPS IN BROCH
DISTRIBUTION

area - low fertility explanation were correct, and is precisely what would be expected if a pattern of different sized areas was imposed over an environment in which good land was more or less evenly distributed.

The only method by which the original explanation can be maintained is to argue that in most of the larger areas the arable land is more fragmented, and that this causes a decrease in efficiency. Chisholm (1968) has demonstrated a ten to fifteen percent fall in the productivity of peasant economies for every kilometre the farmland lies distant from the settlement of the farmer. However, in the present case this model does not seem applicable, because some of the larger areas have so much arable land that unless huge distance diseconomies operated, the groups using the larger areas need never have utilised all of their potential farmland. This being the case, the Thiessen polygons may not correspond even approximately to real Iron Age boundaries of activity.

Suggestion 2), that the pattern is a remnant one, with certain elements missing, is attractive, as it would explain some distortion of size and shape. It would, of course, be arrogant in the extreme to assume that all sites have been correctly located, and this explanation offers the additional attraction of the possibility of developing a predictive model which might help to locate missing sites.

Assuming, for the present, that brochs do tend to be on or near arable land, and prefer coastal locations, it is possible with the aid of the maps of arable land(2, ii, 2) and Thiessen polygons (2, iii, 1) to identify locations in which brochs might reasonably be expected to exist, although none have actually been identified there. Such sites might have been destroyed totally in antiquity, or ruined to such a degree that they have escaped notice. A further criterion was added, and that was that territories should be limited in such a way as to prevent any one territory being split by a major watershed. This was to avoid the creation of territories in which the required total of arable land was reached by the addition of many small areas separated by large expanses of moorland. The resulting map, 2, iii, 2, displays the fourteen likely areas for "missing" broch sites.

Area 1, Norwick (Unst) has no record of a broch, but the place name "Burgar" on the south side of the bay hints at some sort of fortified site, although such names are occasionally applied to natural features. The general character of the area resembles that of Underhoull, on the opposite side of the island where, perhaps significantly, there are both a promontory defence (Blue Mull) and a broch (Underhoull).

Area 2, Mid Yell, is the largest area of good land in Shetland to lack a broch /

a broch site, or even the report of one. A wide variety of possible sites exists, but no structures were located. It is difficult to conceive of local farmers fleeing up the firth to Windhouse broch at the first alarm, and still more so to conceive of a farming group based at Windhouse making the daily trek to work the land around Mid Yell Firth. The intensive use of the land up to the present may have entailed the destruction of a broch in the past, but no memory or rumour survives, and this is unusual for Shetland, where traditions are detailed and die hard.

Area 3, North Roe, is much better served. Two sites are recorded. One at Isbister seems doubtful, the result of confused memory and recording (Appendix 1, items 110 and 111), but the second, at Burgo Taing (ibid, item 83) seems a stronger possibility, although nothing remains on the supposed site. A local informant recalled ruins, near the shoreline, of what "might have been a brough".

Area 4, Collafirth, is perhaps less-likely as a broch site, although parallels for the voe-head location, with damp, acid, soils, do occur, for example at East Burrafirth. No remains were located.

Area 5, Hillswick-Urafirth, has produced material which is putatively of broch or immediate post-broch period, in the form of long-handled combs, pottery, and general midden material. The midden is still to be seen, with a little undiagnostic pottery weathering out of section, but no structural remains could be located (c.f. Appendix 1, item 94).

Area 6, Sullom, again has a reported site (Ashmore, pers. comm.). The supposed site is less than convincing, and indeed of doubtful artificiality. It is situated at Muirs of Marki. The parallel in terms of both site and area would be with Burravoe at Brae.

Area 7, Lunnasting, has a large number of small patches of arable, and looks a likely area. However, its real importance began as a fishing base in relatively recent years, and much of the arable land appears to be of recent creation, originating as appendages to the homes of Shetlanders in their traditional role of "fishermen with crofts".

Area 8, Voe, is today a small village, in a position closely analogous to that of Windhouse (Yell), at the head of a long firth which affords an easy crossing of the mainland. No broch site is recorded from the vicinity, although there is ample arable land around the Kirkhouse Burn to the south.

Area 9, Dury/Laxfirth, is once again devoid of possible sites, despite good land potential. The present settlements lie on the most likely broch-sites, but no trace or memory is preserved.

Area 10 /

Area 14 : Ireland in Dunrossness, a substantial arable area, good grazing, access to the sea, but no broch.

Area 10, Whitesness-Grunnavoe, has a variety of possible locations beside good land. The Neolithic-Bronze Age use of the area was almost total (Whittle, 1979), and it seems surprising not to find any Iron Age habitation site, although burnt mounds are numerous. The only reported site, behind the farm buildings at Pinhoulland, seems to have been an oval house of the type found at South Stany Fields, Brouster or Loch of Grunnavoe, all nearby.

Area 11, Sandsound, has a very sizeable crofting population at present, on good soils. No trace of a broch site could be found, nor is there any local tradition.

Area 12, Skeld, has two settlement nuclei, each associated with a reuted broch site (Appendix 1, items 87 and 105). The apparent absence of broch sites on the map may be a product of the criteria adopted for acceptance of a site as a broch, rather than a real absence of such sites.

Area 13, Gulberwick, is a prosperous crofting community, and although no broch site is known, I. Morrison has recently pointed out masonry in section in the cliff edge at Hevdas, on the north side of the bay, with traces of structures overlying this. Examination of this site in 1979 suggested a promontory fort rather than a broch. The location is very similar to that of Burland, the next broch to the south, although the cliffs at Gulberwick are lower.

Area 14, Bigton-Ireland, in many ways resembles Levenwick, on the opposite side of the mainland, in terms of land-quality and topography. A prosperous Dark Age community is attested by the St. Ninian's Isle treasure, but there seems to be no trace of any earlier community in this area.

Overall, the fourteen areas identified as gaps in the broch distribution have produced evidence for possible sites at five locations, although none of these is convincing enough to be classified as a broch. At least part of the irregularity in the present distribution could be removed, then, by hypothesising the former existence of now-lost brochs. But to bring all of the Thiessen polygons down to the same order of size as the smallest would require a wholly unrealistic number of lost sites.

Clearly, however, the above argument runs the risk of circularity. Unless all rejected sites are reassessed, the examination of only those sites which lie in areas empty of brochs will produce a self-fulfilling prophecy. It is necessary to bear in mind the fact that many of the other rejected sites are at least as convincing as the five above. The simplest /

simplest way of resolving this is to redraw the polygon map to include all sites, both accepted and rejected. Because of fieldwork evidence, based upon ceramic material (see Section 1), the promontory fortifications of known, non-broch, type have been included in the map, 2, iii, 3.

As will be apparent, the character of the pattern has changed little towards regularity, except in Unst, where the addition of three sites produces a more equable division, as is also the case around Bressay Sound. Elsewhere the increase in the number of sites decreases the average size of territories, but does nothing to reduce the range of sizes, which was the main problem. Therefore it is suggested that lost sites alone cannot explain the irregular size of the Thiessen polygons.

To return to the four explanations advanced above, explanation 3) was that some sites may have existed which were equivalent to brochs, but which were not themselves brochs. To a great extent this possibility has been covered above, by the inclusion of the promontory forts and the uncertain sites. Some, at least, of the promontory sites were in use throughout the Iron Age, on the grounds of pottery evidence (Fojut, 1980), while a number of the uncertain sites, while apparently neither brochs nor promontory forts, have produced "broch" pottery, as at the settlement below Underhoull (Small, 1972). These have all been included in Map 2, iii, 3.

Explanation 4), that broch-dwelling groups did not compete for land, can be viewed in alternative ways. Firstly, the brochs which lie closest together did not belong to populations which divided land into specific territories, either because they co-operated in agriculture, or because the brochs which are closest together were not actually in use at the same time. Secondly, broch areas, even at their smallest, were adequate to support their inhabitants in self-sufficiency, with little need to compete for resources with neighbouring groups.

On the principle of simplicity of hypothesis, if it can be shown that the second is a valid proposition, and that even the smallest areas could have supported enough people to build and man a broch, then the variations of the first alternative can be relegated to a lesser position, because they are unnecessarily elaborate. However, they must not be totally rejected, even if they are felt to be less than likely, unless they can be disproved.

To establish /

To establish whether or not areas might be self-sufficient, it is necessary to take what seems to be the most crowded area and to attempt to determine its carrying capacity. To this end, and to attempt to refine further the concept of broch territories, it was decided to make a detailed study of the area of Shetland where brochs are thickest on the ground, namely South Dunrossness. This study will then be used as a control for an attempt to reconstruct the more general economy of the broch period in Shetland.

Part 3 : Dunrossness Case-study

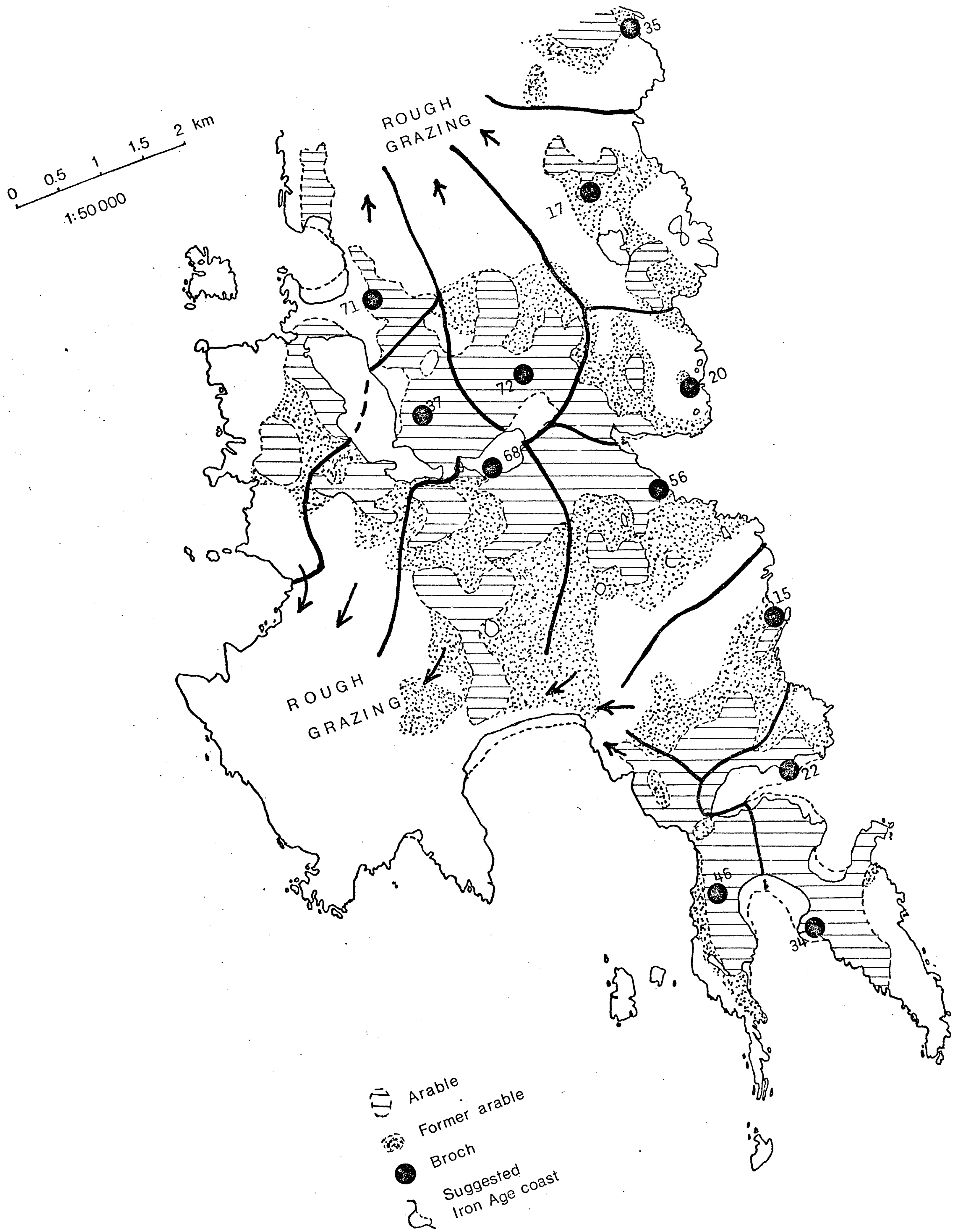
There are more brochs, in terms of density, in the southern part of the Mainland than in any other part of Shetland. Twelve of them are situated, both on the coast and inland, in a total area of some fifty square kilometres, of which the majority is moorland. All of these can with confidence be identified as brochs. In addition there are three sites of the promontory fort class, which are also of putative Middle Iron Age date. Since so little is known of these, they have been left out of consideration, but even should they prove to be of broch-period date in their occupation, this will not distort the results below to too great an extent.

The approach adopted is based on the pre-defined Thiessen polygons, with the addition of the quality of land. This map, 2, iii, 4, is then modified to produce a more likely series of boundaries, as displayed on Map 2, iii, 5.

The Dunrossness area contains the largest contiguous extent of good land in Shetland. Much of this faces south or south-east, and it is mainly well-drained, lying over a sandy subsoil, with some heavier areas of clayey loam. Areas of good grazing fringe this arable core, and these are partly composed of long-abandoned arable and partly of improved moorland and sand-dune grazing. At the present day, much of the annual sowing on the arable is of grass and clover, for use as cut and standing fodder. Beyond the improved grazing land, heather-clad slopes rise to over 200 metres, providing rough grazing of poor quality.

The impediments to agriculture are three: sandblow has covered good land at Quendale and Huesbreck, and around Jarlshof, a process which has been established since the Iron Age at least; eroding shore-lines have removed low-lying land at Quendale, Jarlshof, Virkie and Scousburgh, and to some extent at Boddam, and finally, the form of the landscape, being relatively open, provides little shelter from gales, particularly from the south and east. These three factors probably operated to some degree during the broch period : both sandblow and coastal erosion are evidenced at Jarlshof, and possibly at Eastshore of Virkie.

The intial study was of the still unresolved question of defining broch territories. Whether brochs were fortresses or farmhouses, they cannot have lain too far from the focus of daily life, or they would have been both uneconomic and inefficient. So the broch-centred Thiessen polygons /



ROUGH GRAZING
0 0.5 1 1.5 2 km
1:50000
35
17
71
72
37
68
20
56
15
ROUGH GRAZING
22
46
34
Arable
Former arable
Broch
Suggested Iron Age coast

polygons seemed a reasonable starting-point. These are displayed in Map 2, iii, 4, with the addition of present and former arable land and a suggested Iron Age shoreline where this seems to have been significantly different from the present day. Inspection of the map shows that while all polygons have all three types of land (arable, good grazing and rough grazing), the proportions of these are very variable. Skelberry (72) has arable and little besides, while neighbouring Dalsetter (20) has little arable but plenty of grazing. Some of the territories, notably Clumlie (17), Lunabister (37) and Southvoe (56) have a great deal of similarity, both in form and in the proportions of the different types of land. Lacking any evidence for a marked difference among brochs in terms of population or status, the first aim was to attempt to make the territories more equable and visually convincing.

The basic criteria adopted to this end were:

i) Equality of arable, so far as this can be achieved without the imposition of artificial boundaries.

ii) Access to rough grazing, and to a sufficient area of good grazing.

iii) Access to the sea, at a point suitable for beaching and launching a small boat.

Several boundary changes were necessitated, away from the rigid polygon framework, to provide more arable for Clevigarth (15) and Dalsetter (20) and to give Jarlshof (34), Virkie (46) and Skelberry (72) access to more extensive grazing land. Skelberry was the only site which required the creation of access to the sea. The resulting territories are shown in Map 2, iii, 5. One major change has been made; this is to the status of grazing land. It seems unrealistic, in the light of historical practice and parallel (Hamilton, 1968) to argue for a rigidly proprietorial compartmentation of pasture, but rather, some form of common grazing seems more likely, perhaps with carefully observed rules as regards the level of stock numbers. Consequently, the grazings have been left undivided in the new model. Whether or not grazing was thus organised, there seems no possibility, in this area, of stock having been grazed close enough to the brochs for it to be driven inside speedily in the event of a hostile raid, if indeed this was ever the practice (see above, Section 1, Chapter IV).

Chiefly from the excavations at Jarlshof (34) but also at Virkie (46) and Lunabister (37), together with Eastshore (22), there is some evidence touching upon the nature of the broch economy. Three elements are represented /

are represented; crops (grain impressions upon pottery, plus querns and rubbing-stones), domesticated animals (bones of sheep, cattle, pig and possibly horse) and marine resources (seal and fish bones, whalebone artefacts and quantities of shells). But the Jarlshof excavations did not produce evidence which enables quantification of the contribution of these resources in proportional terms, a matter which must have varied considerably among sites.

The potential grain production, and its food value, can be estimated in approximate terms. Fenton (1978) presents data for the cultivation of bere in eighteenth century Orkney. The average yield was about 1250 kilograms per hectare for the best land. Allowing a 1:4 seed to crop ratio, this leaves some 950 kg for human consumption per hectare of good, intensively-worked, arable land. Clearly, Iron Age yields may well have been lower, due to poorer varieties, although there is no direct proof that this was the case. Also, the practice of manuring may not have been so well-developed, although this is another unknown area. Consequently, a figure somewhat lower must be taken for Iron Age yields, and that of 500 kilograms per hectare (for human consumption) has been adopted here. If this is in error, it certainly errs on the side of conservatism. Taking this figure as the standard, and bearing in mind Clark and Haswell's (1967) conclusion that 210 kilograms per year is the minimum required to support one adult for one year in the absence of all other food sources, it appears that one hectare of good land might have supported 2 or 3 persons, if no other resources were exploited.

Arable land is very fragmented, in small fields separated by paths and ditches, with small marshy or rocky areas, the total of such non-productive usages equal to perhaps five percent of the area farmed. In addition, any single year would find about one-third of the land set aside under fallow. Using these figures, around sixty percent of mapped arable would have been producing grain in any one year. A table can be prepared, using the map of re-defined areas, and showing the present arable land, the total of past and present arable, the likely amount of land cropped in any one year, and the maximum "grain only" population which could have been supported by each broch's supposed economic area.

Site name and number	Present arable (hectares)	Past + present arable (ha.)	Effective area each year (ha.)	Population carrying capacity: Minimum number	Maximum number
Clumlie (17)	57.5	130.0	34.5 to 78.0	86	195
* Scousburgh (71)	155.0	180.0	93.0 to 108.0	232	270
* Lunabister (37)	130.0	170.0	78.0 to 102.0	195	255
Skelberry (72)	140.0	175.0	84.0 to 105.0	210	262
Dalsetter (20)	47.5	105.0	28.5 to 63.0	71	157
* Loch of Brow (68)	167.5	320.0	100.5 to 192.0	251	480
Southvoe (56)	107.5	230.0	64.5 to 138.0	161	345
Clevigarth (15)	52.5	110.0	31.5 to 66.0	78	165
Eastshore (22)	45.0	120.0	27.0 to 72.0	67	180
* Virkie (46)	152.5	180.0	91.5 to 108.0	227	270
Jarlshof (34)	125.5	140.0	75.3 to 84.0	188	210
Mean values	107.3	169.1	64.4 to 101.5	160	253

Notes: 1) Levenwick (35) has been excluded, as the northern boundary of its area is not defined within the present study area.

2) * indicates sites whose arable land is fragmented into a number of small areas, some at a distance from the main areas of arable land.

The figures demonstrate for themselves, without the need of any interpretation, that in a good year arable farming could, by growing barley alone, have supported substantial numbers of people. Even for the poorest areas, that number is at least equal to the normally-assumed minimum broch group-size. That is, the land could have supported enough people to pŏpulate all of the brochs of Dunrossness at one and the same time.

But not every year was a good one. Total crop failures are not infrequent in Shetland, in years when spring comes late, followed by wind and heavy rain in late summer. Current estimates would imply an Iron Age climate somewhat wetter and cooler than the present. Clearly, total reliance upon one crop, or even a combination of crops, would have been tantamount to suicide, and other sources of food must have been exploited.

