CHAPTER 7

Axe Manufacture at the Quarry

7.1 Value-adding in axe manufacture

In the previous Chapter I investigated in what ways and to what extent the selection and extraction of axe making stone could be evaluated as an economic transaction. The selection of axe making raw material was done on well-defined grounds and the extraction process used specific techniques. The tests resulted in the selection and extraction of stone at Gulgong and Warren quarries not being based on the principles of value-adding in economic transactions, although some features of selection and extraction did give a basis for subsequent value-adding behaviour in axe making. The next task is then to test whether the following stages of producing axes fits expectations derived from the economic model. The purpose of the chapter is to evaluate the degree of value-adding in axe manufacture. I begin by reviewing the process of stone axe reduction.

After extraction, raw material may be moved about the landscape. Transport can be either from the extraction locality to some other part of the site, or from the quarry to another place. In addition, the removal of raw material from the quarry can take place at any point along the continuum of production. Certain pieces of worked stone are destined to leave the quarry at some point in the production continuum. The production trajectory in Table 2.1 shows that stone which is not symmetrically shaped and therefore does not pass into exchange, may still be removed from the quarry and used in the local economy.

An example of value-adding decision making is where three pieces of axe stone are reported as being exchanged for one possum skin cape in a transaction at Mount William in the early nineteenth century (Howitt, n.d:37 in McBryde 1984, 272). To what extent this axe stone was modified after extraction is not clear from the description. Yet, in terms of understanding the distribution of material, the case is important. Where the processing of raw material is done as an economic transaction, there will be a value-adding activity. My expectation for production and distribution as an economic transaction is that the alienating exchange transaction will take place at a late stage in production, based on the process of value-adding. By the time ‘three pieces of axe stone’ are offered for transaction, the process of value-adding has been both substantial and significant. The value-adding in the axe stone at this stage is
composed of three elements: (1) right of access; (2) knowledge of raw material and process; (3) time and effort in extraction. The material has been selected and extracted from the quarry resource by the stoneworkers under managed conditions, rather than being procured by direct access. The control over access to resources in Aboriginal Australia is an important element in the social relations between people and groups. Aspects of the organisation and implementation of access to resources are discussed by McBryde (1984) for Mount William axe quarry and Myers (1982) for the Pintupi. In the previous Chapter on selection and extraction I evaluated Aboriginal knowledge of raw material. In this chapter I will consider value-adding knowledge through time and effort after extraction. To achieve this I will investigate efficiency found in the manufacture of axes at the quarry.

Where economic transactions are the basis for production and distribution, there may be an incentive for further value-adding processes to take place under the control of the quarry workers. Within the reduction process, value-adding takes place in the process after extraction to grinding. As an economic activity value-adding involves efficient manufacture of stone axes. Efficiency is required to generate extra value during the stages of production. The process of value-adding does not guarantee cost-control in manufacture of the product. Value-adding in this way sets the limits of the economic transaction between the axe maker and the consumer. When the raw material is in the process of manufacture, then value (to the consumer) is added. Within the stages of reduction efficient actions will control costs. The stages of reduction represent a value-adding assessment of stone axe making, in that as a preform is knapped and shaped in the stages of reduction the additional effort invested in the good will increase the revenue expected from an exchange transaction. This assessment operates within a framework of stone technology and the organisation of production, in that knappers will reduce stone on a basis that calculates a revenue benefit from the additional working of the preform through the stages of reduction.

7.2 Predictions for efficiency and control in knapping behaviour

In Chapter 5 I have discussed the need to achieve symmetry of shape as a guide to making axe preforms at the quarry and to establish the exchangeability of the product. As the preform is passed through the reduction stages to distribution, a value-adding process takes place.

The predictions for efficient behaviour in axe making are developed within the reduction sequence described here. In Chapter 2, I described the production trajectory (Table 2.1) and the general reduction sequence for axe preforms. In this Chapter I will
discuss the stages of #3 blocking out, #4 shaping, and #5 thinning to an advanced stage in the preform. The first and second stages of reduction, that is selection and extraction at the quarry, were considered in the previous Chapter.

I have predicted that the efficient manufacture of axe preforms places some quarry sources at an advantage, when compared with other quarries. In order to test this hypothesis, I have evaluated axe making at the two quarry sites of Gulgong and Warren. My expectations for Gulgong differ from those of Warren because the dispersal of axes from these two quarries across the landscape of Eastern Australia suggest different forms of distributions for the two quarries. The axes from Gulgong show a long distance distribution across the landscape in a particular direction and this dispersal is isomorphic to the movement of axes found from the Moore Creek quarry. On the other hand, the dispersal of axes from Warren is in a limited area around the quarry.

My methods of data collection and means of evaluation were the same for both quarries. I used the study at the two quarries to compare and contrast the results within the hypothesis of axe making as an economic transaction. I predicted that Gulgong axes would have been made as part of a value-adding economic transaction which exports the manufactured preforms from the quarry. Although value-adding decisions can result in the export of axe material from the quarry at any time after selection and extraction of the stone, the tendency is for axe preforms in the late stage of reduction to be passed into the distribution system as trade goods. The Gulgong axes which were part of this economic transaction would have been made by the Aboriginal stone workers under conditions of knapping control which are efficient in production. My expectations are for the efficient making of axes to be identified by a low production error rate, especially for hinge fractures.

At Warren the prediction of no trade in the output of the quarry gives an expectation that abandonment will take place at all stages of reduction with no propensity to manufacture axes into the late stage of reduction. Control in axe making will not result in efficient behaviour that can be recognised on axe preforms, and in flake debris as low error rates. Error rates will be high with frequent hinge fracturing.