Domestic animals must have kept, but to what extent these were cattle for draught, rather than beef, and sheep for wool, rather than mutton, is uncertain. It has been suggested that wool sheep were at a relatively rudimentary stage of development during the Iron Age in the north, but against this must be set the fact that bones from Jarlshof are indistinguishable from the modern Shetland sheep, which produces a soft and easily-utilised fleece which can be removed by hand in the process now termed "rooing". Dairy products from both sheep and cattle (ewe-milking was practised on Foula into this century) would have been important, but the contribution of meat from these animals may not have been particularly great. At only one site, unfortunately outside the Shetlands, is there any relevant evidence. At Dun Mor Vaul, in Tiree, domesticated animals seem to have been used as a stand-by food supply for times of emergency or shortage, and were used thus while the broch itself was under construction (MacKie, 1974, and see above, Section 1, Chapter III). There can be little doubt that meat was a regular, if not plentiful, element of diet, as stock-control would require the culling of selected animals at intervals, to maintain optimum herd and flock compositions. Overwintering of cattle has always been a problem in Shetland, with records from more recent times of animals having to be carried back to the fields in spring, although this inability to walk may have been due to the cramped condition of their winter quarters as much as to a lack of fodder, although the latter is certainly a scarce commodity in the islands.

Perhaps the most that can be done is to suggest that the Iron Age people of Shetland, like their eighteenth-century successors, ".... would eat more animal food than perhaps any others of their rank in Europe ", Low, 1774, p 90.

This state of affairs would have been as much through force of circumstances as through choice. A rough estimate, based upon stock-figures from last century (Fenton, 1978), gives figures of up to 200 sheep and 40 cattle per site, but figures as high as this, especially for cattle, would necessitate the use of some potential arable as high-quality grazing. Nevertheless, the numbers of domesticated animals kept by each group could have been amply large enough to act as a strategic food-reserve, and as an occasional supplement to diet, provided that they were not the sole source of food.

The other main source of protein in Shetland's recorded history is the sea, and there is no reason that the importance of this need have been less in the Iron Age than in Medieval times. Marine mammals were certainly exploited. Whalebone at Jarlshof may have derived from natural strandings, although the shores at Quendale, Virkie and Boddam would have been ideal for driving ashore the ca'in whale, or blackfish. Until the last century, large schools of this gregarious small member of the whale family were frequent in Shetland waters, and were periodically driven ashore by herding them into shallow voes. However, even if such hunting was practised during the broch period, it must have been occasional, and dependent upon the appearance of the prey offshore in favourable weather conditions. It might have been an important boon, but could not have formed a staple food supply. Seal bones occur at Jarlshof, and Dunrossness still forms the main breeding base for the grey seal in Shetland, while numbers of common seal are usually to be found there. The low, shelving slabs of the shores at Mousa, Sumburgh, Scatness, Siggar Ness and Spiggie form ideal beaching areas for seals, and despite frequent disturbance, the present populations show no signs of leaving their habitual summer haunts. Hides, which are the best material for use in skin boats, and seal-bone, used in needles and other tools, must have been used during the broch period, as at all times since, but about the use of the meat there is less certainty. Many societies have food taboos involving the seal, possibly to some extent because of its rather human face, and even at Jarlshof the bones occur only from the middle Iron Age, and are not present at all periods thereafter. This is reflected in the surviving local aversion to the eating of seal flesh (Williamson, pers. comm.).

Fish are by no means the scarcest of Shetland's present-day resources, yet there are very few fish-bones from Jarlshof, and these few are of the larger species. This is almost certainly a function of excavation /

excavation technique rather than of real scarcity, as fish have always played a major role in diet in recorded times. The large quantities of shellfish remains at Jarlshof and other coastal sites are perhaps best interpreted as bait, especially since limpets, the most unpalatable of shellfish, predominate, although other species with a higher food-value do occur in lesser numbers. Limpets were, until recently, utilised as food in the Western Isles, largely because they are quite resilient to human interference with their numbers, and are not mobile, so can be easily located and collected. However, their advantages as bait are also great, centred around the fact, as expressed by one local fisherman, that "they are so tough, they won't come off the hook !" The small numbers of fish bones, and the fact that those found are of the larger species, merely serves to underline the observations in Section 1, that the lack of evidence is almost certainly due to the inadequate nature of the archaeological techniques used at Jarlshof (Clarke, pers. comm.).

There are large numbers of bird-bones at Jarlshof, and while the species of some of these would indicate that they are chance finds, it seems likely that barely-fledged birds, and eggs, would have been collected in season. Most of the auk and gull family share with the seal and whale the production of large quantiities of oily fat, a form of natural insulation which can be rendered down over a slow fire to provide quantities of oil. This would have formed the main source of lighting at the period, as for many centuries after, and the use of oil for lighting is attested by the presence of steatite and sandstone lamps at a number of sites. The plump young fledglings of most cliff-breeding species are not unacceptable to the seasoned palate, and dwellers on the more remote islands have, in times past, lived on a rather monotonous, but high-protein, diet of fish and seafowl. Such may have been the diet of the Dark Age monastic dwellers on the remote promontories of Shetland such as Kame of Isbister (Lamb, 1972).

Other marine foods might have included algae and seaweeds, and the latter would also have served to increase food supplies indirectly, through its use as manure on the fields. Salt, too, may have been produced locally, while driftwood might have served, with peat and probably cattle-dung, as fuel for heating and cooking.

In other words, the variety of food-sources available to the broch-dwellers would have been essentially similar to that available to the more recent inhabitants, and while each in itself would have been inadequate, together they provided a breadth of economy which would have gone far towards ensuring the continued survival of a hardy people prepared to work for a living.

The point of this case-study of Dunrossness has been to demonstrate that a series of territories defined upon the basis of the Thiessen polygons and modified according to the principles of site-catchment analysis and cultural parallel, can be used as the basis for a rational assessment of the population-carrying capacity of the Iron Age Shetland environment. Further, and more importantly, it has been shown that even on the most pessimistic view of the capabilities of Iron Age agriculture, the most restricted of areas attributed to a broch could have supported the requisite size of community, and that such communities may indeed have had considerable "slack" in their economies to allow for harvest failure. The people would probably have enjoyed a fairly basic, but varied, diet based on grain and animal products, with a major input from the produce of the sea. In view of the variety available to the population, it seems reasonable to suggest that each community would have had access to all three elements, arable, pasture and marine resources, either directly or through trade or exchange.

In addition, by demonstrating the viability of this approach to defining economic units, it becomes apparent that all of the groups who were associated with brochs could have existed contemporaneously in Shetland. Neither theft nor co-operation would have been essential to gain a living, although doubtless both occurred, the former through greed and the latter through a need to agree over such matters as ownership of arable land and division of grazing rights.

Dunrossness : The low ground between Boddam and Spiggie, with the lochs of Brow and Spiggie. Lunabister, Loch of Brow and Scousburgh brochs are all visible.

Core-Periphery : Loch of Burraland broch site lies on the far promontory, backed by arable and former arable, the whole surrounded by moorland grazing.

Part 4 : A Modified Area Model

The above case-study has shown that broch-communities could have survived at the same time as their immediate neighbours in the most apparently congested part of Shetland. If this was the case, it would appear that elsewhere in the islands broch groups were not only well able to survive, but may have had considerable capacity within their notional territories for increased productivity. That is, broch groups did not necessarily rely upon the full resource potential of their economic areas.

Although the maximum carrying-capacity of any large extent of land can be estimated (Heisler, 1978), it must always remain extremely difficult to assess the extent to which this capacity is utilised. The traditional carrying-capacity model is based upon a totalling of all resources, followed by a division of this into the maximum possible number of individual nutritional units. It fails to make any allowance for the fact that human beings tend to operate as groups, and both because of their own limitations, and the mere fact of their being organised in larger units, tend to use resources inefficiently. The sources of this inefficiency can be divided into two; the habitual practice of living in groups tends to concentrate attention on the area nearest to the settlement, while land further away receives less care, and on the individual front, factors such as ignorance, prejudice and taboo can severely limit the available resources. There can be no doubt that Shetland supported at least seventy-five groups of perhaps one hundred persons each during the Iron Age, and little doubt that all of these groups could have been in existence at precisely the same time. Even so, there would appear to have been considerable resources, both in terms of farmland and in terms of marine potential, which were under-utilised, if not un-utilised.

Since the full utilisation of land is a pre-requisite for the formation of polygonal territories, which achieve their unusual form from pressure between group territorial expansions, and since the spacing of brochs does not allow a standard form of territory to be defined, it is suggested that the most realistic method by which to limit broch economic areas is, in fact, not to do so. Perfectly adequate working approximations can be obtained by treating the economic area as a core of arable land, near to the broch and usually with access to the sea, surrounded by grazing of good quality which gradually merges into poorer moorland grazing. The establishment of boundaries on this waste and desolate ground would be futile, as they would be impossible to defend, and the moorland enclosed not worth defending.

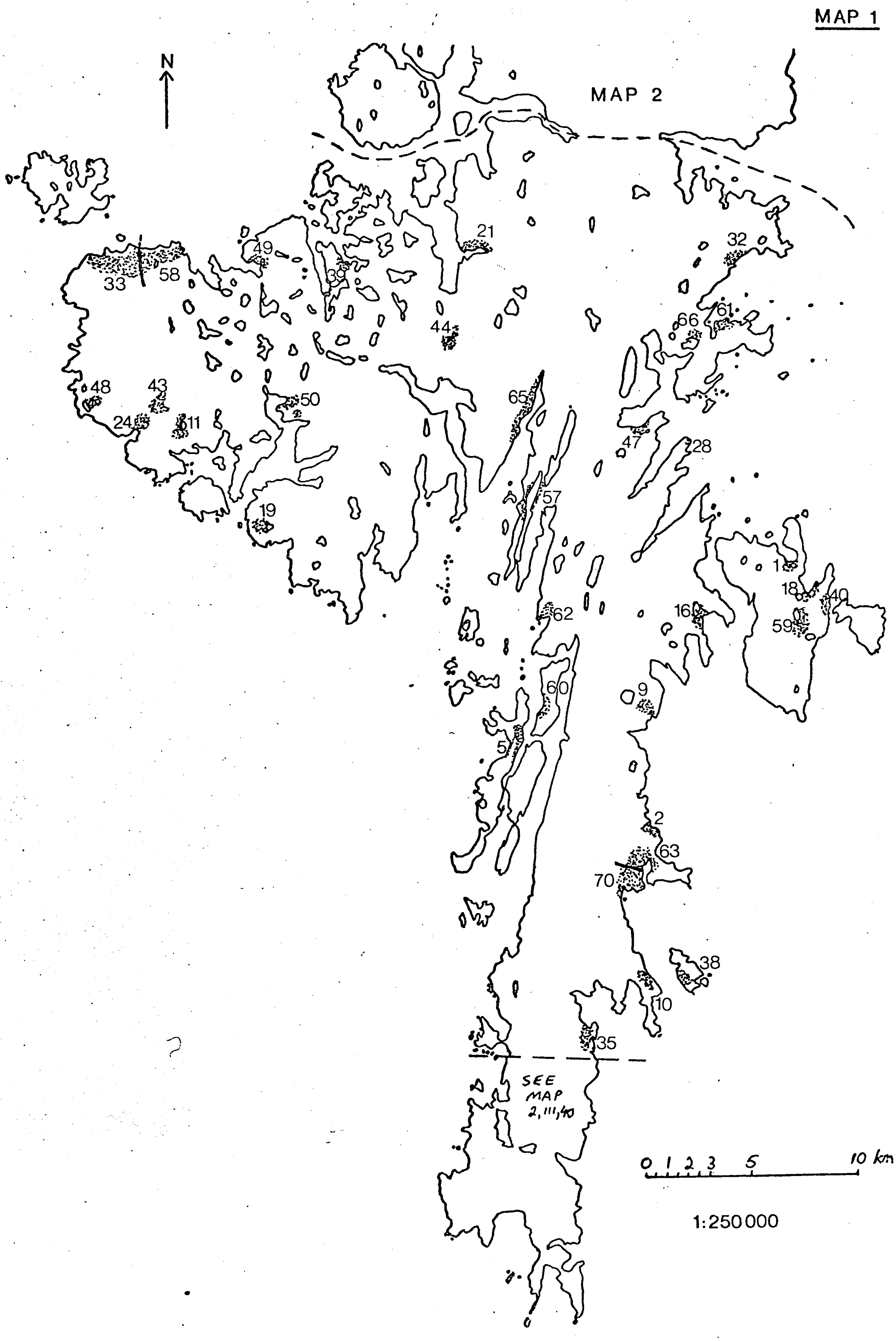
This core-periphery model requires one additional modification. On re-examination of the broch areas over the whole of Shetland, it was noted that almost all of the seventy-five areas have a single area of good land which is much larger than any satellite areas, and this main area is usually close to the broch site. This apparent preference for a unitary area of farmland may help to explain the absence of brochs from some of the likely areas noted above, particularly Areas 4, 7 and 9. In these, arable land occurs in quantity, but only in the form of small patches of roughly equal magnitude. This trait may have been because, where land potential in a particular area was much greater than the numbers to be supported, only the main area of farmland would need to be intensively cultivated to provide the requisite proportion of crops for the overall mixed economic base.

For this reason, the overall total of potential arable land is a less reliable guide to the level of Iron Age population than is the number of brochs. In the fragmented landscape of Shetland, there are many small areas which would have been capable of supporting small communities, but which could not support groups of the size thought to be associated with brochs. These larger groups, in the absence of other evidence, must be assumed to have constituted the vast majority of the Iron Age population. Therefore the macro-scale approach to the estimation of population has been rejected for the present case. This rejection is largely due to the nature of Shetland's terrain, which dictates that, for the number and size of areas associated with brochs, there must be numerous small areas left unused between these. In more regular terrain, such as Caithness, it is possible to fit the areas of these larger groups together in such a way that the interstitial space is minimised, and estimation of population by calculation of total resource potential may come nearer to the truth (Heisler, 1978).

In summary, a rigid approach to the definition of territories, through formal methods, is rejected as inappropriate to the specific circumstances of Shetland, and replaced by a partially subjective model, based loosely upon the guidelines of theory and founded more solidly upon the lineaments of landscape, as it exists and as it can be reconstructed. It is felt that such an approach is better able to answer the questions of total population and economic variety, by enabling a synthesis based upon the examination of individual units, than can the overall approach which begins with the whole and proceeds to the parts by subdivision of generalised answers.

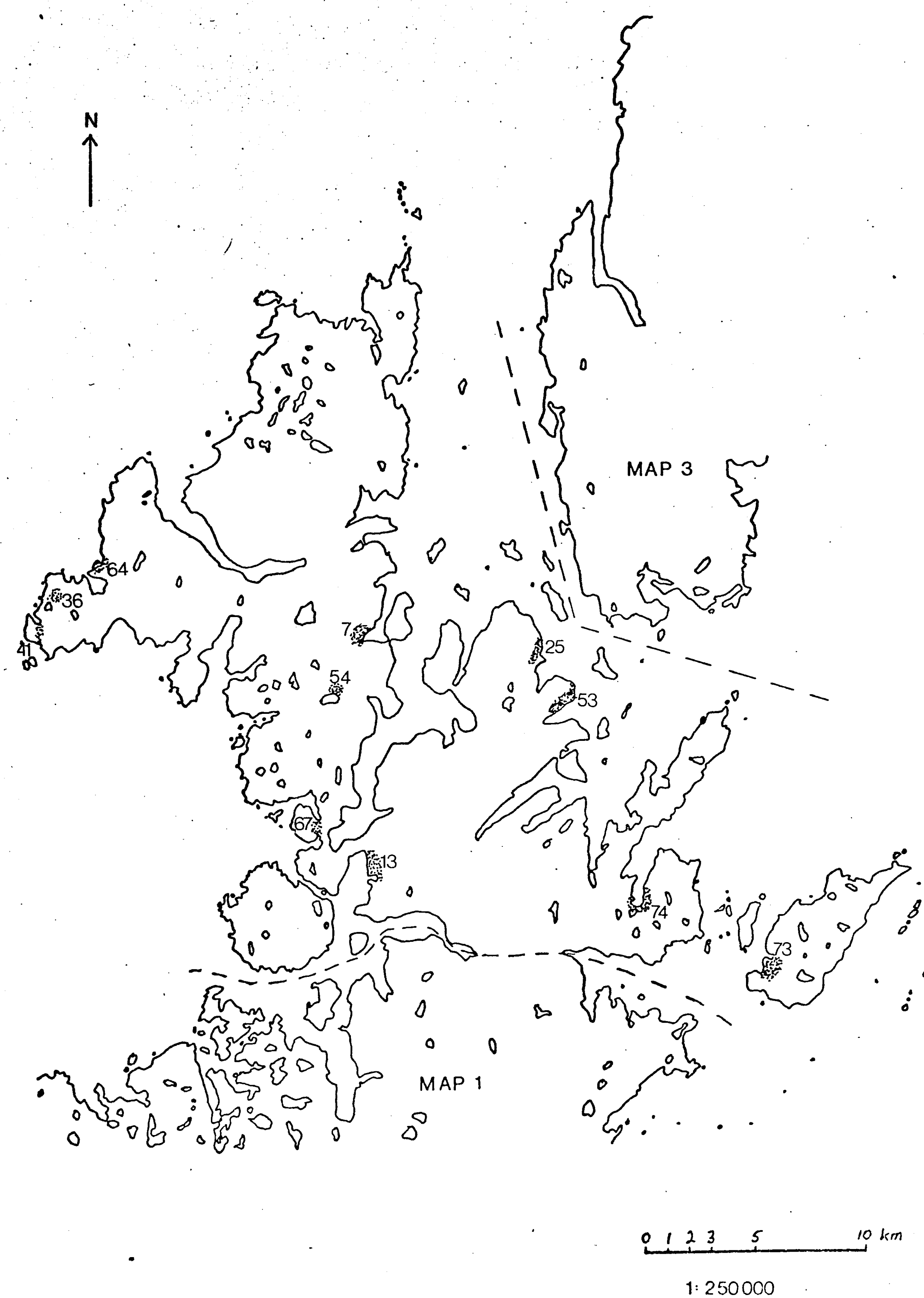
BROCH ARABLE

CORE AREAS



BROCH ARABLE
CORE AREAS

MAP 2



BROCH ARABLE
CORE AREAS

MAP 3

Part 5 : The Shetland Broch-Period Economy

Variation

Having arrived at what is, if not a definition, at least a means of estimating the extent of broch economic areas in Shetland, it is now possible to construct a map of arable cores for all seventy-five of the broch sites under investigation. Map 2, iii, 6 is such an attempt, and it does not, as explained above, delimit the periphery of each area by a rigid boundary running through the intervening moorland. The boundary between two sites should be thought of in terms of diminishing interest, and it will be apparent that the effective boundary will lie where both groups care least to exploit the land. The idea of a rigid limit is clearly inappropriate, as such a limit would run exactly where the inhabitants of nearby areas could not care less about the ownership or rights to land.

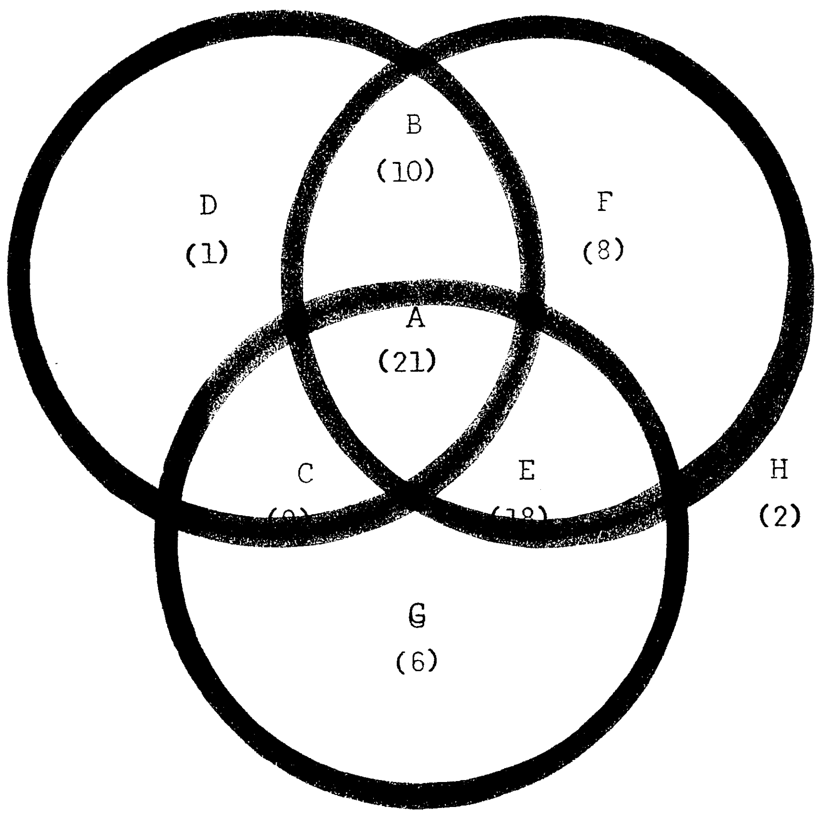
Where grazing is scarce and brochs numerous, some form of communal control on stock numbers might be necessary. Likewise, where broch-groups had restricted cropland, it would perhaps be resonable to expect this to be divided, and worked rather more intensively than elsewhere. It is a basic truism of agriculture that yields do not increase as rapidly as input of labour, and there was probably a level of intensity of working, considering manuring and drainage, beyond which any advance brought but little reward (Boserup, 1965).The normal level of the broch-dwellers' economy was probably far below its theoretical maximum potential.