The reduction sequence produces axes for exchange made to be symmetrical and for other products to be output from the process. Examples of other outputs from this process include (1) axes with no symmetry and therefore not exchangeable, and (2) hammerstones used on site in axe making. In the axe manufacturing process knapping errors occurred and preforms were abandoned or recycled. It is these knapping
behaviours and abandonment decisions which can be used to register the degree of efficiency in the making of axes at quarries, such as Gulgong and Warren. We can therefore predict that axe preforms were abandoned with certain technological features resulting from knapping procedure, and flaking features and which indicate the degree of control of force. The technological features I consider relevant are the reason for abandonment of the preform and type of flake termination. For this reason my approach to symmetry and efficiency in axe making considers control in the reduction sequence at the quarries. Efficiency requires control in manufacture, which is evaluated through knapping features found on the preforms and in the flaked debris at the quarries.

I have classified the reasons for abandonment of preforms as: (1) transverse snap (Figure 7.1); (2) edge damage (Figure 7.2); (3) mass removal (Figure 7.3); and (4) raw material flaw (Figure 7.4). Of these features, the first three are most relevant to control.

I further expect that efficiency will be reflected in the form of control in the knapping process and lead to a low error rate. These efficient traits are underpinned by a selection process in which stone of a suitable size and shape is selected from the material extracted for use in axe making. The high cost of extraction will promote the selection of the stone from that already extracted. This will be the case especially with extraction of raw material from the solid outcrops of stone. Gulgong is a case of solid rock outcrops, whereas Warren is mainly loose blocks. The selection of loose blocks is preferred (all other things being equal) because the costs are lower.

The knapping features important in the evaluation of efficiency are the types of flake terminations, and to a lesser extent the condition of the point of force application (PFA) and surface fracture ripples. I have classified the types of flake termination on the axe preforms and waste flakes as either (1) stepped or (2) hinged. Of these I concentrate on hinged fractures as being most relevant to measuring control in the efficient making of axes (Figure 7.5). The PFA features found on flakes are classified as either (1) intact or (2) crushed (Figure 7.6). These features are inputs for monitoring control over knapping.

The degree of control exercised by the stone knapper has been discussed by Bucy (1974, 6) in terms of the approach to core preparation and the resulting flakes produced. The high degree of control exercised by stone knappers in prehistory and the modern experimental replication is observed in cases where the shape of the face of the core is prepared to determine the shape of the flake produced. Such flakes were used as
tools, or modified by subsequent flaking. Bucy (1974, 7) argues this high degree of control is important in the manufacture of bifaces. Crabtree (1972, 16) defined a 'biface' as an 'artefact bearing flake scars on both faces'. While not all axes are bifacial, this definition will be important for identifying studies by stone tool technologists which are relevant to my research in stone axes.

If a high degree of control can be exercised by a skilled stone knapper, then what is the significance of mistakes or accidents in the making of stone tools? Control in knapping can be determined by skill, the tool-kits used by the stone knappers, or the practice of a routine in production. Skill is based on knowledge and is not invariably the result of efficiency. For example, recovery techniques from hinge terminations are possible in a repertoire of knapping skills.

The type of mistake in the form of the stone detachment is valuable information for the skilled stone tool maker. It is axiomatic that the mistakes in stone tool-making are not 'intended', in that their production is a deviation from a plan, or pattern of working (Davidson and Noble 1990). The mistake in knapping gives information about the working properties of the stone, because of the high degree of control exercised in much stone work. For example, there may be flaws in the material that were not apparent in earlier stages of reduction; or the amount of force required for a successful detachment may have been misjudged. Knowing whether a termination results in a step or hinge fracture can help the stone tool maker decide upon a course of action, for the present workpiece and for subsequent blanks.

Where skill and experience set the pattern of work, knapping to recover from mistakes will take place. The same response to the recovery from errors will not necessarily be found with knapping control related to efficiency. With value-adding as a guide to behaviour there will be different responses to the same problem of recovery from errors, depending on the gain calculated from one course of action or another. For a workpiece in this condition, the action can be either recovery from the mistake (see Edmonds 1989) or abandonment of the workpiece, because of the difficulty of recovery. In the value-adding and efficiency model of economic transactions axe preforms are treated differently. For example, efficient traits in production suggest recovery knapping in the late stages of reduction are more likely to be attempted than in the early stages. The early stages of reduction have a lower value-added factor, and require more knapping work to achieve maximum value-adding.

7.3 Attributes used in the evaluation of efficiency in axe making
To monitor the properties discussed so far I have chosen a number of variables: (1) flake size, expressed as flake length, (2) flake morphology, and (3) knapping control features, such as step and hinge fractures.

The results of experimental work by Mauldin and Amick (1989) suggest flake size has a weak trend through the reduction process. Whereas length is not of much help in predicting the reduction stage, the early reduction stages have larger flakes than those found in the later stages. Typically all stages are dominated by small debris. Mauldin and Amick (1989) suggest the combination of several individual attributes may overcome the complications of distinguishing the stages of reduction. Burton (1980) measured ten variables on whole flakes and found that mass or weight, accounted for most of the difference in flake categories between the reduction stages of manufacture. I have followed his lead in choosing flake size.

The potential of this approach may be limited. Patterson (1990, 550) argues there is no generally applicable analytical method for identifying stages of reduction in biface production using only the attributes of waste flakes. Others have noted that the initial core (and axe blank) size and shape will complicate attribute interpretation for reduction (Ahler 1989; Mauldin and Amick 1989). The variability of the size and shape of the starting blanks used for experimental manufacture is given by Patterson (1990) as the reason for the flake-size distribution across a reduction sequence not being used to distinguish the various stages of bifacial reduction. So if a set of attributes that are commonly used to infer the relative position of an individual flake in the reduction process cannot be used as a guide for analysis, then how can collections of stonedebitage be characterised through the attributes of individual flakes?

Stone tool manufacture is a subtractive technology. This fundamental property of the material and its working in production must be the basis on which any attribute analysis can be developed. As a generalisation about stone working, reduction will move inward from the outer surface of the material. This will be done by removing layer by layer, and should be identified with successively finer flaking as the piece of material becomes thinner and smaller. In this process there is an underlying regularity, such that the size of waste flakes from the manufacture of stone axes will decrease from the initial to the final stages of the bifacial manufacture. The size distribution of waste flakes is here used to distinguish the sequential stages of biface manufacture. Stahle and Dunn (1982) plot flake size categories by stages of reduction and show an increasing proportion of smaller flake size categories from the initial stage to the final stage of reduction.
If flake size categories can be recognised, although not without some doubts as to their analytical value, then are there other ways of creating flake categories of use in understanding technological behaviour in stone tool making? Baulmer and Downum (1989) used three categories of flake that seem to have relevance to lithic assemblages studied in stone axe production. These categories distinguish complete flakes from a broken flake and shatter as debris with multiple angular faces. I record the whole flakes and angular categories of flake from experimental knapping of preforms in the reduction process. They form part of my predictions for efficient behaviour at the quarry.

The fracture properties of raw material will influence the amount of flake breakage in an assemblage. For example, the presence of incipient fracture planes will reduce the number of whole flakes and increase the number of fragments (Prentiss and Romanski 1989). These factors are important in understanding the debris found at a stone axe quarry. The complete flakes in an assemblage from stone axe manufacturing are few compared to the total pieces of stone. The expected by-product of stone axe manufacture is a mass of debris within which some flakes may be complete. Here the complete flakes are not part of an expected end product, such as may be selected for bifacial trimming in a core tool technology. Yet they may represent some significant feature of the manufacturing process. For example, in the controlled bifacial reduction of axe blanks the production of complete flakes might be expected in the sequence. These complete flakes might indicate regularities related to points along the reduction sequence and demonstrate the use of appropriate strategies in production. I use complete flakes from experimental knapping to recognise features of efficiency and control in the debris from axe making found at the quarries.

One of the problems with using flaking features, such as hinge fractures, is the influence of raw material properties on the incidence of hinge fractures. In other words, does the raw material have a propensity to form a particular type of termination, such as hinging, regardless of the amount of impact or the skills of the individual knapper, as is sometimes suggested by studies in stone tool technology? (see Shott 1994) The variation in formal flaking attributes found in raw material may occur in a way which is independent of the reduction mode (Goodman 1944; Shott 1994). If the raw material will hinge because the properties of the stone give this propensity, then hinging should occur regardless of control by the knapper. Leudtke (1992, 85) discusses the fracture situations which occur independent of knapping practices. She cites chert as giving hinge flake attributes which can be a function of rock type properties (that is, homogeneity, elasticity and isotropy). The problem becomes complex across rock types. For example, expectations of microsilaceous cherts and that of hard rock basalts may differ.
The situation is important where more than one rock type is being evaluated. With more than one rock type there may be problems in distinguishing the performance properties of the stone from the influence of the knapping practices and the degree of control over those performance properties. As an alternative approach, use of the same raw material type in two different situations should give valuable comparison in evaluating the influence of knapping behaviour in stone axe flaking. Clarification of the performance properties of stone in this area is important for the evaluation of knapping skills in relation to a particular stone type. With the raw material influence on the types and frequency of flake termination adequately evaluated, then there remains the control of the knapper and the adequacy of force applied to achieve detachment. My approach to the problem has been to undertake experimental trials using stone classed as suitable and possessing the same properties as the archaeological stone found in the quarry site.

The archaeological problem of efficiency requires traits which can be identified in the available material remains. Error rates in stone knapping can be identified from certain material remains, such as flakes and axe preforms. For the error rates to be useful they must be capable of unambiguous identification in the archaeological sample. At a stone axe quarry there is all of the debris from axe manufacture and some preforms. The knapping errors which occur on the individual flakes can be identified but from the mass of debris they are not sorted into the context of production. On the other hand the individual preforms abandoned at a quarry carry some information about knapping practices and certain errors can be identified. Some errors, such as crushed impact platforms, cannot be identified on preforms sufficiently to calculate an error rate. But preforms give good information on flake detachments, such as hinge fractures, where some terminations are problematic for further knapping. There are collections of knapping features on preforms which are capable of recording the process and decisions taken in knapping.

In my study I equate a low error rate with efficient axe making and describe errors in terms of hinge fractures. Where there are many on a preform, axemaking has inefficient behaviours because of developing problems of mass removal. There may be other efficiency traits in axemaking but they are difficult to determine clearly at this level of axemaking. Hinge fractures are visible on the surface of preforms as scars and on the detached flakes. Some researchers have not distinguished between hinge and step fractures (Edmonds 1989) and treated them as one category for analysis of knapping errors on preforms. I have distinguished between hinge and step fractures and classified these two types of detachment from my experimental material and quarry data. Hinge fractures and step fractures are distinguished as being deviations from the knapping of...
feather termination flakes, where there is a complete detachment and consequently less of a problem with mass removal. There is less certainty of the process producing the step fractures than the hinge fractures, so I have maintained a distinction between step and hinge fractures on the basis of: (i) the hinge flakes resulted from inadequate force from the percussor; and (ii) the step flakes had causes in the raw material as a metamorphosed and laminated sediment. Step fractures are less clearly the result of knapping error.