The data and sketch maps in Appendices 2 and 3 make it possible to make a broadly realistic reconstruction of the economic basis of all 75 broch areas, on the lines of the Dunrossness example detailed above. However, it seems highly likely that the economies of these areas would have represented a continuum of variation on the three themes of arable, pastoral and marine exploitation. This makes it somewhat redundant to characterise each area in detail, and instead a tentative classification of the areas into different types of economic basis can be undertaken.

The first stage of this process is to establish the possible range of economies. Here a very simple approach has been taken. While it may be difficult, or impossible, to calculate the precise potential of any area with regard to a particular resources, it is invariably possible to decide whether an area is well-endowed or otherwise in that respect. Taking this as a basis, an exhaustive set of possible types of economic base can be defined, as follows:

Type code	Arable	Pastoral	Marine	Number of sites
A	GOOD	GOOD	GOOD	21
B	GOOD	GOOD	POOR	10
C	GOOD	POOR	GOOD	9
D	GOOD	POOR	POOR	1
E	POOR	GOOD	GOOD	18
F	POOR	GOOD	POOR	8
G	POOR	POOR	GOOD	6
H	POOR	POOR	POOR	2
			Total	75

This classification can also be displayed in the form of a Venn diagram, in which the universe is the set of all broch sites and the subsets are the sets of brochs which achieve a "good" rating under each of the three types of resource:



Looking at the individual aspects, the figures are:

Good arable potential	41 sites
Good pastoral potential	57 sites
Good marine potential	55 sites

By simple arithmetic, the average broch area has a "good" rating on two aspects (41+57+55 = 153; 153/75 = 2.03). This figure means very little, as it represents such a wide range of variation.

It is plain that while some arable, or potential arable, seems to have been required, the actual amount or quality of this land may be very low. On the other hand, brochs that have very little grazing land are extremely scarce, and those that are ranked poor on this count are mainly those which have low-quality grazing, although this may be very extensive. The general rule is "a little cropland and plenty of grassland". The marine potential figures exclude a few coastal brochs which are either on difficult coasts, or opposite areas of low productivity in the present day.

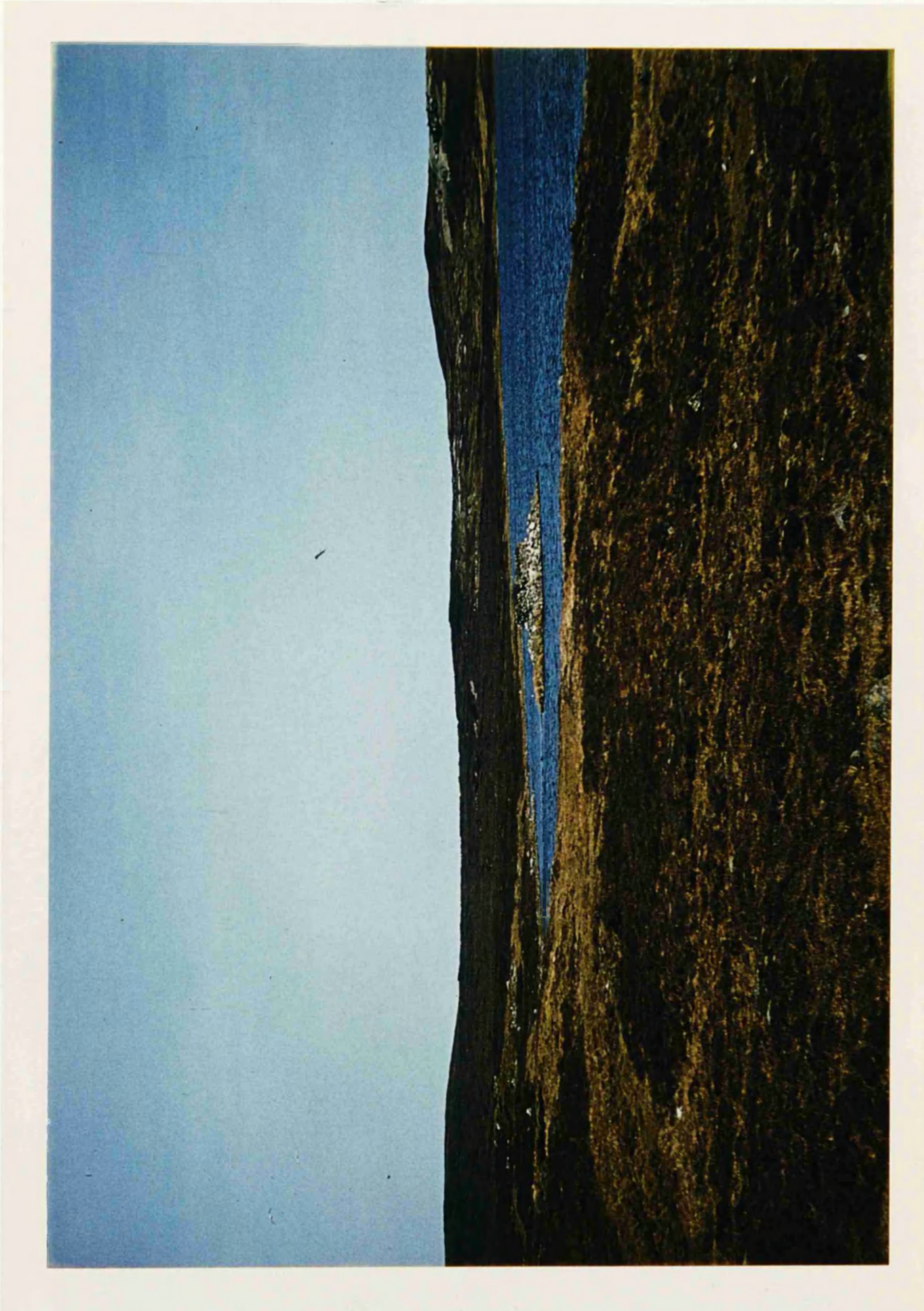
Since the Dunrossness examples were heavily biased towards arable acreage, since this is the only aspect where we can hope to achieve some precision of estimate, it remains to broaden the picture of economic strategy gained from that study. To this end the table above provides a good starting-point. One broch area has been selected from each of the eight classes, and is examined in detail below. Unlike some of the other selections in this research, this was made upon a non-random basis, and the areas chosen are those with which the author was most familiar in the field, and which gave the clearest impression of the variety present in the potential economy of the different groups which possessed their brochs. However, an effort was made not to select "tidy" areas for the sake of simplicity of treatment.

Areas selected for closer examination were:

A West Sandwick, Yell (75)
B Stoura, West Walls (43)
C Burravoe, Yell (14)
D Skelberry, Dunrossness (72)
E Burra Ness, Yell (12)
F Aithsetter, Cunningsburgh (2)
G Sae Breck, Esha Ness (41)
H Loch of Houlland, Esha Ness (36)

Each area is dealt with in turn, except for the last-named pair, which being adjacent, can conveniently be treated together. The aim will be to provide an overview of the range of interplay available in the different combinations of the three basic aspects of environmental potential.

Arable potential : Papil Bay, Fetlar, near the broch site at Houbie. Not only arable, but pastoral potential. The sandy beach, however, is not a good landing.



Pastoral potential : Loch of Kettlester, showing the extensive hill land surrounding the loch which shelters the islet site from attack.

Marine potential : The broch remains at Noss Sound, showing the access to good fishing waters, a good landing place (still in use) and an anchorage.

Type A : West Sandwick. Map 2, iii, 7

While there remains a little doubt about the precise nature of the archaeological remains at West Sandwick (Williamson, pers. comm.), their general character is such as to suggest a broch as the most likely former structure to have occupied the site, although there has been considerable later disturbance.

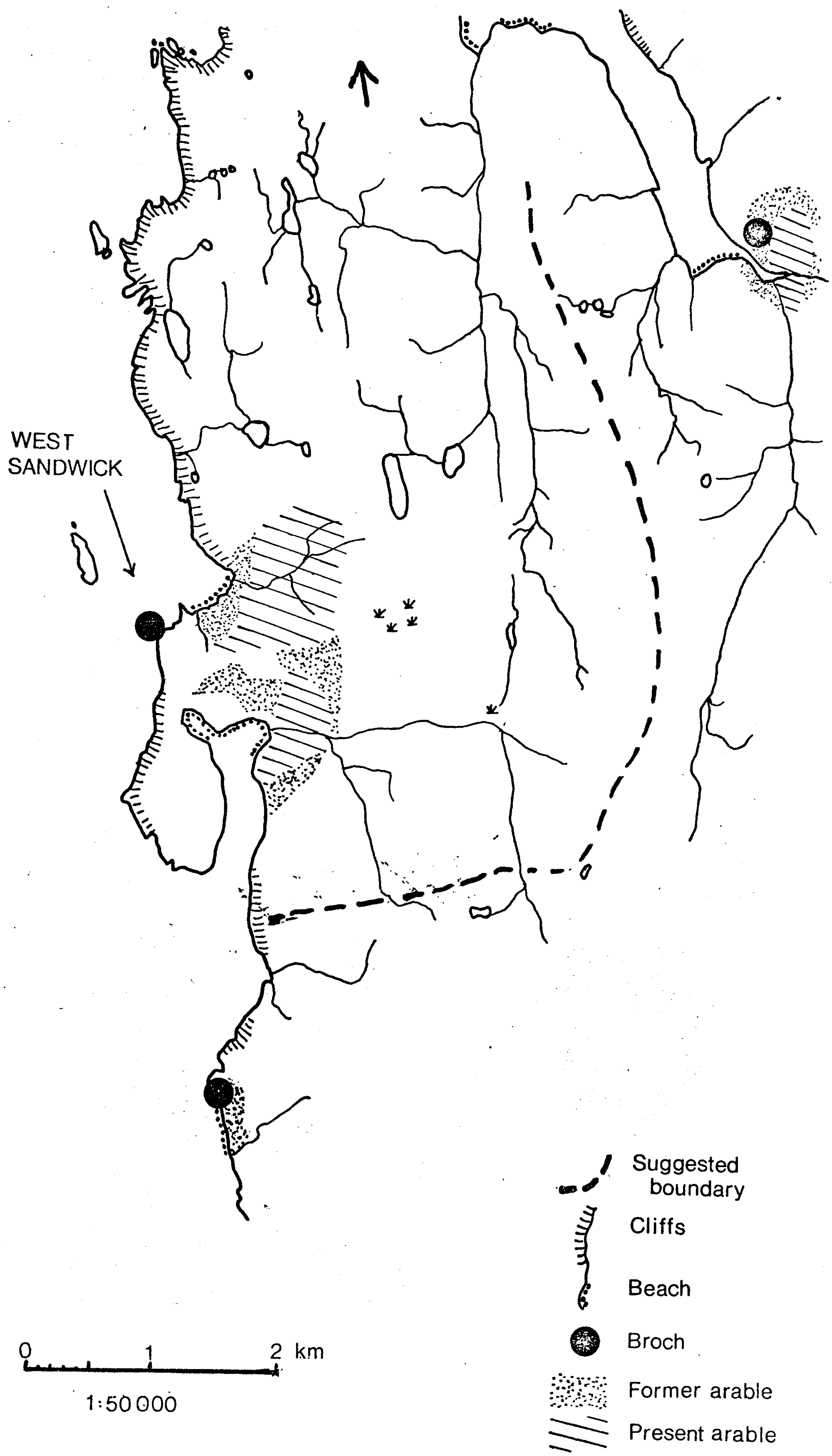
West Sandwick is today a medium-sized crofting township of some 25 households, housing perhaps 75 to 85 persons. Little fishing is carried on now from the pier, except for pleasure and for personal consumption, and many of the working population have employment in other parts of the islands. The crofts and small farms are still cared for, although arable acreages are much reduced within living memory.

The township's good land is, and always has been, in two main units, divided by a low ridge which runs east-west and links the mainland to the peninsula on which stands the broch. It is clearly impossible to determine whether both areas of land were exploited from the broch, although the fact that the southern half is invisible from the site may be significant. A total area of about 90 hectares of good quality land exists, about equally divided between north and south townships. The land is slightly sandy, and well-drained below the houses, and above runs back into heavier, clayey, soils based on the underlying glacial deposits.

Behind the former arable, and on the exposed promontory, there is good quality grazing developed over peat (another resource in abundant supply). This gradually rises towards the east, giving way to scantily-grazed heather/grass moorland. This stretches unbroken to the north and east for some miles.

The beaches of West Sand Wick (the northern bay) are varied, with the shingle portion, most suitable for beaching boats, at the western side, near the broch site. Five hundred metres to the south, across the isthmus, Southadie Voe provides an alternative sheltered landing-place. Fishing is good, although hazardous to the novice due to currents in the deep waters of Yell Sound. Dolphins and porpoises are frequent visitors, as are seals and the larger cetaceans, although the latter are much more scarce than formerly (local informant). There seems to be no record of the local exploitation of these latter resources within the past century.

The territory of West Sandwick broch could have been extensive, with the nearest brochs at Head of Brough (3.5 km south) and Windhouse (5.5 km north-east). The potential population would be considerably in excess of the present numbers, which constitute the basic size of community usually proposed for brochs.


WEST
SANDWICK
Suggested
boundary
Cliffs
Beach
Broch
Former arable
Present arable
0
1
2 km
1:50 000

Type B : Stoura. Map 2, iii, 8

The broch behind the croft at Stoura has been almost totally removed, but the name itself (Stourabrough Hill is "the hill of the big broch"), together with local testimony, are ample evidence for the former structure. Traces of the ground-plan can still be made out on the flat area behind the croft.

About fifty people live today in the area overlooked by the site, and more around the head of the voe at Footabrough, although these are in what would have been the local area of the eponymous broch, which stands on the shore. At least as many crofts lie deserted as are occupied, and the extent of arable has clearly decreased drastically over the past century or less. The total potentially-cultivable land amounts to some 60 hectares; although much of this is marshy, the soil is fertile when drained.

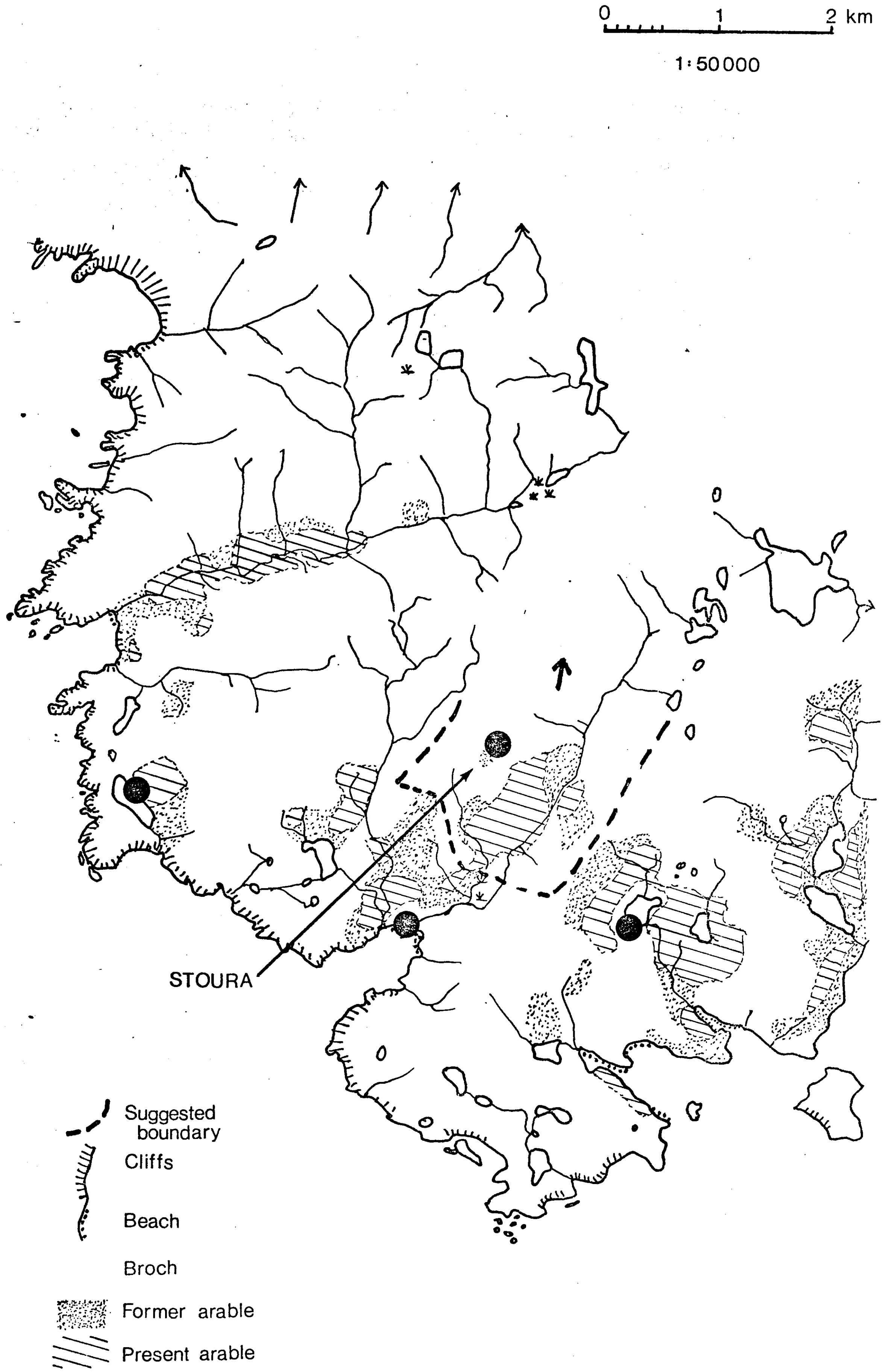
On the slopes of Burn of Setter there is ample grazing of good quality. This gives way beyond Sother's Daal, at the head of the valley, to hill grazing. Present stock numbers, mainly sheep, suggest under-grazing, and this is attested by recent encroachment of heather back over the cleared grassland at Sother's Daal. Remains of all periods occur, with burnt mounds, Bronze Age (?) homesteads and a Neolithic chambered cairn, plus numerous clearance mounds. That this evidence is mainly on the rough grazing land is almost certainly due simply to differential destruction.

The site has no ready access to the sea. The only likely landing-place, at Footabrough, is below the mound which represents another broch. This poses the question of whether two broch-groups might have functioned in co-operation to achieve a more rational use of resources, even when, on strict calorie-intake calculations, they could have survived independently. Footabrough has a Type E economic area, which means it is short of arable potential, and it is tempting to envisage some form of symbiotic relationship, with co-operation over the exploitation of marine resources, in which respect Stoura is poorly-provided, and cropland, of which Footabrough has but a little, and that thin-soiled and poorly-drained.

Type C : Burravoe. Map 2, iii, 9

Burravoe broch has been largely removed, and a later structure, and latterly a flagpole, erected on the site, but there is little doubt of the correctness of the identification implied by its place-name.