In summary, predictions for symmetrical shaping and efficient behaviour in axe making at the Gulgong and Warren quarries can be assessed from features of the flaked stone identified in the reduction sequence. The identification of relevant stone attributes is not clear cut from the studies of stone tool technologists. But the subtractive nature of stone tool technology gives guidance on those features which are both accessible and relevant to my study. The stages of reduction represent an assessment of the degree of value-adding stone axe manufacture. This assessment operates within a framework of stone technology and the organisation of production. To assess this situation, some distinction must be made between directions in knapping. Control in knapping can be related to skill, which is not invariably an efficiency trait, or to the practice of a routine in production. The method of accessing this behaviour from the archaeological record is discussed in the following section.

7.4 Reduction sequences at Gulgong and Warren quarries

Although the general model for reduction presented in Chapter 2 applies to the processes at both the Gulgong and Warren sites, there are differences in how the reduction is carried out at each site. In this section I will describe each sequence for Gulgong and Warren. My approach to establishing the reduction process at the quarries is to adopt and adapt the results of other relevant experimental axe making.

In Table 7.1, I show how my stages relate to previous work by Newcomer, Burton and others. This general structure is incorporated into the production and use-life trajectory of axes as the blocking out from extraction, shaping and the thinning of advanced preforms. The selection and extraction of stone at the quarries will precede this stage. The reduction sequence and the production trajectory will be revised and modified from observation and analysis of stone working at Gulgong and Warren. These revisions will be incorporated in the discussion on the three stages of reduction. The proposed reduction sequences for Gulgong and Warren is given in Figure 7.7. The differences between the two quarries will be discussed below.
7.4.1 Gulgong quarry reduction sequence

**Blocking out** and primary trimming are the first stage of reduction in axe making. At Gulgong the raw material selected was a block which was extracted from the outcropping rock. The extracted block required some form of primary modification before it could be handled and worked into a preform. This stage may have been carried out by a block on block bashing against another large or fixed block, as is described for Lowes Mount quarry by Baker (1987) and for Mount William by McBryde (1984). Large hammerstones may also have been used in this part of the reduction. The result of both techniques was the production of massive waste flakes. These waste flakes may have been large enough for axe blanks, although they were not necessarily a suitable shape for axe manufacture.

The objective of this stage in reduction was the blocking out of material to reach a form which would enable one axe to be produced from the piece of material. The size of the piece in this stage should have been small enough to be held with one hand and struck with a hammerstone held in the other hand. Experiment and observation suggests an appropriate size is between 180 and 250mm, with a weight of less than 1200 gm. This part of the production process is likely to follow an observation by Crabtree (quoted by Gunn in Swanson, 1975): 'early stages of removal are often of a random nature in both size and character'.

The output of the blocking out stage (stage #3) that is, the state of the worked material at this point along the reduction continuum is recorded in my analysis of worked stone from Gulgong as 'block'. From experimental data, Burton (1980, 133) has described the massive flakes trimmed from the block at this part of the reduction sequence as typically measuring 100 x 100 x 50mm (L-W-T). The characteristic flakes of these reduction stages are illustrated in Figure 7.8.

In the second stage of the reduction sequence, the 'shaping' stage, flakes are struck from a block by direct percussion with a hammerstone. As a result, it is expected there would have been a series of thick, squat flakes, typically wider than they are long (Figure 7.9). These flakes will comprise a high proportion in the assemblage compared to the massive flakes that typify the first stage of reduction. The squat flakes of the blank preparation stage are recorded by Burton (1980) from his experimental bifacial flaking to measure 50 x 100 x 20mm (Figure 7.8). Newcomer (1971) described this stage as having consistency in the flakes removed. The flakes tended to be thick and wide with well developed bulbs and cones of percussion. Flakes fitting
the expected criteria can be observed in the assemblage at Gulgong and also occurred in the experimental work with stone from that quarry.

The third stage of reduction is described in my classification of axe preforms at Gulgong as 'advanced'. By advanced I mean predominantly thinning flake scars can be observed on all sides of the biface. The number of flake scars is high and dorsal ridges are visible even on small thinning flakes. The flakes tend to be thin, typically less than 10mm. for fine grained material, and either as long, or in some cases longer, than they are wide (Figure 7.10). Burton (1980) noted that flakes at this stage of his axe reduction sequence measure about 100 x 50 x 5mm. This shaping and thinning stage was commented upon by Newcomer (1971) as being characterised by long, thin flakes with the scars and ridges of other flakes on the dorsal surface. In Newcomer's analysis of the flake debris the characteristics on the dorsal side are key attributes, as well as their size or length/width ratio.

This part of the reduction sequence results in a preform axe ready for grinding. Further flakes may also be taken to remove the flaking ridges and make the grinding process quicker and easier. These flakes will be thin and small, occasionally long, but mostly short, and the PFA (that is, the point of force application) for flaking behind the ridge. Of all the flakes associated with axe production, they are the least likely to be found on a quarry site.

7.4.2 Reduction sequence from sources at Warren

The reduction sequence at the Warren quarries differs in a number of respects from Gulgong (see Figure 7.1). At Gulgong the extracted block is broken from the rock outcrop of suitable material. In contrast, at Warren loose blocks suitable for reduction are available as loose rubble and extraction is not necessary. The other aspect of the Warren reduction sequence that differs from Gulgong concerns the production trajectory of the blanks from the shaped blocks. A large flake or a shaped block can be used as a blank for axe preforms. The use of large flakes as axe material was observed by Witter (1992b) and appears more common at Warren than at Gulgong. At the same time, blocks formed cores for the production of flake tools. I observed single platform cores on the quarries at Warren, which were probably formed at an early stage in the reduction sequence.

After the selection of blocks, the first stage of reduction resulted in a block suitable for shaping to a blank for an axe, or a core suitable for producing flakes. Since in many cases blocks for the blanks are loose stones, the massive flakes removed will
have cortex on the dorsal surface. Due to the nature of the raw material at Warren and the irregular shape of stone at Gulgong, blocking out would have required less effort and fewer flakes at Warren.

The **second stage** of the reduction sequence at Warren is characterised by the presence of early bifacial flaking and the detachment of flakes. I have recorded this stage of reduction as 'shaping' in my observations and analysis of the axe preforms on the quarries. The flaking removed a large portion of the cortical surface particularly from blocks detached along fissures. These have fewer fresh surfaces than stone detached from quarried outcrops. The resulting workpiece could be hand held for reduction knapping with a hammerstone and the debris was comprised of a series of thick, squat flakes with a higher proportion in the assemblage than the massive flakes, which come from an earlier stage of reduction. The squat flakes of the blank preparation stage were recorded in Burton's (1980) experimental work to measure 50 x 100 x 20mm. The flakes tend to be thick and wide with well developed cones of percussion.

I have classified the **third stage** of the reduction sequence for the stone at Warren as 'advanced' because the working on the stone suggests only light dressing along edges was needed to prepare an edge for grinding. In some cases the shaped stone could be used as an impact tool with a strong edge without any grinding. In technological terms the blank was advanced to a preform because the small flake size made for a frequency that gives many small, thin flakes. There would have been many dorsal ridges for the small size of the (whole flake) debris. The bifacially shaped preform shows many flake scars, with smaller platforms than in early reduction and struck closer to the edge. When a preform reached this stage of the reduction sequence little more work took place at the quarry.

The abraded and worn slabs at the Warren quarries suggest that manufacturing processes continued into edge grinding. Grinding is stage 6 of the reduction sequence. At Gulgong there are no indications of grinding on the quarry site. Nearby units of coarse material do not have abraded grooves or rubbed surfaces. At Warren, the Little Mount quarry has signs of grinding on slabs of the rock. Here the same material was used for the axe preforms and for grinding.

**7.5 Experiment as a method of approach to the analysis of debitage**
I introduce the use of experiment in the evaluation of axe making at the quarries, with discussion on objectives and the constraints on achieving them. My approach to investigation of efficient behaviour in preform manufacture at the quarries is to identify and record relevant attributes and features. These attributes and features are given for preforms found at Gulgong and Warren in Table 7.2 and for the flakes from excavation in Table 7.3. The focus of the study of quarries can be either the flakes or the preforms. Phagan (1976, 33) argues that flakes should be used for analysis of the technology in manufacture, because they have more technological information.

In a subtractive technology such as stone working, the ventral surface of the flake is the mirror image of the outer surface of the core or blank. With stone axe making this outer surface is removed in further reduction. Consequently, information on the continuum of the production trajectory is contained on the flakes, whereas the face of the core or axe preform contains information about which specific point or stage in the reduction sequence the artefact was abandoned (Newcomer and Sieveking 1980). The status of preforms found on site is established by study of their surface for features which suggest the reason for abandonment (Leach and Leach 1980). In this way, most of the preforms are 'rejects' in the process of axe making, in that no further work was performed on the object. The presence of rejects abandoned on the site does not mean that they would not have been recycled in some way, including being reworked as axes.

In my study of the nature of production at the quarry which considered both flake debris and preforms, 'debris' and 'debitage' are interchangeable terms referring to the waste lithic material found at sites, including quarries, and not satisfactorily defined outside of the context of their findspots (Crabtree 1972, 32; Shott 1994). A 'preform' is a more specific tool type than a 'blank' and whereas both are artefacts, a 'preform' is shaped and worked along a trajectory towards completion (Crabtree 1972, 49). Study of both flakes and preforms will give better understanding of the nature of production at the quarry. What my approach needs is a set of expectations as to relevance, so that 'significant selections can be made from the infinity of characteristics potentially present in the body of empirical material being studied' (Binford 1972, 249). Before I can evaluate the archaeological material and range of features available from these, some guidance on the expectations must be developed. This can done through experimental trials with archaeological material (Sankalia 1964; Malina 1983).

The measurement of flake attributes and the analysis of variables is the usual way to treat experimental data and archaeological assemblages. In any collection of flaked stone there is a multitude of possible attributes to record or measure. In this
situation recording attributes becomes a question of selecting those which are of relevance to the inquiry. Shennan (1988) recommends recording more than enough features from the flaked stone, to allow for shifts in which variables are considered relevant. In contrast to this approach, guidance in identifying relevant features comes from experimental stone knapping.

The experimental production of stone tools is not solely the replication of stone tools used by people at different times and places in prehistory and offered as modern day demonstrations of the tools and skills. Archaeological inquiry uses experimental archaeology to generate testable hypotheses and suggest fruitful lines of investigation. Well-formulated questions can then be followed by sound data collection.