The /


0
1
2 km
1:50000
STOURA
Suggested boundary
Cliffs
Beach
Broch
Former arable
Present arable

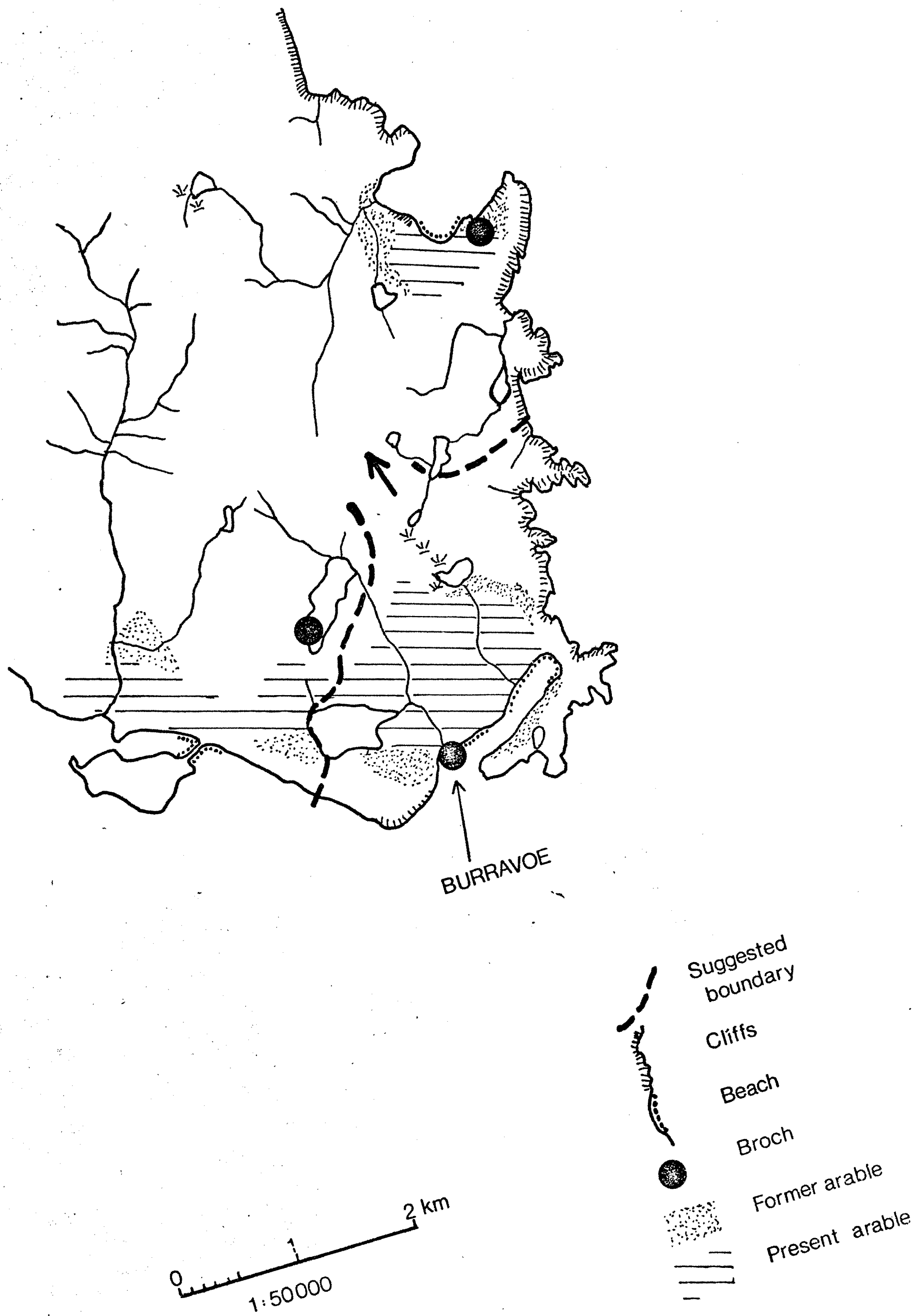
The area immediately north of the site constitutes the second-largest extent of arable land in Yell, with a potentially-cultivable area of about 100 hectares. Although some of this may be Medieval intake from the moor (locally termed "inbrek" or "inbrake"), most would seem to be long-established. The present population of the small village of Burravoe is about one hundred, making this the largest nucleus of settlement in South Yell.

The soil is relatively rich, largely through being long-worked and much-manured, and is based upon a mixture of peat and a sandy glacial till. Although most of it is freely-drained and fertile, the cultivated acreage is steadily decreasing in line with the overall trend in the Shetlands.

Grazing is less freely-available, with only the exposed promontories of Heoga and Burra Ness, where the sward is stunted by salt winds, and a strip of rough, heather-clad, moorland running north up the coast. The former status of part of the grazing is indicated by the placename of Heoga Ness, as heoga/hoga is the Norse term for land grazed by cattle.

Marine access is immediate, and the voe beside the broch site has enough depth of water to provide an anchorage for a light boat, as well as possessing a good shingle landing-beach. Offshore waters are rich in fish, with seal occasional visitors. At the present day, larger marine mammals are rarely sighted, but there are eighteenth and nineteenth-century records of strandings of schools of ca'in whales, for which the voe would have provided an ideal trap.

Once again, co-operation with the neighbouring broch group, that at Loch of Kettlester, would have acted to the benefit of both groups, as this site has little arable, although what it has is of good quality, and is not situated to make access to the sea easy. On the other hand, it has ample and extensive grazing land, both of good and poor quality. So attractive is the idea that the two functioned as one, that it has been suggested that the structure in Loch of Kettlester is in fact a subsidiary fortification, in the form of an outpost or retreat for the people of Burravoe, and that only one group is involved (Williamson, pers. comm.). The demonstration, or otherwise, of this theory must await excavation, but there is no reason, from an economic standpoint, that there should not have been two co-existent groups, one based by the sea at Burravoe, and the other by the moorland-girt Loch of Kettlester.


BURRAVOE
Suggested boundary
Cliffs
Beach
Broch
Former arable
Present arable
0
1
2 km
1:50000

Type D : Skelberry. For map see 2, iii, 5, above.

Little is visible of the broch at Skelberry, but its existence is supported by periodic discoveries of appropriate stonework below the modern ground level, during building operations, and by occasional finds of pottery and artefacts such as hammerstones.

The area has already been discussed in general terms, as part of the Dunrossness case-study, and the reason it has been selected for further treatment here is that it is the sole representative of Type D, being remarkable in the context of Shetland for the extent of good land around the broch site, and the lack of grazing land and easy access to the sea.

Some 175 hectares of the land ascribed to this broch is of arable quality, and all of this shows signs of having been cultivated at some time, although almost all is now under permanent pasture, with only a few small fields under cultivation at present.

The lack of any readily-accessible extent of definite grazing land which has not at some time been cultivated could mean that the inhabitants of the broch concentrated their activities on crop-raising, but is more likely to imply that not all of the potentially-arable land was cropped, and that part of it was set aside as grazing. This highlights a problem in this approach, and that is the difficulty of assessing Iron Age areas of cultivation, since so many changes have taken place since then in the use of land.

There is relatively little rough grazing immediately beside the broch, and that to the north is in an area of moorland which might have been disputed with two other groups, unless it was shared, as is suggested above.

The modified territory defined in Section 3, above, provided access to the sea for this group, but this access is at some distance from the broch. However, the voe at Boddam is a good harbour, and is still used by small craft at present. The offshore waters are not particularly rich in fish, and currents are treacherous, a problem shared with all of the Dunrossness brochs.

Type E : Burra Ness. Map 2, iii, 10.

Burra Ness broch is one of the best-surviving examples of broch structure in Shetland (Appendix 1, item 12), and there can be no doubt about its identification.

The area provides a sharp contrast to those already discussed. The present population is nil, only a single ruined croft standing on the site. The nearest inhabited croft is Kirkabister, 1.8 km to the west.

Despite /

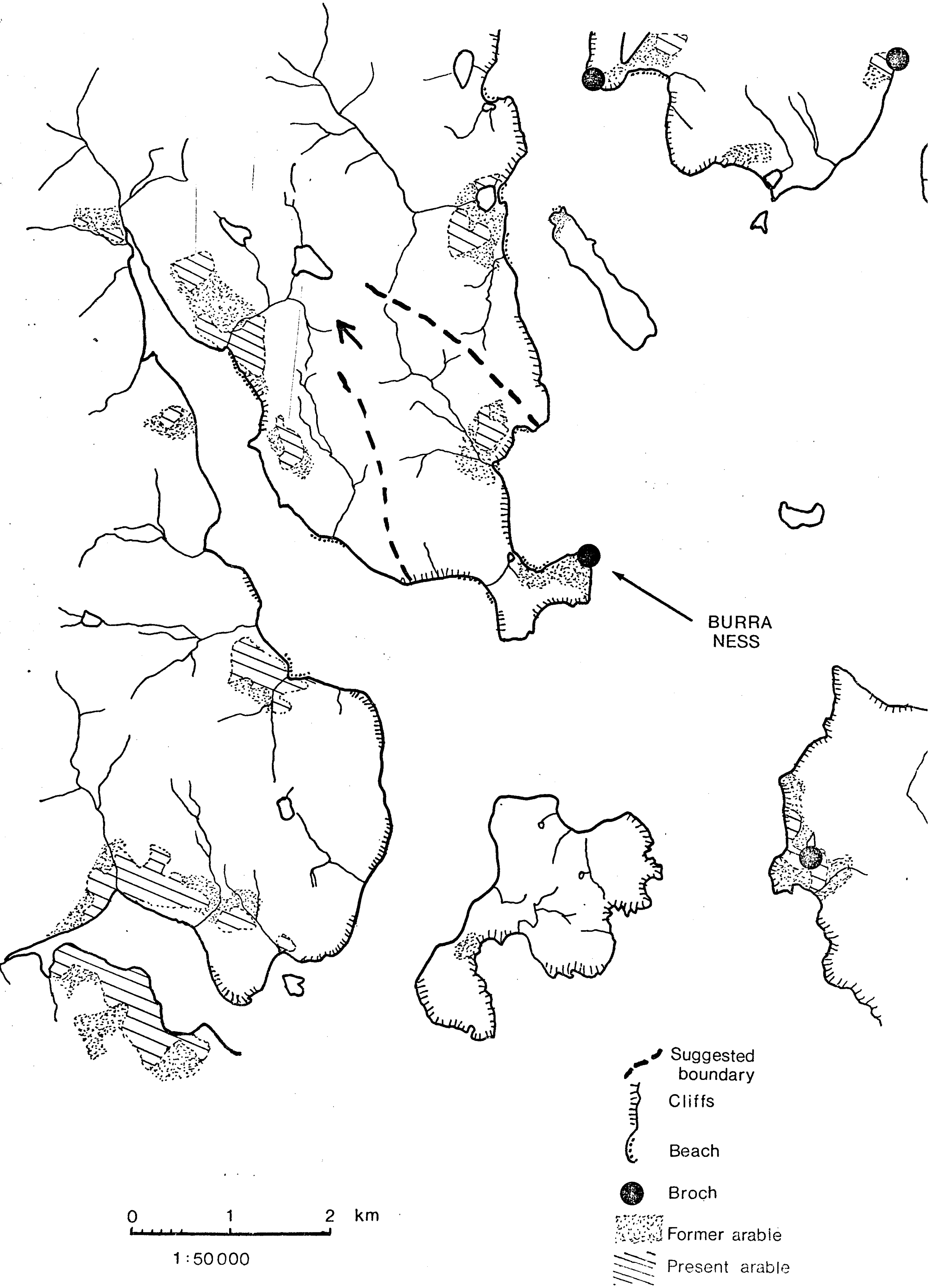
Despite the low, exposed, location of the area, which is a marshy promontory probably formed by the linking of a low island to the shore by shingle bars, attempts have been made to establish cultivation. This is evidenced by the clearance cairns which dot the seaward end of the promontory. The exact date of these cannot as yet be determined, but they are of two dates, one considerably older than the other. Since the only two phases of activity visible are the broch and the Medieval croft, it seems reasonable to suggest that the earlier phase of clearance may, indeed, belong to the broch-period. The arable land has long since been abandoned to pasture, but Low, writing in 1774, records a field of grain, presumably barley, growing right up to the walls of the broch (Low, 1774).

The grazing land is extensive. In addition to the former arable now under grass, there is a broad band of rich, marshy, grazing land on the neck of the promontory, and beyond this is rougher grazing, with heather, on the hill above Kirkabister. It may be that some of this marshland was under water during the Iron Age, but to judge from the lie of the land, this may have been relatively little compared with the total area of land to the west of the broch.

It is, of course, notoriously difficult to assess the carrying-capacity of pastoral farming in human terms, and even stock-levels are hard to estimate. However, rough estimates of one sheep per 0.4 hectares on good grazing and one per 2.0 hectares on moorland, and of one cow per hectare on good land (derived from Fenton, 1978) would suggest a total stock of perhaps 20 cattle and 200 sheep, the latter figure being open to increase.

The possibility of using arable land at North Sandwick has been considered, but this would mean a short boat journey or a difficult and exposed cliff-top walk of some twenty minutes. If this land were used, it would have added materially to the diversity of the economy of this group, but this would not have been essential to their survival.

The extremely exposed location suggests a desire to make access to offshore resources as easy as possible. The difficult waters in the sounds between Yell, Unst, Fetlar and Hascosay would have provided plentiful fish, with occasional seals and cetaceans. The ruined croft may well have been as much a fishing-station as a farm, and the noost, or boat shelter, survives at the head of the beach. A like function may be suggested for the broch.



BURRA NESS
Suggested boundary
Cliffs
Beach
Broch
Former arable
Present arable
0
1
2
km
1:50000

Type F : Aithsetter. Map 2, iii, 11.

The ruined broch of Aithsetter is perched on a cliffed promontory, and is a good example of a "coastal" site with no direct access to the sea below.

The small township of Aithsetter has a potential arable acreage of about 20 hectares, with a few small fields still in use for potatoes and green crops. The soil is heavy, and has required careful drainage to prevent waterlogging. This factor, combined with the exposure of the area to strong onshore winds, makes yields very unpredictable. Plenty of good ploughland is available over the hill behind the site, around Aith Voe, but this is out of site from the broch, and is also beside a possible broch site at Gord.

There is extensive good-quality grazing land around the broch, both along the cliff-tops and further inland, where the better land backs on to the high moorland grazings above Cunningsburgh. (Incidentally the name of Cunningsburgh, literally "the king's stronghold" has yet to be given an explanation, as there is no evidence of any stronghold other than the present site, which is far from the present or the historic core of the area so named.)

Access to the nearby sea is difficult, and the nearest landing place is at Aith, to the north, with another at Okraquoy, to the south. Both are about one kilometre away.

The resources of the area, even allowing for the possible exploitation of seabirds nesting on the cliffs, would not have sufficed to provide more than a scanty living for a group of sixty or seventy, and there could have been little "slack" in the economy to allow for poor years.

Type G : Sae Breck

Type H : Loch of Houlland. Both Map 2, iii, 12.

These two examples, both of which are demonstrably brochs, stand 1.3 kilometres apart on the Esha Ness plateau, which is a peninsula. Sae Breck was excavated by Calder in the 1940's.

The total population of present-day Esha Ness is about forty, and this includes the staff of the lighthouse on the headland. Arable land is presently restricted to small plots which are sheltered by high walls from the frequent gales, which make this one of the most inhospitable, albeit impressive, parts of Shetland. Only around Ure (north-east of Loch of Houlland) and Tangwick to the east is there any moderately extensive /

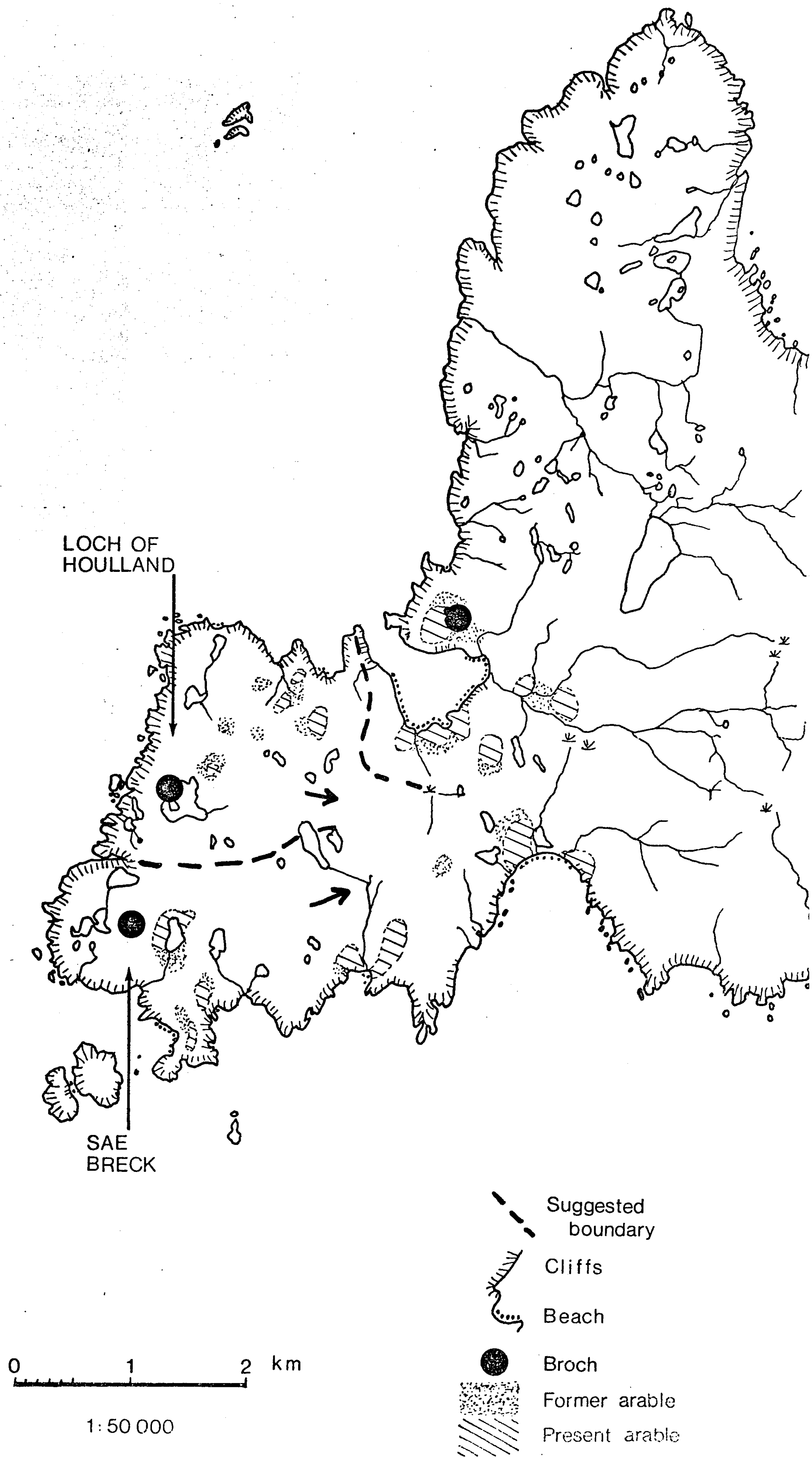
extensive development of arable, and these places are both over one kilometre from either broch, across wet moorland.

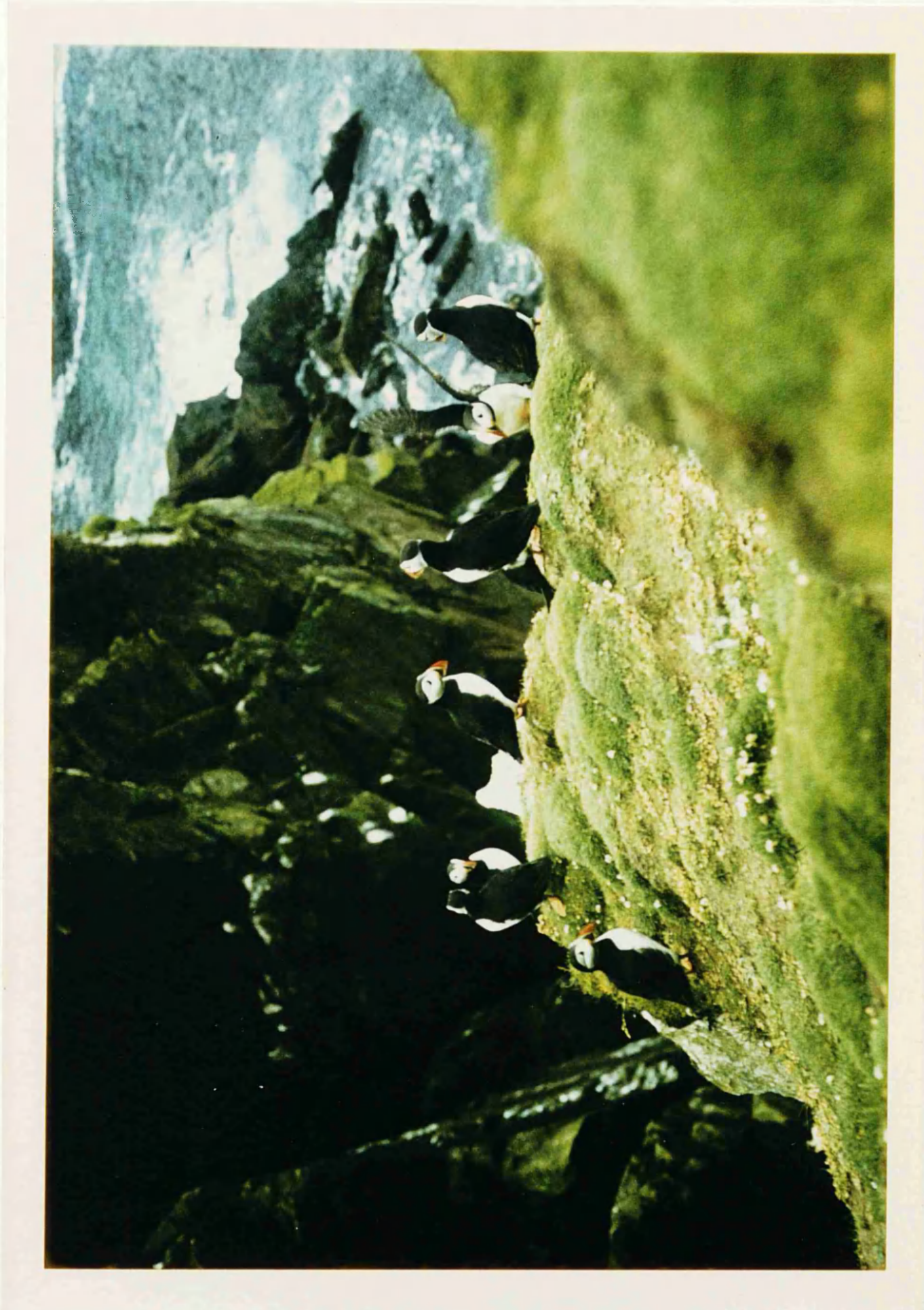
Nearly all of the land is used as grazing for sheep, and there are a few ponies. The sward is poor, salt-stunted grazing along the cliff-tops giving way to boggy heather/sedge moorland inland. Areas of bog and small lochans dot the landscape, and rock is always close to the surface where peat is not developed, or has been cleared. Better grazing is only available at some distance, across the neck of the Breiwick isthmus to the east.

Loch of Houlland broch has no convenient access to the sea, being on a promontory in a loch which stands on the plateau above some of the wildest cliffs in Shetland. The nearest safe landing-place, along with the nearest arable land, is to the north-east, at Dale of Ure. The broch at Sae Breck, although in an even more elevated and exposed position, overlooks the shore at Stenness, where the shingle beach was until this century one of the main landing-places and bases for men engaged on the haaf fishery (long-lining for deep-water fish) in the seas towards Foula, and in St. Magnus Bay (Goodlad, 1971).

One other major resources is available, which would be classified as quasi-marine. Esha Ness has one of the four main seabird breeding centres in the islands (Foula, Hermaness and Bressay/Noss are the other three). A stretch of cliffs some three kilometres in length is populated by all of the major species of sea-fowl, excepting only gannets. The eggs and fledglings from these cliffs were collected until late in the nineteenth century, and provided food, feathers, skins and oil. The Loch of Houlland broch is placed centrally with respect to this resource, and is also close to clifftop pools which are frequented by wildfowl on migration.

Both areas are relatively poor in both agricultural elements of the subsistence economy, but are plentifully supplied with marine and avian resources. Together with nearby Hamnavoe broch (Appendix 1, item 64), it might be possible to envisage the brochs of the Esha Ness area as to some degree analogous to the later fishermen, although on a less commercial basis. Fish and seafowl might have been exchanged for the deficient agricultural produce, in trade with brochs less well-place for the sea, but this clearly cannot be demonstrated. There are instances of whole communities subsisting on little but fish and fowl (Low, 1774), but this seems difficult to accept if the option of exchange was open to the communities involved.


LOCH OF
HOULLAND
SAE
BRECK
Suggested
boundary
Cliffs
Beach
Broch
Former arable
Present arable
0
1
2
km
1:50 000



Quasi-marine resources : The puffins of Herma Ness, which are still tame enough to approach, after two millennia of providing food and oil for humans.


0 5 10 15 km
1 : 500 000
N
MAJOR
SEABIRD
COLONIES

GREY SEALS

Independence, Interdependence or Trade ?

From the above, it will be seen that it is relatively easy to show that a basic subsistence mode of life would have been possible for the people of each broch area, living only upon their local resources, although in some cases this livelihood would have been very close to the limits of viability. The capability of some brochs' supposed economic areas to produce adequate food from the land alone must be acknowledged (Types A? B and D), but in some cases, survival would have been possible only on the edge of starvation (Types F, G and H). In all cases, a succession of poor harvests would have been a major blow, while even a bad lambing season could have had severe repercussions on the areas which were dominantly pastoral. The sea is only a resource when it can be approached, and there are records from later times of whole years in which the sea was seldom calm enough to allow offshore fishing.

Nevertheless, in view of the precarious nature of the agriculture available to many groups, the sea must have played a major role in stabilising the economy, adding additional protein and supplying many raw materials. Indeed, it might be suggested that, notwithstanding the comments of Low (1774) on the position of meat in the Shetland diet, the majority of the animal protein in the Iron Age diet was derived from fish and seabirds, with the domesticated animals as an occasional provider of food and as a stand-by supply. All sources of animal protein are also sources of important by-products, and the production of these may have gone hand in hand with the production of food. If cattle are killed for meat, the hides and bones will be used, while if seabirds are killed for oil and feathers, the flesh may be eaten. To this extent the aspects of food and material resources are interlinked.

Reviewing the data above, and that in Appendix 2, it will be seen that of the seventeen sites returning "poor" on two or all three economic elements, seven are close to substantial seabird nesting-cliffs, a valuable added resource. Such colonies are liable to move and fluctuate in size, but by and large the presence of larger colonies is dictated by the availability of suitable ledges, which in turn depends upon geology, and this has not changed since the Iron Age. Major modern colonies are shown on Map 2, iii, 13.

While each community could, through using its naturally-provided resources to the full, have eked out a living in isolation from all other groups, this would have resulted in considerable inequality, with some areas supporting, or capable of supporting, much larger populations than others. If brochs were the permanent homes of these people, and the circumstantial /

circumstantial evidence seems to favour this, at least for Shetland, there is no evidence in favour of the idea that brochs supported populations which varied substantially in numbers. For this reason, and simply because it is a more plausible proposition, there was probably some means of exchange, whereby the surplus production of one group could be traded for surplusses of other kinds from other areas. Thus every area would have had access to all three elements of the basic broch economy. Two comments must be made, however. Firstly, trade is not the only mechanism for equalising or distributing resources: theft is also very efficient, while the role of gift-exchange may be considered. Secondly, and this may be demonstrable by excavation, although each group could have obtained food from all areas of resource, the groups which possessed areas of great natural potential would have had the choice between less work, to produce tolerable living standards, or the same effort as groups in poorer areas, in which case any mechanisms of trade or exchange would have tended to leave them with a better share of whatever passed for stored wealth in the Middle Iron Age. In other words, while every group could have had a balanced diet, there would still have been rich and poor, and this distinction may have found expression in social or political terms.

Theft doubtless occurred, but the evidence is non-existent: indeed, it is difficult to know what evidence to expect. As discussed in Section One, brochs cannot provide protection against thefts of stock or of reaped sheaves, although they might serve to protect the thieves from subsequent reprisals. The whole concept of small neighbouring groups in total hostility one to another has no real parallel in either history or anthropology. Even if a general air of suspiscion was the case, the necessities of inter-marriage would have introduced some ties, and some groups would have been in a position to gain much by mutual co-operation. Once the idea of such co-operation had become established, it would have spread readily.

The idea of exchange on the basis of a pairing of sites with complementary types of economic area is attractive, as it provides an economical way of achieving an equalisation of natural differentials without the need to hypothesise any very formal societal inter-relation on the large scale. The advantage of such pairings would be to provide a much broader base to the economy, and thus allow more freedom from the vagaries of the environment in its effect of any one food source.

The most attractive of these pairings are:

Aithsetter + Gord	(F + C)
Belmont + Snabrough	(C + F)
Burravoe + Kettlester	(C + B)
Cullingsburgh + Brough + Noss Sound	(A + B + E)
Feal + Houbie	(A + F)
Footabrough + Stoura	(E + B)
Sae Breck + Loch of Houlland + Hamnavoe	(G + H + C)
Skelberry + Dalsetter	(D + F)

Clearly, little more can be done than give an indication of this possibility. Archaeology does not as yet have the methods to demonstrate such contacts. Perhaps detailed matching of artefacts from neighbouring sites might go some way towards demonstrating close contact, but there is no prospect of two neighbouring brochs being excavated with sufficient care and attention to detail.

The possibility of trade is simply a wider-scale expression of the above. There are a number of parts of Shetland where all of the areas have much the same natural attributes, so that a surplus in, say, grain at one would be matched by a surplus in the same item at the others. In this case, exchange would have to be over a longer distance, although its basis in surplus and deficit would remain. Whether such contact would have been regularised enough to be termed trade is doubtful, but there is a critical difference between the mutual help of neighbours, as discussed above, and the more long-range disposal of surplus production, in which partnerships would have been less exclusive.

If such contacts as those considered above did, indeed, take place, they might have provided a vehicle for the establishment of personal and family ties between groups, and for the reception and transmission of new ideas, without the necessity of population movements or the input of innovations from dominant groups (pace Hamilton, 1968).

Preferences ?

To a certain extent, it may be possible to determine the preferences of the groups who originally settled the areas within which brochs were later erected. The eight economic "types" can be ranked in order of frequency, although it must be appreciated that such a ranking may to a certain degree reflect the scarcity of particular types of area, rather than an actual preference : it would be unreasonable to say that Type D areas are not popular, because there is only one Type D area in Shetland, and that one has a broch in it. However, in the case of each of the other economic types, there are numbers of possible broch economic areas in the island which, while apparently suitable, do not have brochs. Thus such a ranking can be used as a basis, although Type D must be omitted, as it has a frequency determined by topography rather than by choice.

Order of frequency	Economic type	Arable	Pastoral	Marine	Number of areas
1	A	+	+	+	21
2	E	-	+	+	18
3	B	+	+	-	10
4	C	+	-	+	9
5	F	-	+	-	8
6	G	-	-	+	6
7	H	-	-	-	2

This table elegantly supports the validity of the three-element approach, in that the types are ranked, in total number of good points, in the order 3, 2, 2, 2, 1, 1, 0. Further inspection of the table allows a ranking of the elements in individual order of preference, thus:

Let P = pastoral, A = arable, and M = marine (positive scores),

then:

$$E = P + M$$
$$B = A + P$$
$$C = A + M \qquad \text{and since } E > B > C$$

it follows that :

$$(P + M) > (A + P) > (A + M)$$
$$\Rightarrow (P + M) > (A + P) \text{ and } (A + P) > (A + M)$$
$$\Rightarrow M > A \text{ and } P > M$$
$$\Rightarrow P > M > A.$$

This statement is the formal expression of the Venn diagram on page 73, above, and is confirmed by the order of frequency of the groups which have only one good resource, F? G? D. That is, the poorly-endowed areas also have their favourable elements ranked in descending order: pastoral, marine, arable.

The classification of areas into the eight types was made before the above symbolic analysis, and care was taken in the analysis to check that there were a good number of unused areas of each type, so that frequency was not dictated by natural constraints.

While it would be rash to interpret the above in dogmatic terms, a few observations can be made on the results, which in general confirm the intuitive impressions gained during fieldwork. Naturally enough, the first settlers would have looked for the areas which have good potential resources of all three types. If they failed to find such areas, or to find such areas unoccupied, they might be content with good potential on two of the three resource-types, and dispense to some extent with the third. In practice arable land seems to be most readily dispensed-with, and pastoral land least readily. It must be remembered that most areas ranked "poor" on either arable or pastoral do, in fact, have some potential in these respects, even if that potential is not great.

The theoretical result makes admirable sense in the light of the possible logistic arrangements of exchange. Arable production, particularly grain, is readily-stored, and is comparatively easy to transport. Animal protein, while it can transport itself, is harder to keep, and must be used within a reasonable time after killing. An ideal combination would be to transport grain on the backs of cattle ! Marine products will keep for considerable lengths of time, but are harder to transport, being very bulky for their weight and food-content. Therefore, it might be expected that grain would be moved more frequently than cattle or fish, and may have been stored, perhaps even in broch galleries (but see Section 1, Chapter IV).

Finally, there is good historical precedent in support of such a pattern of trade in later Shetland, with grain being the main food-supply to be moved on any scale, chiefly going to the areas which were concentrating upon fishery. In the Medieval recorded situation, the pattern was more complex, in that money enters into the account, and fish was sold to pay for grain. Perhaps barter might be more appropriate for this area at the date in question.

The Broch Period Economy : Summary.

The overall delineation of the middle Iron Age economy in Shetland has been materially aided by the methods of analysis introduced above, and a sharper resolution has been afforded to the rather vague general statements which have been made on this subject to date (Hamilton 1956, 1968, for example). The suggested system is one of mixed farming, with a rather variable arable component (largely grain, with perhaps some vegetables such as the Celtic bean, although evidence for this is absent), an essential pastoral element fulfilling the roles of meat-provider, milk-producer, source of hides and bone, and emergency food reserve, and a major, though as yet unquantifiable, marine input.

The general characteristics of variability between the potential economies of different areas can be considered as conducive to exchange, with surplus grain, hides, cheese/butter (?), and dried fish changing hands, depending upon the character of each area. By such means the maximum of variety and stability could be introduced into the diet of the inhabitants of the islands as a whole. The best evidence for such exchange remains, however, the illogicality of not having such a process under the prevailing circumstances. The detailed excavations have not yet been carried out which would enable the above hypotheses to be tested, if indeed the techniques are yet available.

Allowing for the growth of commercialism, it is remarkable how similar the suggested economy is to that of early nineteenth-century times. Perhaps, when reduced to dependence upon only what the islands can provide, this is the only way of life open to Shetlanders. Only the wider economic linkages of modern times have allowed the natives of the region to adopt the more varied eating habits of the rest of Britain.

Against this idea of "the only possible" way of life can be set the preliminary findings of a similar study, by P. Winham, into the location of the Neolithic/Bronze Age house sites noted by Calder (1956) and at present under study by Whittle (1979). Winham's findings, as yet unpublished, suggest that settlement of this period is consistently further inland, and using the terminology of the above analysis,

Arable > Pastoral > Marine.

Sites tend to be on hill shoulders, overlooking areas which would have been capable of arable production, but are now largely impoverished and covered by peat, through over-use of the cropland without due care for the soil. Thus another combination of the basic elements of resource available is possible, so the particular combination of emphasis identified for the broch-period is not entirely determined by the environment.

Thus the economic system defined above as pertaining to the broch period seems to be the first full manifestation of the system which has continued, disturbed only in detail by the Norse immigrations, up to the end of last century, and which still survives as a background to the changes underway today.

Part 6 : The Population of Shetland in the Middle Iron Age.

It is now possible to return to the question of the total population of broch-period Shetland. Cunliffe (1978) has suggested methods of quantifying population carrying capacity of areas as a primary research priority, and indeed has singled-out Shetland for especial mention in this context. There are two methods by which such an estimate can be approached. One, exemplified by Heisler's 1978 quantification of the carrying-capacity of Iron Age Caithness, starts from total acreages for arable land, good pasture land and rough grazing, and an estimate of marine productivity. It proceeds from this to a calculation of the total number of calories available, and thus can give a figure for the theoretical maximum number of inhabitants. From this, simple division will give the number of persons per broch, always assuming contemporaneity. The particular results for this approach in Caithness were that the population would have been 213 per broch (Heisler 1978, and pers. comm.). The second method is that adopted here, in which a start is made with the individual community. The aggregate of different individual groups is then built up to provide the overall result.

For several reasons, the second can be preferred over the first. This approach seems far more likely to produce a really meaningful figure for population, as it must be noted that population is always less than total carrying capacity, by the very nature of that latter value.

1) The effects of variability in the landscape and climate, which will lead to differences in local economies, can be considered from the start.
2) Flaws in reasoning are more easily identified and excised when reference can be made to recognisable areas, rather than the rather abstract overall situation.
3) Overall data tends to be too crude to produce accurate results, and the end product of using such data is simply a figure, with no supporting detail.
4) People do not appear to operate as individuals, in the sense that we rarely have archaeological evidence for human activities which are not those of groups.

The last comment is the critical reason that the approach used here is favoured. The overall approach only works successfully if people can be assumed to be totally free agents, and able to move anywhere in the region to exploit resources. This is what the averaging process implies. Only the individually-constructed estimate, as used here, takes account of the /

of the fact that the community is the basic unit of society. The broch can only exist because of the community, and the centring of each area upon the broch means that the areas of land furthest from the broch are under-exploited, or used inefficiently. In short, the overall approach to carrying capacity, via a model based upon totals and averages, fails because it treats the population as being spread thinly and evenly over the countryside, when in fact this has never been the case. A far more useful figure is some sort of societal carrying-capacity, defined as the number of groups which could have existed, practising a given way of life, at any one time in the region. Taking the broch as the indicator of the existence of a group, this would give a figure of 75 groups for Shetland, which allowing for the incompleteness of data, might mean an Iron Age total of about 100 communities.

This divorces the concept of capacity from that of population. Population need not necessarily approach capacity, and indeed there is ample evidence that it rarely does so (Higgs, 1975, for examples). It is more meaningful to define population as the product of the number of groups and the average size of these groups, or even better, the total of individual group sizes, if these can be obtained. The minimum number associated with a broch must be capable of organising the building of the structure, carrying on a viable way of life, and defending their possessions and lives when necessary. The maximum will be the carrying capacity of the area. Thus carrying capacity provides only the upper extreme of the range of possibilities. In reality, carrying capacity will not be reached, because, due to the inefficiency inherent in all human land use, population pressure will become intolerable before the theoretical capacity of the land is exhausted. The chief cause of this inefficiency is the existence of agglomerations of people — communities.

To illustrate this, with an example from the present study, if the minimum population of each broch is 40, allowing 25 able-bodied adults, then the population of Shetland would be about 4000. With a likely maximum number per broch of, on average, 75 (based upon the broch's capacity), the population would be 7500. The theoretical maximum, or the carrying capacity, is no less than 30 000, based on the calculations used by Heisler (1978) for Caithness, with Shetland data substituted. This would mean either 300 persons per broch or 225 missing sites. Both possibilities seem unlikely.

Such a total population has only been approached through the operation of external, commercial, forces, with the growth of fishing for the outside market, and there is no reason to suppose that such forces could have operated in the Iron Age.

Therefore, it is submitted that the population figures achieved by the use of the carrying-capacity model as normally applied are liable to gross over-estimation, deriving as they do from assumptions about the way in which people operate and which are not relavent to the real world. The archaeologist needs to know what might have been, given all available data. He has no need to know what might have happened in an ideal situation when known factors, which would have militated against the ideal, are ignored.

Part 7 : Summary of Results of Meso-Scale Analysis.

The Shetland broch can be seen as the equivalent, both in economy and population, to a small crofting township. The fact that the areas ascribed to each broch would in no case have failed to be capable of supporting a group of this size is not conclusive proof, but points towards the possibility of contemporaneity. The fact that rather higher population figures are suggested by late Medieval data can be explained partly by the increased impact of commercialism on society, and partly by the fact that Medieval settlement, freed from the need for communal defence, was able to spread more evenly across the land, and thus make use of small areas of land which were not viable under the conditions thought to have prevailed while the brochs were in use.