Experimental archaeology provides an opportunity for generating inferences about the meaning of archaeological data from sources that are independent of the archaeological record (Amick and Mauldin 1989). The resulting expectations are then contrasted with the archaeological material as the basis for interpretation (Binford 1981). This is an interactive process. My strategy for experimental stone work is exploratory and based on recognition models. Recognition models are found as patterns from data through experimental archaeology (Amick, Mauldin and Binford 1989). The approach allows for limited observations, but the recognition model is quantitative and operates to make the problem capable of analysis. I follow this approach in collecting data related to the testing of my hypotheses.

What question can be reasonably asked in a situation where experimental archaeology takes place? There may be particular difficulties where the modern experimenter works in an isolated manner using the raw material known to be used by prehistoric stone knappers, but has none of the skills nor the context of the stone workers in prehistory. The casual workings of modern stone knappers must be organised firmly in a framework where a research question can be investigated. The question must be relevant, in spite of the difference between modern and prehistoric stone workers in terms of skill and the imperatives of economic and social life.

Under these circumstances replication of artefacts is a modern skill rather than investigation of a whole technology set in a social context. For example, the replication of a stone axe is an activity that demonstrates the skill of the modern stone knapper rather than the technology of axe production and methods of manufacture used by the stone workers in prehistory. There is no equal order of skill between the modern stone worker and the knapper in prehistory. Much experimental work is done with little or no experience of the working properties of the particular stone resource. In fact the
modern stone knapper may structure experiments to find the working properties of stone known to be used as tool-stone. For the prehistoric stone worker the problem is different. As Collins (1975, 24) points out, a knapper in prehistory is a member of a cultural group and will gain an intimate knowledge of the stone materials in particular resource bases. However, he or she will not have a generalised knowledge of all possible raw material properties and the appropriate manufacturing techniques.

7.5.1 Objective of the experimental archaeology.

I undertook to evaluate actions in knapping related to manufacturing an axe through the early stages of reduction. It was not my purpose to knap a complete advanced preform from the block but to tackle specific aspects of reduction in an ad hoc, but not uncontrolled, fashion. Obviously in a subtractive technology (as described by Deetz 1967) it is not possible to complete the advanced stage of reduction, before passing through the other two stages. But it is possible to knap parts of reduction sequences on parts of already partly reduced axes. This is possible only where early stages of reduction are specifically tested and some from the early stages are used later.

The purpose of the experimental work conducted on the raw material was (1) to test the reduction sequence proposed for axe making at the quarries; (2) to evaluate the efficiency and degree of control found in the axe making process at the quarries. The basis of the reduction sequence came from experimental work by Newcomer (1971), Burton (1980) and Edwards (1989). Their reduction sequences concentrated on the stages after extraction, where the hand held axe preform is shaped and reduced to the point where it can be ground. Since my reduction sequence is based on the range of activities from selection and extraction of raw material through shaping to grinding, I needed more information on the early stages not specially addressed by these Ethic specialists.

So the defined goal of the experiment must be something that is achievable given the limitations of the situation. This does not mean that the experimental work cannot connect with important questions in archaeological research. The experimental work is on how the early stage of reduction relates to the whole production trajectory. My objective was to define the early stages of the reduction process from the experimental material and not to describe the full reduction sequence. I therefore concentrated on the 'blocking out' and 'shaping' stages which were knapped from the Gulgong stone, and these stages were linked with the extraction process.
At the early stages of reduction in a quarry of solid rock outcrops (like Gulgong), extracted material is selected and effort is invested in the knapping process. Because only irregular shaped blocks are available, the knapping behaviours are going to follow a flexible pattern in these early stages of reduction. The early stages are often uncontrolled and haphazard, but it is at this point that the knapping behaviours will decide the suitability of the selected stone for further reduction. The success at setting the pattern of reduction on the irregular shaped blocks will reduce the number of blocks which are abandoned, and the ease with which subsequent reduction can take place. Later stages of reduction will focus on preforms in which the effort invested has accumulated. The last stage of reduction requires flaking where control does not result in damage and abandonment from heavy reduction and difficult removals.

7.5.2 Experimental archaeology at Gulgong and Warren

Experimental stone working on material from Gulgong and Warren was conducted in four separate sessions. These four are listed below and then described.

1. Gulgong extraction experiments at Gulgong. The session was directed to the extraction of solid blocks from Gulgong material outcropping from rock exposed by a road cutting. The object of this work was to test the potential of extraction using direct heavy hammerstone reduction.

2. Warren material experiments at the commercial quarry. The session used large blocks extracted from solid rock outcrops to test reduction with heavy hammerstones.

3. Gulgong material experiments at Gulgong. The objective of this session was to concentrate on the initial reduction of heavy blocks. The work was designed to be done with hammerstones.

4. Gulgong material experiments at UNE-Armidale. The object of this experimental session was to test the Gulgong stone in the early stages of reduction. The session used the skills of three stone knappers from UNE and was designed to collect data on the reduction of preforms by direct percussion.

The work I did at the four experimental sessions is discussed below:

1. Gulgong extraction experiment on site at Gulgong.
This session was directed to the extraction of solid blocks from material exposed by a road cutting located at the south end of the quarry site (see Chapter 4). The object of this work was to test the potential for extraction using direct heavy hammerstone reduction. Firing as means of extraction was not included in the trial.