In fact, the population-nucleation represented by the brochs is of a higher degree by far than any other for which we have evidence, either before or after, although in the immediate post-broch period there seems, from the clusters of houses around some brochs, to have been a little reluctance to leave the larger community. If this is indeed the case, and broch-period Shetland has a highly-nucleated pattern of settlement, it may be remarked that in general highly-nucleated patterns tend towards very inefficient use of land (Chisholm, 1962). In Shetland, this effect seems to have been severe, with only areas large enough to support a broch-group being utilised. This would mean that a substantial number of areas, capable of supporting a few people each, stood unoccupied. This emptiness of the interstices between the broch areas is attested by the almost complete absence of any evidence for smaller-scale settlement sites at this period.

The classification of broch economic areas into tentative categories on the basis of their endowment with natural resource-potential has opened the way to a discussion of the possible relationships which might develop within a society where numerous groups with differing economic strengths existed. Indeed, some idea has been gained of the Iron Age "ideal home". It has already been shown (Section 1) that all brochs were capable of being permanent habitations, and the results of the present study have shown that some of these habitations may have been farmhouses, while others were nearer in affinity to fishing-stations.

Such suggestions as the above will require reinforcement in the form of excavated evidence, but it remains at present difficult to envisage techniques which will enable acceptance, modification, or rejection, of most of the above inferences. The main immediate contribution /

contribution which excavation can make to economic reconstruction is the assessment of the remains of fauna and flora associated with the brochs, to determine the importance of the different sources of protein. In particular, it might be possible to distinguish between a low-meat diet and a high-meat diet, through establishment of the ages of animals killed for food. The question of grain production and consumption will remain harder to resolve, in the absence of storage places (unless this is one of the many functions of the broch). The potential of the land around the broch will probably remain the best guide.

What seems certain is that, because economies are less-easily excavated than defences, the obvious role of the broch as a defence has been consistently overstated at the expense of the less-obvious role of the broch as a centre for an everyday farming life. The work of Sir Lindsay Scott (1947, 1948) forms an honourable exception to this tendency. Each broch indicates the former existence of an Iron Age community, and in the absence of techniques capable of quantifying the composition of the Iron Age economy of Shetland through excavation, it is respectfully submitted that fieldwork environmental data, recorded at the level of detail of individual areas, provides the best means of achieving such a quantification.

Chapter IV

Micro-Scale Considerations

Having examined the wider regional setting and the details of the local environment, and having achieved some progress in the definition both of societal inter-relationships and of economic activities, it remains to examine the smallest scale at which fieldwork data can be used to further the reconstruction of the fabric of the past.

As a working definition, the micro-scale has been taken to mean the detailed setting of the broch within the economic area, the latter concept having been defined in the last chapter. It is only on this very localised scale that the actual nature of the structure has any great significance, apart from in its aspects of group-size and the possibilities of an integrated defence system, discussed in Chapters 3 and 2 respectively. Up until this stage, the discussions have centred around the activities of a group of people, or a number of groups, of a certain order of size. It follows from this that only at the micro-scale can we be absolutely certain that it is the actions and decisions of the Iron Age people which are under consideration: all of the data discussed at the macro and meso scales might relate to Neolithic or Bronze Age arrival and settlement. Nevertheless, in the middle Iron Age, conditions of settlement either existed, or changed, so that the building of brochs became possible and desirable for all of the groups in which society was organised at that time. And when the decision to build a broch was made, a site had to be chosen, from within the area which was controlled or owned by each group. It should be possible, by searching for trends in the attributes of sites, not only to isolate the normal characteristics of broch sites, but to use these to make inferences upon what appear to be the preferred characteristics, and from these, what the intended function of teh broch was.

Fortunately, the meaning of the term "site" is not quite so hotly debated as that of "economic area" or "territory", and can generally be taken as understood, signifying those aspects about the particular spot chosen which make it distinctive and allow it to be distinguished from the surrounding landscape. This ease of practical definition is fortunate indeed, as formal classification of the individual units of geomorphology which compose the landscape is extraordinarily difficult (Tricart and Cailleux, 1956).

An apparently simple subject can be made over-complex by too close attention, for example, if a broch is on top of a knoll, what is the "site": is it the top of the knoll, or the whole knoll, or the flat area around plus the knoll....? In situations such as this, it seems advisable to cut the Gordian knot and take up the "site is a site is a site" principle. This approach is doubly attractive, for not only does it avoid definitional semantics, but it provides a working concept. A site does not have to be defined for its effects to be measured, any more than an army has to be counted to know that it is an army.

The effects of a site are measured by their influence upon the various human activities which take place centred upon the structure which stands upon the site. Thus even if we cannot define precisely what the site is, we can measure its effect on any activity by comparing the actual case with the case if the structure had been located elsewhere in the area. At the micro-scale, the chief concern will be with two particular activities in which we can safely infer Iron Age groups had a vested interest. The broch was 1) a defensive structure, and 2) a centre for daily life. The nature of the defensive tactics employed have been discussed in Section 1, while the nature of the daily life has been outlined in Chapter III of this Section.

It was hoped that by examining the siting of brochs in detail it might be possible to compare the relative importance placed upon each of these two functions, and thus to discover whether the site was dictated primarily by the need for easy defence or by the need for a position which did not interfere with daily life to an undue extent. For this to be possible, it is essential that the achievement of each of these functions should be spatially incompatible with the achievement of the other. This assumption is basic to the following discussions, for if the best defensive site were also the most convenient for normal economic activities, spatial differentiation would not exist, and analysis could not indicate which was the primary siting constraint.

The approach taken is to define what is meant by siting, and to outline two models, one for defensive location and one for location according to the dictates of convenience. The analysis will attempt to measure the extent to which each model is reflected in reality, and by this means determine the importance of each model in explaining the observed siting characteristics of Shetland brochs.

Siting can be defined as those details of the setting of the broch which are likely to have influenced the builders in their choice of where to construct the building. The main factors which might be expected to have been influential include the position of the site relative to the parts of the economic area in which most of the daily activity took place, the topography of the site relative to the immediate surroundings, and the extent to which the area around could be clearly seen from the site. Minor considerations might have been availability of building materials, aspect, and the drainage of the proposed site. It is a possibility, but difficult to assess, that brochs may in some cases have been built on a particular spot because it was near to where people were already living. In the case of Shetland, this is difficult to decide, as the only excavated sites which have earlier dwellings are in "unusual" positions, which might be chosen at any time. Thus Clickhimin, on its small islet, might well have been sited there even if there was no earlier settlement, because of the character of the site. At Jarlshof, so far as can be known from the excavated evidence, the site was deserted immediately prior to the broch phase, so that in effect the site was re-chosen for the broch. The most that can be done is to analyse the factors of siting as if they were to be considered afresh before the broch was sited, bearing in mind the above comments. The end result can then be assessed to decide how valid this assumption appears to be.

While it would be possible to analyse each of the factors separately and in combinations, as was done in Chapter II, it was decided to approach the micro-scale from the viewpoint of function, since the main aim of investigation is to determine which of the suggested functions for brochs seems to have had most influence upon their siting.

Data-collection

Following upon this pragmatic treatment, most of the data gathered concerning siting will be expressed in ways which relate to the various ways in which living at a particular spot would have affected the different activities which are attributed to the broch-dwellers. However, much of the data, as gathered in the field, concerned physical attributes of the site. Basically, all siting data can be split into two classes:

i) Physical characteristics of the site

ii) Likely effects of the site.

All of the data was originally collected in the form of class i).

Type i) data includes aspect, drainage, water-supply, relationship to arable land, relationship to shore, geomorphological unit, maximum and minimum approach slopes and outward vantage. This data, in its crude form, was gathered in the field, but the attempts to analyse this were not particularly rewarding, and are not presented here for reasons of space and irrelevance. The general results of correlation were highly predictable, along the lines of "hilltop sites have good outward vantage in all directions, are well-drained, have no particular aspect and are more than average distances away from fresh water".

This data was therefore transformed into a series of categories based upon the criterion, "Is the site good for activity x ?" Usually one of three responses was possible:

a) It is the best site in the area for this activity.
b) It is one of the best sites, but there are others which would have done equally well.
c) It is not one of the best sites, and there is at least one other possible site which is clearly better for this activity.

Although these responses are very simple to elicit, and can be easily analysed, it is essential that the activities to be considered should be carefully thought out, and their siting requirements followed through. The two main functions considered here are defence and farming. Defence is envisaged as following the patterns outlined in Section 1, Chapters IV and VII, and subsistence farming as on the lines proposed in Chapter III of this Section. Because these activities were only themselves defined as part of the process of post-fieldwork analysis, it had not been decided to gather data in class ii) form in the field. Where such data could not be constructed from the class i) data which was collected, together with site photographs taken at this time, it was checked during the 1979 field season's programme.

Assumptions

Before presenting the analysis, it as, as always, essential to consider the assumptions underlying and conditioning the process of data-collection and analysis.

Type i) data is, so far as can be, objective, and is not governed by any major mental preconceptions. It is, of course, open to the usual range of operator errors, chiefly centred upon the difficulties of field work, particularly in environments as difficult as Shetland's can be in adverse weather conditions. As outlined in Chapter II of this Section, the only real safeguard against such error is care. Another source of error which can enter at this stage is the failure to consider /

consider a relevant factor. This, again, can only be prevented by circumspection in the preparation of plans for fieldwork.

Type ii) data, in sharp contrast, depends upon a single central assumption. This is, that for any particular activity, the best site available will be chosen. This is the underlying assumption of all location theory. To some extent, it will be expected that the best site for one activity will not be the best for another, so that in the final choice of site will be reflected a weighted product of the interplay of the different functional requirements of the site.

In the assessment of "best" there are many pitfalls. The most convenient site need not be the most efficient, and even worse, there may be non-rational judgements involved. A good example of the latter case is the reputed Norse practice of casting the seat-pillars into the surf, and settling where they came to land. Nevertheless, it is truly remarkable how often the seat pillars found the best land (Alcock, pers. comm.).

This basic assumption, that prehistoric man was logical and made decisions regarding location and siting in a strictly rational fashion, does not bear close examination. Given the apparent illogicality of the distribution of additional defensive outworks around Shetland brochs (Section 1, Chapter VII), and bearing in mind the extent of the influence of the perceived and interpreted supernatural to be found in the earliest legends which survive elsewhere in the Atlantic fringe (Jackson, 1964), it would not be at all remarkable if location and siting were even more illogical than in fact they appear to be.

The basis for analysis

The basis of the analysis is that each activity should require a specific type of site and that this type of site should not be the same as that required by any other activity. Without this incompatibility of requirements, no progress can be made.

Clearly, there are some activities which could be carried out no matter where the broch was sited (such as eating or sleeping), some which could be carried out better, or more easily, at some sites than at others (farming, defence, are the main cases, fishing might be another), and some activities which could only be carried out at one specific site in each area. Examples of the last category seem hard to find in Shetland, but might include siting to achieve intervisibility with another broch, or to achieve a maximum of concealment from a particular direction (the latter may obtain in Shetland in a few cases, see below).

Most activities are of the second type, where there will be a

whole /

whole range of possible sites, with some better than others. However, if the demands of two activities are in conflict, either the requirements of one will over-ride those of the other, or a compromise site will be chosen, which while not ideal for either activity, makes neither too difficult.

The technique to be used for analysis is another variant of the chi-squared test. Because of the difficulties found in formulating a null hypothesis in each case, it is impossible to measure how likely it is that a given pattern of location relative to one activity is to have occurred by chance. This is because we are analysing data which includes a class of "not the best site", such sites must be almost infinite in number, and therefore a set of "expected" values cannot be calculated, and the chi-squared test cannot be used. However, since the data for each postulated activity is available in the same format, in frequency-distributions for three classes, it is possible to use the chi-squared test to compare the extent to which two different activities are favoured by the observed pattern of siting. The null hypothesis is based upon a situation in which neither of the two activities is more favoured by the site, and takes the form,

"The frequency distribution of sites among the three classes for activity <u>a</u> is the same as that for activity <u>b</u>."

Rejection of the null hypothesis through the chi-squared test will mean that there is a strong spatial difference in the type of site required by each activity. Generally, it can be shown that this can be quantified by examination of the data, and that the relative importance of each activity as an influence upon siting can be assessed. Care must be taken with this approach, to avoid circularity of argument, as increasing refinement of a model based only upon data will result in a model which is simply a picture of reality, "the only model which explains everything perfectly".

Despite the above strictures, it can be shown that significant order in siting constraints can be isolated, measured and described by the same type of very basic statistical tool which has served throughout this study.

A highly defensive site : Culswick, perched on a hill with steep cliffs on one side, a loch in front, and open, exposed approaches on the remaining sides.

Shetlands. Even a slight knoll will serve to slow a determined rush, and it does seem to have been a primary desire of the broch-builders to slow down or halt any attempt to reach the wall-foot rapidly, and in force. The very nature of the defences of brochs, both essential and additional, suggests that the main fear of the defenders is that rapid access will be afforded the attackers to the wall-foot. This is evidenced by the design if the outer ramparts, where these exist, and also by the positioning of broch entrances (see below) in awkward points of the circumference, so that it is difficult to enter the broch with a rush. So the chief part of the defensive assistance offered by the chosen site would have been that it made approach to the broch difficult.

It might be possible to attempt to quantify the geomorphological nature of each site and its surroundings, by analysis of the area into units, followed by the digitation of these and the establishment of computer-aided weighted classifications. This level of detail is, fortunately, somewhat superfluous to the present purpose, since all that is necessary is to know whether the broch is sited on the best defensive position available within each area.

A simple normative model was used, with three levels of defensive suitability, defined as follows:

1) Best site: no other site within the area presents such an obstacle, or series of obstacles, to a rush attack on foot. Or, if another site is equally good on this count: no other site has better outward visibility over the likely approaches.
2) Equally good site: one or more other sites is essentially just as suited to defence, and none is particularly outstanding as regards vantage.
3) Not the best site: another site within the area has better natural defensibility, or failing this, another site of equal capacity for defence has better outward visibility.

The assessment of difficulty of access is easily achieved by the application of experimental techniques: the best way of establishing the defensive capacity of a broch, in terms of the extent to which it is on a site which impedes easy access, is to attempt to reach the ruins of the broch as quickly as possible, starting from a set distance away (50 metres was found to be a good starting distance). Vantage is similarly amenable to measurement in the field, particular attention being paid to "dead ground", a major disadvantage to a site which is to support a structure which depends upon early warning of impending attack (see Section I, Chapters IV and VII).

The figures for the 75 Shetland brochs are as follows:

Best site	47
Equally good site	24
Not the best site	4
Total sites	75

Although this table superficially resembles some of those displayed in earlier chapters, the data here is not amenable to treatment by chi-squared techniques, for methodological reasons. The chi-squared test depends upon comparison of the observed to the expected distribution of sites among classes. However, there is no way of obtaining an expected set of values, because while within each area there will be one "best" site, or a number of "equally good" sites, there will be an infinite number of "not best" sites. So if broch-builders had paid no attention to the defensibility of the site, the preponderance of brochs would be on sites which are "not the best", but there is no way of quantifying just how great this preponderance would be. Theoretically, there would be no brochs at all on the best site in their area, but the chi-squared test cannot be used where any class equals 0 in the expected value set.

Visual inspection of the results is the only alternative, although comparative methods can be used against other functions (see below). here the pattern is clear-cut:within the confines of the broch economic area, the broch-builders seem to have sought the best naturally-defended site available to them.

Convenience for daily life was treated in approximately similar terms, but it was possible to define the different classes in slightly more formality.

A purely topological approach was adopted initially, to consider the relationship of each site to its core area (normally the main arable tract). This was after the failure of analysis based upon geomorphology (data in Appendix 2, item 59). This geomorphological approach is noted here because it did involve the classification of each site in basic terms relative to the landscape, and this classification is presented here in total value form, for comparison with other areas of Scotland. The attribution of each site to its class is contained in Appendix 2, item 59.

Each site was given a code on one of three counts:

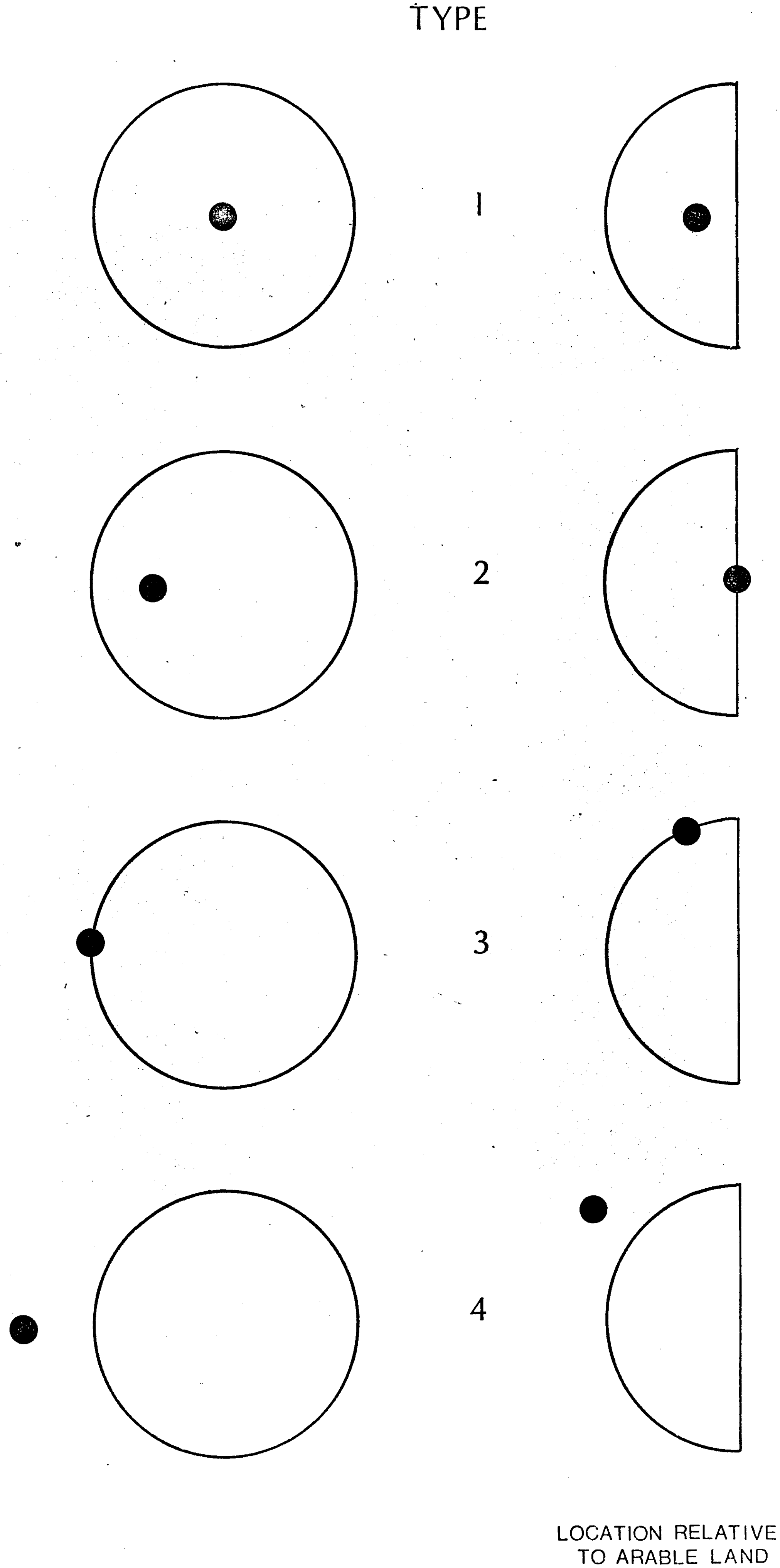
		Total sites
a) Position relative to the coast		
1) inland		16
2) lochside		10
3) coastal		49
		75
b) Local relief category		
1) low relief amplitude	non-coastal	5
2) high relief amplitude	non-coastal	26
3) shelving shores	coastal	31
4) cliffed shores	coastal	13
		75
c) Position in local landscape		
1) hilltop		8
2) spur		6
3) hillside step or bench		10
4) islet		13
5) promontory tip		15
6) promontory base		8
7) no distinguishing features		15
		75

The above table has certain interesting features, the most significant of which is the fact that, in part c), it will be seen that the majority of brochs stand on sites which are distinctive points in the landscape, and that very few brochs stand in the open fields, in unremarkable sites. To some extent this may be due to the relatively wide variety of the Shetland landscape, but it seems more likely to be a result of the fact that the best defensive sites are on "difficult" points.

However, as within any of the classes above there are many shades of convenience or inconvenience for daily life (there being steep hills and gentle hills, islets far offshore and almost connected to the shore, and so forth), it was decided to attempt a different classification.

The relationship of the site to the arable core of each economic area was classified relative to the model illustrated in Diagram 2, iv, 1. The classes are:

1	Central	21 sites
2	Most convenient periphery	21 sites
3	Periphery (other)	15 sites
4	Outwith arable	18 sites
		75 sites


TYPE
1
2
3
4
LOCATION RELATIVE
TO ARABLE LAND

A highly convenient site : Burraland, in Walls, sits beside the loch, surrounded by arable and former arable land.

This fairly even spread was not particularly revealing. There were numerous cases which required qualification, for instance Clickhimin (16), which is, strictly speaking, central to its arable area, but is in fact in a very awkward position for regular access, as it is sited on an islet which is separated from the surrounding arable by a marshy area on one side, and a loch on the others. Because of this, and many other similar situations, the rigid topological classification was relaxed, and a modified system evolved, termed "convenience status", and comparable in broad outline to "defensive status" above. This is detailed in Appendix 2, item 66.

Classes were defined thus:

Convenience status	Number of sites	Topological class
1	26	1, 2 unless awkward to reach
2	21	3 + difficult 1 & 2
3	28	4 + difficult 3

Not only can convenience status be compared visually to defensive status, but it can be compared statistically. This is because the two classifications are both of the same structure, in terms of classes. This makes it possible to compare the two by the chi-squared test.

The first stage is a correlation table:

		Defensive status 1	2	3	Total
Convenience status	1	15	8	3	26
	2	8	12	1	21
	3	23	5	0	28
		46	25	4	75

By setting up "expected" tables for various hypotheses, these can be tested by the chi-squared method for likelihood. It was decided to examine four hypotheses concerning the relative importance of the two types of status of sites. The four hypotheses are:

A Neither defence nor convenience are considered during siting.

B Defence is considered, convenience is not.

C Convenience is considered, defence is not.

D Both defence and convenience are considered, and are equally important.

Taking each of these as a hypothesis, it is possible to construct tables which /

which represent what would be expected if the 75 brochs were sited according to the assumptions of each hypothesis. For the sake of ease of calculation, indifference is taking as producing a ratio between classes of 2 : 2 : 2, and preference 3 : 2 : 1. The main reason for these ratios is to avoid the problem of having 0 as an expected value, which makes the chi-squared test invalid. The expected tables for each hypothesis are as follows.

Hypothesis A

	1	2	3	Total
1	8.33	8.33	8.33	25
2	8.33	8.33	8.33	25
3	8.33	8.33	8.33	25
Total	25	25	25	75

Hypothesis B

	1	2	3	Total
1	12.5	8.33	4.17	25
2	12.5	8.33	4.17	25
3	12.5	8.33	4.17	25
Total	37.5	25	12.5	75

Hypothesis C

	1	2	3	Total
1	12.5	12.5	12.5	37.5
2	8.33	8.33	8.33	25
3	4.17	4.17	4.17	12.5
Total	25	25	25	75

Hypothesis D

	1	2	3	Total
1	12.5	10.42	8.33	31.25
2	10.42	8.33	6.25	25
3	8.33	6.25	4.17	18.75
Total	31.25	25	18.75	75

Notes : a) Figures are rounded to the second decimal place.

b) Defensive status classes run along the top of each table, convenience status classes down the side.

c) Degrees of freedom for each table = 8.

The chi-squared test can then be used to assess the significance of the variations between the observed distribution and the four hypothetical distributions. The chi-squared statistics are:

Hypothesis A	55.72
Hypothesis B	20.80
Hypothesis C	106.88
Hypothesis D	41.29

Here, unlike the earlier tests, the aim is to match the model to reality, rather than to prove a significant difference. So the desired model is that which shows the least divergence from reality, and that is Hypothesis B. Hypothesis C is the least likely, on the basis of the above.

This approach can be carried further, and by adjustment of the ratios of the different classes one to the other, but this falls foul of the fact that the ideal set of ratios will, of course, mirror the actual data. For the models above to be of any use, they must retain a significant measure of generality.

The meaning of the above discussion is, in simple terms, that the actual pattern of siting, relative to considerations of defence and convenience for daily life, seems closest to that which would be found if defence were a locational consideration, but convenience were not.

However, limits to this observation exist. Firstly, since each site's status for defence and convenience are defined relative to the "broch economic area", the concepts are already limited. A more meaningful comparison between the two concepts might be possible if it could be shown that there are, in fact, limits beyond which one or the other cannot be dispensed with. This is intuitively known to be correct: a broch which cannot be defended would be of little use (if it stood below a cliff, for example), while a broch which was so inaccessible that even its defenders could not reach it would have a similarly low value. Between these rather absurd extremes, there should be identifiable limits to the dominance of one consideration over the other.

Twelve sites exist where defence appears to be outweighed by convenience :

Clumlie	Cullinsburgh	Brough (Bressay)
Gossabrough	Housabister	Jarlshof
Levenwick	Virkie	Brough Lodge
Southvoe	Gord	Hamnavoe.

As in most of these cases the broch is still on one of the best defensive sites available, it is necessary further to limit the discussion, to the sites which are definitely <u>not</u> the best defensive site available. These are /

are four in number: Clumlie Housabister
Southvoe Gord.

In each case the better defensive site, which was available but not used, is much farther away from the arable land than is the site chosen (Clumlie 500 metres, Housabister 300 metres, Southvoe 500 metres, Gord 450 metres). In each case the alternative is farther from the landing beach than the site used. For practical purposes, these can be combined to suggest that the focus of daily life would have been the head of the landing-beach, below the arable land. Thus the point at which a poorer defensive site is chosen seems to be when the choice of a better site would require the broch users to make an additional journey of some five minutes hard walking to go from the focus of their activity. Since all of the brochs which are near the coast seem to lie within about five minutes'walk of it, there would seem to be a point about ten minutes' walk from the coast, at which the whole object of building a broch seems to be defeated.

This can be interpreted in two fashions. The threat against which brochs are a response may have been considered to be such that putting a broch five minutes farther away from where people would most likely be would be sufficient to render the broch useless. That is, the fear was of a sudden attack, with little warning, and the defence had to be near to the people as they went about their normal life. Alternatively, it might be that attack was perceived to be a fairly unlikely event, in which case five minutes extra effort on each trip was not considered worthwhile for the greater degree of security which the better site would offer if, by any chance, there should be an attack. It is, quite simply, impossible to decide between the two explanations. The mere fact that brochs were built at all might perhaps favour the former rather than the latter.

The concept of the limited potency of siting requirements can be pursued further. The basic premise is that for any activity there is a limit, be it distance, or type of site, which causes so much difficulty in the exercise of that activity that if the site is chosen, the particular activity is precluded. Thus there will be certain types of site and location in which the discovery of an archaeological monument of a particular type would be an indication that preconceptions concerning the functions of that type of monument might require revision.

Often /

Often, this type of limitation is not specifically recorded in this form; for example Fergusson's observation that the siting of many brochs was such as to make the rapid entrance of domesticated animals a practical impossibility is in fact a recognition of the fact that there was a type of site which lay beyond the extreme limit of viability for this function (Fergusson, 1879).

More generally, the major constraint must be that recognised above, the desire to make the normal process of food-production as effortless as possible. The extent to which another siting requirement creates a pattern of location which is not optimal for food-production is a good measure of the importance accorded to that other factor.

There are, then, limits to the distortion of possible location decisions: in the case of Shetland's brochs, the desire for defence can introduce a distortion of five minutes, but not ten. It may also be remarked that the extreme cases are always rare. Not only is it rare to find a broch in an extremely disadvantageous location from a defensive viewpoint, but it is in fact difficult to find a location in which a broch could be placed (bearing in mind the form of the structure) so that it would be so disadvantaged. The only possibility would be a site at the immediate foot of a very steep slope.

The general value of this concept might be to observe critical distances or site-types. Clearly, location on a rocky arete (Balta) or a small islet well offshore (Holm of Copister) would, as observed above, preclude these brochs being used to shelter cattle. Similarly, there must be a certain distance from the sea at which the regular exploitation of marine resources becomes impossible, or the economic equivalent, unprofitable in terms of food-return on labour expended.

What this amounts to is a potential method for the assessment of the ease or willingness with which groups will dispense with one element of their potential activities. Hopefully, it should prove possible to evolve a system of quantifying what has, up until now, been a very subjective aspect of settlement studies, the comparison of the relative importance of different desired activities on the choice of a site.

Siting and the Logicality of Additional Defences.

From the last comments, it will be seen that there are two possible interpretations of the broch's function (see also Section 1, Chapter IV). These are strongly contrasted.

The first (high-defence) picture is of groups of Iron Age farmer-fishermen working the landing and sea with a continual watch for sudden attack, at which they would flee to the broch. The latter was built because the people believed it very likely that they would be attacked, and brochs would have seen use at least once in the lifetime of each, and perhaps more frequently. If this state of affairs were the case, it might be expected that where brochs were not built on strong natural sites, their position would be reinforced by the addition of outer walls, ramparts, and ditches.

The second (low-defence) picture is of similar groups, who have adopted the broch-type fortification, perhaps because there is a real threat, but a threat perceived as remote, but mainly because brochs happen to be what powerful groups or leaders build elsewhere. The idea of prestige-building is not unknown in the northern Iron Age, and the well-known fort at Chesters, Drem, East Lothian, has been suggested as an example of a non-functional fortification which may reflect status-seeking rather than fear of attack. The provision of an impressive structure, or series of structures, may be a function of social pressure as much as of military or political threat. If this were the state of affairs relating to brochs, it might be expected that the additional defensive works often noted around brochs would bear less relationship to the natural defensibility, or otherwise, of the sites on which they occur. In fact, it might be possible, by judicious use of existing natural features , to build a set of outworks which were particularly impressive to the viewer, even if the broch was not in need of such strengthening.

These alternative views present radically different views of the role of the broch, and of its external defence works. In the first, they are defences pure and simple. In the second, they are as much symbolic as functional. Whatever is the correct answer, it has already been shown that brochs are consistently near to the central foci of daily life, so they are presumably structures which saw regular use. The likelihood of the two scenarios can be investigated by use of the chi-squared test.

Convenience status	1	2	3	Total
Artificial defences	16	8	15	39
No " "	10	13	13	36
	26	21	28	75

The above is the table of observations. The expected data can be calculated from the null hypothesis, which is that brochs having outer defences are not related in their distribution to brochs which are in convenient sites for daily life. The "expected" table is

Convenience status	1	2	3	Total
Artificial defences	13	10.5	14	37.5
No " "	13	10.5	14	37.5
	26	21	28	75

The chi-squared statistic is 2.718 (D.F. = 5). This is not statistically significant. Therefore, there is no observed correlation between the presence of external defensive works and the convenience status of the site. Thi suggests that although brochs might be expected to have added defences when they are sited on poorer defensive sites so as to be in a convenient position for normal economic activities, this is not, in fact, observed in Shetland.

However, as a site may be both highly convenient and highly defensive, a cross-check was run, using defensive status in place of convenience.

Defensive status	1	2	3	Total
Artificial defences	25	11	2	38
No " "	21	14	2	37
	46	25	4	75

Expected values are:

Defensive status	1	2	3	Total
Artificial defences	23	12.5	2	37.5
No " "	23	12.5	2	37.5
	46	25	4	75

The chi-squared statistic is 0.708 (D.F. = 5)

The result of this test is in fact a surprising one, and seems to confirm the second alternative, that the provision of external defensive works around a broch has in fact very little to do with the lack of natural defensibility of a site. The null hypothesis, that there is no relation between additional defences and defensive status of sites, fails to be rejected, and by a very large margin, even at the 75 percent level of statistical significance.

The statistical tests can be used to support the inference that, although brochs are fully functional defensive structures, the elaboration of defences around brochs seems to make no coherent contribution to the defence. Instead of being added to strengthen weak sites, these ramparts are distributed almost impartially between naturally strong and naturally weak sites. Prestige may well be as important as practicality.

Some Minor Considerations

Availability of building stone, site-drainage and aspect were mentioned in the introduction to this chapter, as possible influences on the choice of site.

Within the local area, availability of stone cannot be observed to have exercised any influence on siting. In some cases the broch will stand on top of the outcrop which furnished its stone, while in others the stone-source may lie several hundred metres distant, as at Culswick. There appears to be no example of a broch which has been sited in such a way as to be inconvenient for normal activities, or for defence, merely so that a convenient source of stone could be exploited. But in most cases, the stone has not had to be transported for any great distance, simply because outcrops are very numerous in most parts of Shetland.

Site drainage proved a little more interesting, and also more challenging. The structures of brochs, particularly in ruin, are so massive as to totally derange normal patterns of drainage. In general, the fact that most brochs are situated upon rises makes for well-drained sites, but in any case, this may not have been particularly important. All broch excavations to date have demonstrated the broch-builders to be very competent drainage engineers: in fact, the drains in some brochs are the most impressive feature (Dun Mor Vaul, for instance, MacKie, 1974). A small number of brochs on low marine islets seem to have been built so close to the water that the foot of their outer walls would have been wave-swept, even in normal storms. This observation takes account of the estimated two-metre rise in relative sea-level in Shetland since the Iron Age. Burravoe at Brae, Noonsbrough and Footabrough are good examples of such brochs. In such brochs, the lower courses of the wall seem to be particularly well-built; the lower courses at Burravoe are so heavily-constructed that they have survived the deliberate dismantling of the ruin.

Where coastal brochs are particularly exposed, the entrance will tend to point away from the direction of greatest exposure. Also, the entrances of some brochs are so placed upon the circuit as to combine with natural defences to make access awkward. Where there are outer defence works, these usually take account of the entrance, by affording it extra protection. All of these aspects have been discussed above, in the context of broch structure (Section 1, Chapter VII).

The aspect of broch sites gives little cause for interest. Most sites tend to have a rather more open aspect than their immediate area, but no more than would be afforded by any slightly raised location. If it is necessary to choose between aspect and defensibility as siting considerations, the latter must surely be preferred. The only consistent trend of site aspect was that often all of the arable land is on a slope facing in one direction, with the broch sited so that it can overlook this land, but also look in directions not visble from the land. Thus some sort of lookout function may be ascribed to brochs, but this is not a primary function, as the need for a lookout would be just as easily fulfilled by stationing a man upon the site, rather than a broch.

One interesting feature of siting was observed which was very difficult to name, and impossible to quantify. In a number of cases, brochs built upon promontories or islets in voes seem to occupy sites which are partially concealed from the open sea. East and West Burrafirth, Noonsbrough and Wadbister occupy such sites. Also, some of the "inland basin" brochs have analogous sites. If these brochs had been built to a sufficient height (and the required heights are quite moderate, six to ten metres or thereby) an observer on the wall-head could have looked out from the broch, to the open sea or the approaches beyond the basin, but the broch itself would have remained invisible from outside. Snabrough on Unst is a good example of the basin-type site with this characteristic.

The significance of this is doubtful. All of the brochs noted are also built upon the best defensive site in the area. So this type of outward visibility advantage was probably a welcome bonus rather than a primary locational desire. Against the idea that the broch-owners wished to conceal themselves must be set the counter-examples of the many brochs which are situated so as to be visible from all directions for many miles, such as Culswick or Hawks Ness. It may, in conclusion, be noted that Mousa is so sited as to look out over the low saddle in the centre of the island to the open sea. But if the main aim of the broch-builders were concealment, they could have taken to the hills at the first opportunity at any sign of danger.

From these minor considerations, a few points of interest have emerged, but nothing which could reasonably be taken as an influencing factor upon the actual choice of broch sites.

Summary of Micro-Scale Results.

At the micro-scale, the investigation of siting by means of basic statistical methods has revealed significant patterns in the choice of broch-sites.

It has been demonstrated that the detailed site of the broch is generally chosen to be as defensive as possible by nature of its own topography. However, it has also been shown that there is a limit to how inconvenient a broch will be made for everyday activities by this desire for a defensive site. Further, it has been suggested that the additional defensive works at many sites may relate partly to such nebulous concepts as prestige, a suggestion that has already been made for the brochs themselves (Section 1, Chapter IV). It may be coincidence that the most defensive site is often the most prominent in the landscape, but this fact may have been welcomed under such circumstances.

The concept of an equilibrium between the different demands made upon the site is an attractive one, as it makes possible a quantification of the perceived importance of different functions to be carried on at each site. In the specific case of convenience versus defence, it was found that five minutes extra inconvenience was not worth the added defence possible at that distance. Various explanations are possible for this.

While the fact that a broch, rather than any other structure, was being built only becomes significant at the micro-scale, at that scale it is of paramount importance. The overall result of the above analysis is that while all brochs were built to be lived in, they were also built to be as defensive as possible. Some, by virtue of later (?) ramparts, which do not relate to a need for such protection, were rendered much more defensible than others. Some, indeed, seem so heavily defended that it is difficult to understand how other broch-groups hoped to survive without such defences. The answer to this problem should be sought in the social conditions of the period.

This concludes the scale-by-scale discussion of the factors affecting the location of Shetland brochs, and the analysis of data relevant to these discussions. It is now possible to use this data to construct a model of locational decision-making.

Chapter V

A Partial Location-Decision Model for Iron Age Shetland

Location Models in General

As with all other theoretical approaches, in all subjects, there are two basic types of location model, the inductive and the deductive. The former works by a process which could be summarised as :

Observation -- Classification -- Analysis -- Formulation

The deductive process, in similar schematic form, is :

Formulation -- Observation -- Classification -- Analysis -- Verification.

These two approaches are not equivalent, as they imply fundamentally different attitudes to the data and to the desired results. The inductive approach is geared to starting from the basic facts, as these can be observed in nature, and building up a model specifically designed to explain observed regularities by reference to the operation of appropriate processes. The deductive approach is designed to verify or refine a theory based upon derived or abstract principles, and the actual data may be a very secondary consideration to the theory under test. By their nature, inductive models tend to be more case-specific, while deductive models aim at more general conclusions regarding universal principles.

Although the inductive approach was preferred for most of this study, since there was no reliable pre-existing model to refine, there were certain quasi-deductive basic assumptions. These are :

1) The settlement process worked by the location of groups, not of individuals, and functioned thereafter by group action.
2) Groups were free to move, albeit slowly, within the region, so that they might locate the best available areas and sites for settlement.
3) Groups were capable of rationally assessing the economic potential of areas, and of acting rationally upon this information.
4) Spatial constraints upon activity will tend to be reflected by observable order in location and siting.

Thereafter, the process of constructing a location-decision model is one of logical and sequential argument, starting with the macro-scale and working downward. The analytical results are built into a framework which approximates to the pattern of decision-making undertaken by the generations of settlers whose ultimate descendents constructed the brochs. Most of the decisions are social and economic in their context, although only the economic can be singled out here, as it is [illegible] that the /

that the fieldwork can provide evidence. The actual structural nature of the broch only becomes an issue at the micro-scale, although its concomitant, the size of group, is a major consideration in the size of area required and the total resource-potential necessary, at the meso-scale of analysis.

Clearly, a model can only be constructed after detailed analysis and consideration of the data concerning distribution, location, and siting, as above. The accuracy of the model is conditioned by the accuracy of the analytical results and conclusions, which depend, in turn, upon the reliability of the field-gathered data.

The Uses of Models.

Once established, an inductive model of the type proposed here can be used as the basis for deductive modelling of other situations. Thus from an inductive broch-location model for Shetland brochs, the next stages of research would be either the deductive testing of this model for the location of brochs in other regions, or the deductive testing of location patterns for other types of monument in Shetland.

Thus the specific model, founded upon fixed region and period, will allow comparison of either other regions at this period, or other periods in this region. The detail of the refinements required to make the Shetland broch model fit other situations would be a measure of the extent to which the Shetland brochs are located in a different manner from the other situation.

The comparison of other situations with the one presented here can, naturally, be carried out by the same techniques as those used in the construction of the inductive Shetland broch model. This is because, pedantically speaking, the patterns observed for the location of these sites represents the deviation from a deductive model founded upon absolute conformity with all natural distributions.