My expectations were for direct percussion extraction to be possible, but for little control over the outcome of this initial detachment. From the raw material available and the requirements developed for raw material selection (see Chapter 5), I recorded the results of the trial in terms of how many pieces would be suitable for entry into the reduction sequence (see Figure 7.11). Not all of the stone at the point of detachment will be in the condition needed for passing to the blocking out stage (stage 3). My expectations were based on the features of size, shape and quality, that is the presence or absence of flaws in the raw material. I expected to select stone above a size of 250mm in length with a regular shape and no flaws in the surface of the raw material. The size above 250mm included any stone large enough to be broken into two pieces which could both be shaped into axe preforms. A 'regular' shaped block would need few detachments, mostly of promontories, before becoming a suitable hand held piece for stage 3. An 'irregular' shaped block is more likely to be greater than 250mm. The pieces of stone selected were recorded in size, shape and quality.

2. Warren material experiments at the commercial quarry

I conducted the trials at Warren to detach about 6 blocks suitable for selection as blocks for stage 3 of the reduction sequence (see Figure 7.12). The experiment was directed towards finding if the direct percussion technique could extract stone of the type used at the Warren Aboriginal quarries by detachment from rock outcrops. I selected those stones suitable for axe making. The session used large blocks extracted from solid rock outcrops at the quarry to test reduction with heavy hammerstones rather than the use of fire. Angular rocks were chosen for detachment of the raw material with local hammerstones from the quarry.

3. Gulgong material experiment on site at Gulgong.

For this experiment I worked with Patrick Gaynor (PG) on two blocks of the raw material from Gulgong (Figure 7.13). The objective of this session was to concentrate on the initial reduction of heavy blocks, which were expected to provide the stone to enter the third stage of my reduction sequence, that is 'blocking out'. The material would be selected for further reduction and the value-adding process continued.
The work at this stage was designed to be done with hammerstones, rather than using firing to reduce the raw material. The first block was tested to see if it could be split into two useable pieces of stone for axe making. The hammerstone work was done with the stone resting on the ground and then supported and steadied by myself and PG (Figure 7.13).

4. Reduction experiments at UNE-Armidale on material from Gulgong.

The 14 experiments were carried out with a team of three knappers and three assistants (see Figure 7.14(a)). The knappers were: Patrick Gaynor (PG); Graham Knuckey (GK); and Warwick Pearson (WP). Of these three, only Gaynor had experience with the raw material from Gulgong. Patrick Gaynor and I had already worked some material at Gulgong in the experiment on heavy reduction of blocks (see 'Gulgong material experiments at Gulgong' in section 3). The set up and recording of the work as it was in progress was done by myself (RSC), Malcolm Ridges (MR), and Matthew Fischer (MF).

The stone reduction and knapping for each experiment was recorded on a worksheet, which contained input details of the stone used, the persons involved and the special features of the experiment. Table 7.4 gives a list of these input details with a brief comment on the conditions affecting these inputs. The input details recorded were those considered important for the experimental work planned. The attributes recorded in the trials are listed in Table 7.5. Experimental stone knappers have commented on the important influence of the size and condition of the stone to be used as a workpiece (Patterson and Sollberger 1978; Sullivan and Rozen 1985; Odell 1989). In my experimental work I have recorded the weight of the selected stone at the start of the trial and at the end. I have also recorded the condition of the stone in terms of shape as either round or angular, whether the stone is flawed and the occurrence of surface cortex. In Table 7.6 I have shown the data on attributes from the fourteen trials conducted.

One important feature of collection and analysis for this part of my research program was to record the actions of knappers and process of axe making to give data in the stages of reduction. The aspects of the activity recorded were related to possible variation in stoneworking performance and the reduction sequence. I used the information recorded to determine the knapping 'events' taking place in the trials. The actions which make 'events' are listed in Table 7.7.
The experimental work was set up on a concrete area outside UNE's Archaeology Department (Figure 7.14(b)). Two knapping units, three metres by three metres, were made by laying out plastic sheets and dividing it by another sheet hung vertically. The sheets were used to catch the flaked material from the reduction work. They were then cleaned and the debris bagged. The ground sheets were divided into metre squares with the view to recording the spatial pattern of flaked material but this has not been pursued in the subsequent analysis. From my observations, most flakes fell within one metre of the workpiece and most were close to the block being worked. Very few flakes flew off the workpiece and travelled metres of distance.

My choice of format for the set up and equipment excluded the approach to stone detachment from large blocks where inertia was increased by setting the workpiece in a hollow in the earth (Phagan 1976; Baker 1987). In the UNE experiments two heavy blocks of concrete were set on the sheet to be used as anvil rests for some of the large blocks used in the reduction experiment (Figure 7.14(b)). Occasionally someone steadied the workpiece with their hands. The weight of a person assisting the process in this way increased the mass of the workpiece.

The choice of hammerstones was made from a selection of available raw material from Gulgong and stones from other sources. Only Gaynor (PG) used the same hammerstone throughout the experiments: a piece of dense quartzite the size of a large fist. The other two knappers experienced some difficulty with hammerstones breaking in use, although the Gulgong material held fast. A steel hammer was used in the trials as a means of breaking an impasse, when the reduction could not be achieved by stone hammer. The use of the steel hammer allowed for progress to another aspect of the reduction sequence.

The recording and assigning of actions in knapping to stages in reduction was done by means of 'events', after which the debris was bagged. Before the start of the experimental work, I had some idea of the types of actions which could form an 'event'. These actions came from observations of other experimental stonework, and some introspection on what pattern of actions would lead to a culmination and then change in the knapper's activity. A knapping 'event' is a series of consecutive flake detachments intended to produce a result in shaping or working the stone. The result, such as establishing a bifacial edge or bevel end, will vary depending on the problem.