It is anticipated that the next developments of the approach presented here will be the extension of environmental and economic analyses into the broch-period in other regions, to establish the generality, or otherwise, of the model presented here.

The Shetland Model.

The scale treatment of the processes of decision-making in Iron Age Shetland has made it possible to produce a scaled schematic system, commencing with the arrival of the first settlers in Shetland and ending with the construction of the brochs. The evidence used is drawn from both excavated sites and, more substantially, from original field work.

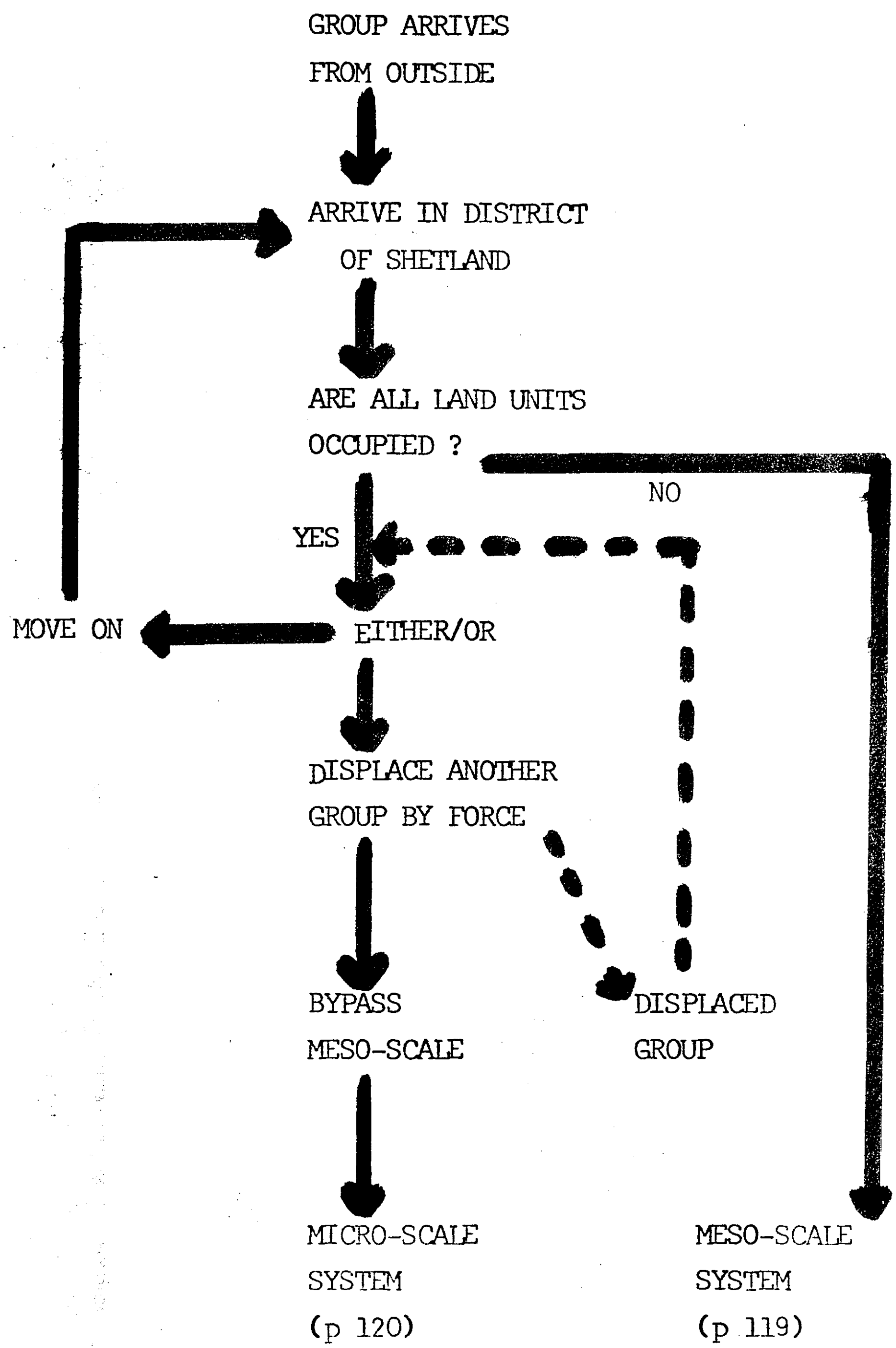
It should be noted that the majority of the early decisions in this /

this model are constrained by economic considerations, and that only at the lower end of the spectrum of scale does the actual fact of the broch qua broch take on any great significance in terms of the spatial pattern of decision-making. The corollary to this is that the early stages of the model are in no way tied to the same period of prehistory of the brochs, but could be set at any time prior to their building. The only constraint on how early this part of the process of location took place is the fact that the location patterns for Neolithic/Bronze Age settlement appear to be significantly different (Calder, 1956; Whittle, 1979).

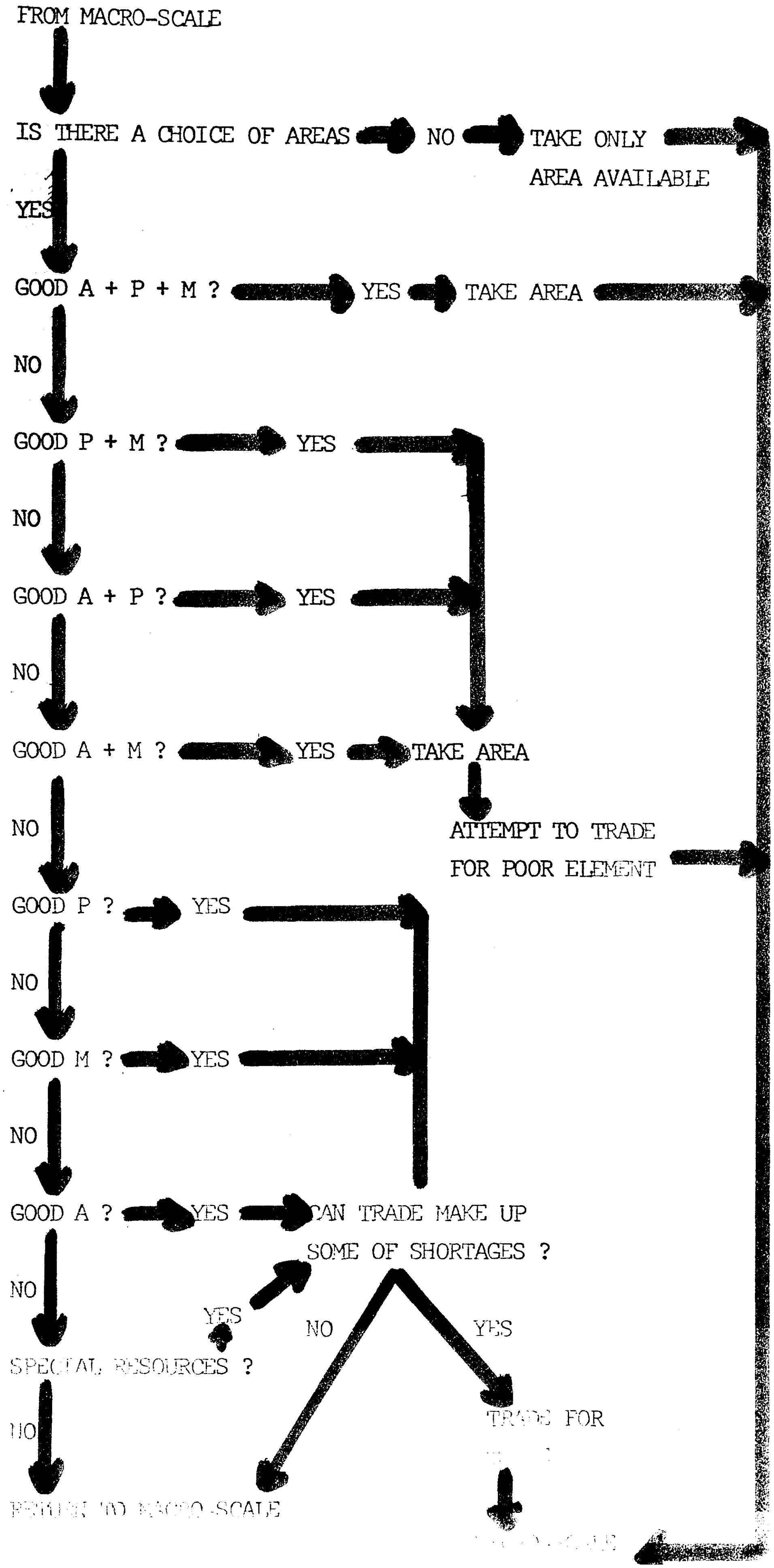
The overall schema for locational decision-making can most succinctly be displayed in the form of a diagram, and this is done through three flow charts (following pages). These attempt to break down the choice of region, area and site into stages identified by this study, and to incorporate the observed preferences of the settlers. These diagrams provide a convenient framework within which to examine the circumstances of any individual broch as compared with the general trend.

It must be noted that the diagrams describe only the process of location as analysed in this Section, and do not include the major social constraints which must have operated, and which have been referred to obliquely from time to time. Therefore, the model is only partial. The parallel model, based upon social systems and processes, has not yet been formulated, and at present there appears to be inadequate data for such a formulation.

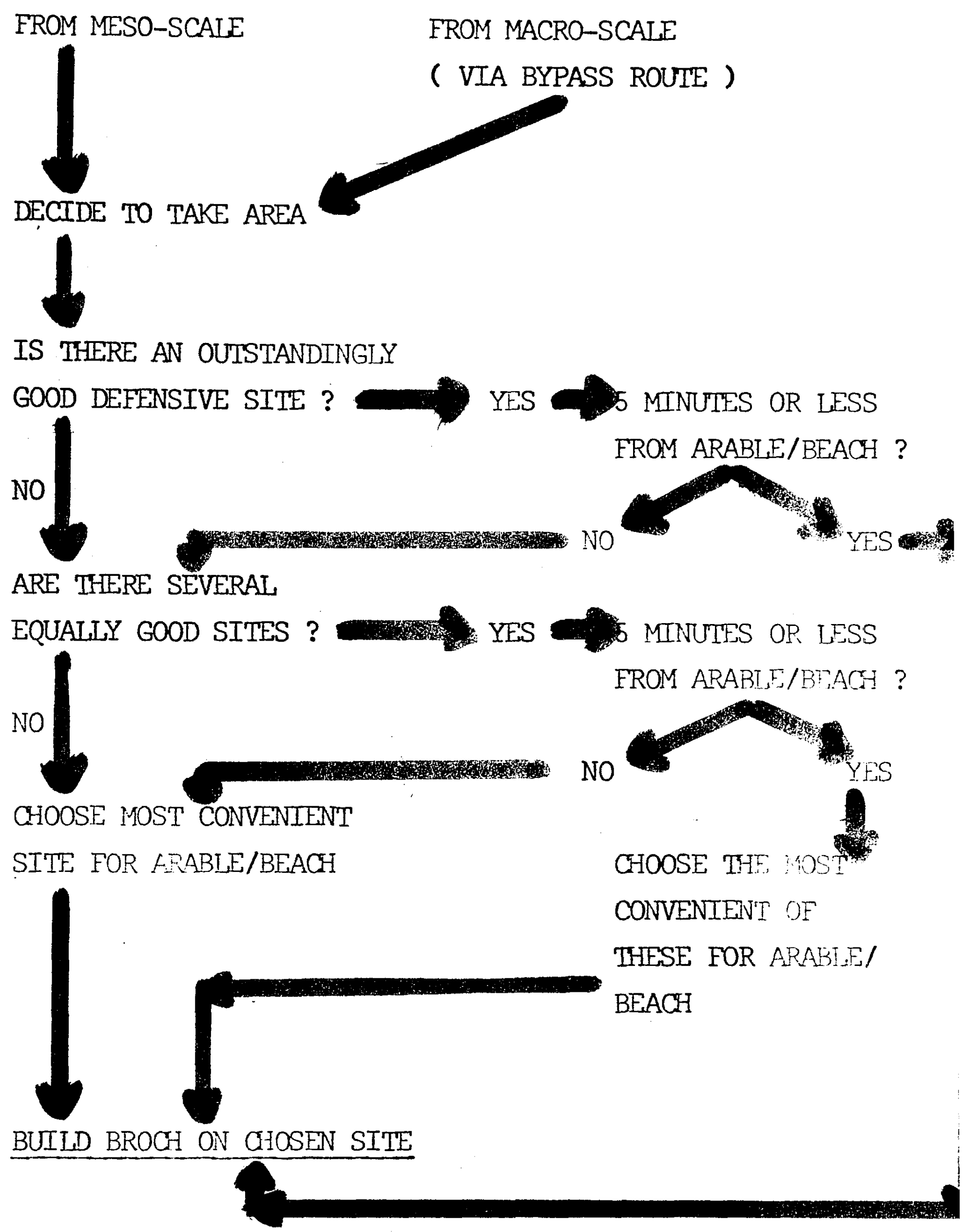
MACRO-SCALE


GROUP ARRIVES
FROM OUTSIDE
ARRIVE IN DISTRICT
OF SHETLAND
ARE ALL LAND UNITS
OCCUPIED ?
NO
YES
MOVE ON
EITHER/OR
DISPLACE ANOTHER
GROUP BY FORCE
BYPASS
MESO-SCALE
DISPLACED
GROUP
MICRO-SCALE
SYSTEM
(p 120)
MESO-SCALE
SYSTEM
(p 119)

MESO-SCALE


FROM MACRO-SCALE
IS THERE A CHOICE OF AREAS
NO
TAKE ONLY AREA AVAILABLE
YES
GOOD A + P + M ?
YES
TAKE AREA
NO
GOOD P + M ?
YES
NO
GOOD A + P ?
YES
NO
GOOD A + M ?
YES
TAKE AREA
ATTEMPT TO TRADE FOR POOR ELEMENT
NO
GOOD P ?
YES
NO
GOOD M ?
YES
NO
GOOD A ?
YES
CAN TRADE MAKE UP SOME OF SHORTAGES ?
NO
YES
NO
YES
SPECIAL RESOURCES ?
NO

MICRO-SCALE


FROM MESO-SCALE
FROM MACRO-SCALE
(VIA BYPASS ROUTE)
DECIDE TO TAKE AREA
IS THERE AN OUTSTANDINGLY GOOD DEFENSIVE SITE ?
YES
5 MINUTES OR LESS FROM ARABLE/BEACH ?
NO
NO
YES
ARE THERE SEVERAL EQUALLY GOOD SITES ?
YES
5 MINUTES OR LESS FROM ARABLE/BEACH ?
NO
NO
YES
CHOOSE MOST CONVENIENT SITE FOR ARABLE/BEACH
CHOOSE THE MOST CONVENIENT OF THESE FOR ARABLE/ BEACH
BUILD BROCH ON CHOSEN SITE

Chapter VI

Concluding Remarks : Methodological Contributions

It is convenient to attempt to summarise, at this point, the contribution which the analysis of environmental data has made to the general understanding of the nature and functions of brochs.

Such contribution has taken two forms. Firstly, a series of classificatory techniques has been advanced, which makes possible the statistical description of broch areas and sites. Much can be learned from such classifications, even by visual inspection alone. Further, some methods of quantification have emerged which enable well-known concepts to be defined with a new measure of precision. Chief among these is a method for quantifying the formerly imprecise term "coastalness".

Secondly, a series of simple analyses of the correlations between broch distributions and environmental factors has made it possible to advance suggestions about the economic structure of broch groups, their apparent preferences as regards areas of settlement, and the threat against which brochs were built. Not only is it possible to demonstrate that brochs could well have functioned as farmhouses, but it can be suggested that some of the siting constraints which are observed to operate at the micro-scale would only do so if this function of farmhouse was a major consideration on the part of those who chose the site.

On the subject of defences, it has been shown that the pattern of distribution of additional defensive works is such as to suggest that they are not essential to the defence of brochs, and in a limited fashion this must represent one of the first attempts, albeit inadvertent, to quantify the element of prestige that may have been present in the building of many prehistoric monumnets.

But overall, the main contribution has been the demonstration that a wealth of data exists, which can be readily collected and simply analysed to give a broad picture of the economic modes and preferences of a whole division of society : this is something which excavation could not achieve at realistic costs of time, labour and finance. The answers have been general, but this is because general questions were asked. General information is often what archaeology lacks, especially in Scotland, where much is known about the detail of a very few sites. Although we can never hope to excavate a large enough number of [illegible] to a high enough standard, this need not deter us from asking general questions, particularly in the fields studied here, where [illegible] evidence /

evidence often acts merely as a pointer. Excavation can tell us what the resources utilised were, but <u>only</u> fieldwork is capable of demonstrating the available stocks and relative proportions of these.

Thus excavation has suggested priorities for fieldwork, and field work for excavation. The two must be complementary, not in opposition or isolation. The main priority identified by the present study has been a necessity for good environmental data, in the form of faunal and floral assemblages based upon the analysis of organic material from relevant sites. This would enable much infilling of detail upon the necessarily scanty picture of the broch-period economy used in the model created above. Such a programme of research can be initiated in the near future, for it is not nearly so costly as full-scale excavation.

It is submitted that the level of detail which can be attained by the analysis of fieldwork data is sufficiently high to make an extension of this approach to other areas and other periods of prehistory a desirable event for archaeology in general.

Methodology : Conclusions and Prospect.

It should not be necessary, by this stage, to demonstrate the value of the contribution to archaeology which can be made by the careful application of very basic analytical techniques. It has been emphasised throughout this study that, for most archaeological requirements, the simplest of such techniques are not only adequate, but are to be preferred over other, more complex, methods. Much of the reaction against the hypothesis-testing paradigm of the "New Archaeology" has been due to the bewilderingly numerate approach of the leading proponents, and by the way in which techniques are often "borrowed" wholesale from other disciplines, particularly geography.

This wariness of statistical approaches may be justified, at least to a degree. Certainly, there have been notable misuses of geography in archaeology, and these have occasionally reached publication through the attitude that "we weren't happy about the archaeology, but the geography looked interesting" (Dr J Graham Campbell, editor of *Medieval Archaeology*, discussing Cottam and Small, 1974, pers. comm.). The major problem is an apparent inability, or unwillingness, to accept that the data-base available to the field archaeologist is in general of much lower quality than that available to the geographer. Questionnaires cannot be conducted amongst the dead, nor can their activities be directly observed.

Further, it may be suggested that, in the field of palaeoeconomic reconstruction /

reconstruction, archaeology has not yet advanced beyond that stage of scientific growth generally characterised as the "primary-inductive" or "data-gathering" level. It is to be doubted whether this aspect of the subject has advanced far into stage two, the "taxonomic" or "classifying" level. It seems certain that, at least for Northern Britain, there is not enough data to allow generalisations about prehistoric economic strategy in other than very area- or site-specific ways about restricted periods.

The key to the assessment of the structure of economies must lie in an understanding of the potential resources available to each site from its catchment area. Such an understanding must be a matter of detailed knowledge, not broad total figures. This must be allied to actual evidence from excavated sites regarding the resources which were, and which were not, exploited. That is, the basic requirement for progress in palaeoeconomic reconstruction is the fusion of fieldwork and excavation approaches into a coherent whole, rather than the present pattern of often-divergent interests and aims between the two main strands of archaeology.

It has been submitted here that the most basic techniques are appropriate tools to be used in this fusion. It is possible to suggest that what progress is to be made at the geographical/archaeological interface will be made not as a result of converting high-powered techniques from other disciplines, but as a result of painstaking accumulation, through trial and error, fieldwork and field-testing, of an array of tests and model-building procedures which are appropriate to the nature of archaeological data, with all of its own distinctive and idiosyncratic lack of qualities. Progress can, indeed, be made by analogies with other disciplines, but it must be made upon a firmly archaeological footing, so that the constraints of the data can be built into the procedures from the start.

While the reluctance to accept statistical methods is doubtless due partially to a general lack of skill in their use, "the bad workman blaming his tools", it is in part due to the recognition of fact that the tools are often inappropriate to the task.

Archaeology is a young science, and most archaeologists want what are, by the standards of most sciences, very simple answers to very basic questions. It is hoped that for one area of archaeology, this study has shown the simple methods which will help to provide the answers.