I recorded the number of hammerstone strikes or blows on the workpiece in each event. These knapping strikes were delivered by short blows and only rarely with a full arm swing, which is mostly associated with block on block using an anvil.
this work the hammerstone was held in one hand, and only on one occasion was a two
handed grip used for part of a reduction event. Within each stage of reduction there
were typically between 2 and 5 events (Table 7.7). Usually the event leads to work
being directed to another part of the preform or another aspect of the reduction problem.
The events recognised are based on either the effect on the preform, such as working
along a bifacial edge and shaping the bevel end, or the relationship of the knapper and
toolkit to the workpiece. An example of this relationship is the selection of one
hammerstone to work with and the change to another hammerstone.

In the results of experimental trials, the flake debris from events was grouped
into the relevant stage of reduction. My expectations in allocating events to stages were
that: (1) several events are found in any stage of reduction; (2) the number of events in a
reduction stage will vary between experiments; (3) early stages of reduction will have
different collection of events from the late stages of reduction. So for example, in the
complete sequence of reduction for the shaping and mass removal of stage 4, I expected
to record the following events, although not necessarily in this order:
1 shaping of the bevel end
2 bifacial working of one edge/margin
3 bifacial working of second edge
4 return to bevel end
5 shaping butt end
6 mass removal from mid portion of the surface

The knapping 'events' recognised and recorded in Table 7.7 from the
experimental work diverged from my expectations to some extent, and I have modified
my data collection to allow for this situation. These collections were recorded and
formed the basis of the analysis of flaked material from the experiments.

The results of the experimental trials are discussed from the recording of flaked
material, which I have classified as follows:

(1) The shape of flaked material (angular blocks) in the early stages of
reduction. In this classification the flaked material produced experimentally was
divided into two classes: either flat thin flakes, or angular blocks.

(2) Flake size measures (LWT) in reduction stages. In this classification the
whole flakes were selected for study.

7.6 Results of experimental stone work
I have presented the results of the experimental stone work in the four sets of experiments.
1. Gulgong extraction trials at Reef Road, Gulgong site
2. Warren at Mount Foster commercial council-operated quarry
3. Gulgong on raw material at Gulgong
4. UNE using material from Gulgong site.

7.6.1. Gulgong extraction experiments on site at Gulgong

The results of the trials on the rock at the road is that all of the selected blocks, that is detachments from the rock, are angular blocks. In these 5 blocks there are 2 blocks measuring less than 250mm in length. I classified one of the detached pieces as flawed and two as irregular in shape. The flawed material would not be selected for further working as axe stone, because the pattern of flaws would prevent successful extraction of a block suitable as an axe preform. The irregular shape of detached raw material was recorded at this stage to show when the further working of the stone is needed between extraction and the blocking out stage. The length and weight of the selected raw material is given in Table 7.8.

7.6.2. Warren material experiments at the commercial quarry

At the Mount Foster gravel quarry I conducted experimental trials on blocks of the quartz feldspar porphyry material used for axe preforms. The rock was already detached from the quarry face by the commercial operators.

The initial detachment from the large block was difficult and only achieved with local hammerstones in two cases. Two other detachments were made with a steel hammer, weighing 2.5 kilograms. This action gave me two small pieces of stone suitable for making axe preforms. These four blocks are described in Table 7.9. Three out of the four stones were angular blocks, struck from large blocks or outcrops of rock. One piece struck with the steel hammer was suitable as a flake for making an axe. An axe could be made by unifacial flaking of the stone. The result of the trial was that suitable axe material was detached from the boulders, but the process was difficult and needed techniques associated with heavy reduction, such as the use of large two-handed hammerstones or possibly fire.

7.6.3. Gulgong raw material experiments on site at Gulgong
This was the first experiment conducted to test the working of the Gulgong raw material. Some of the output of the first experiment was subsequently used in the experimental knapping trials done at UNE. The results of the reduction for stone of 80mm in length or more are given in Table 7.10. From the first block there were 35 pieces detached measuring 80mm or more in length. Of these large pieces 27 (77% of the total) were angular blocks of the shape expected from the early stages of reduction. In the second trial the large block did not split to produce pieces suitable for passing into the 'blocking out' stage. There were no blocks longer than 250mm in the 14 pieces recorded as greater than 80mm in length. As with the Gulgong extraction experiments at Gulgong (#1), the angular block material formed the majority of the detached stone. There were 12 (86% of total) pieces of stone with angular block shape.

7.6.4. At UNE using material from Gulgong

I have divided the results of the experimental trials on the basis of three sets of data which I was able to collect during the trials. These classes relate to (1) the shape of the debris, (2) the flake measures and (3) flake terminations of the stone detached during the experimental trials.

(1) In the first set of results discussed, the angular block material is classified on the basis of dimensions which compare with other descriptions. The range of this continuum is from angular block to flat thin flakes.

(2) Flake measures of length, width and thickness (LWT) in reduction stages are the basis of data on squat and long flakes, and on thin and thick flakes.

(3) Flake terminations described in the literature on knapping experiments are the basis of my focus on hinged flake fractures.

(1) Angular block material in the early stages of reduction

The flake shape was recorded to test the importance of angular block stone where this shape of stone is predicted to be most frequent from early stages of reduction. Experimental work on the early stages of reduction of axe preforms and cores often report angular block material being produced from the process (Baker 1987; Bucy 1974). The flaked material (>30mm in length) from the experimental stone working of Gulgong material is classified as either flat and thin in shape or as angular block material (see Figure 7.15). The results of the experimental stone working included stone classed as flat thin, and angular block is shown in Table 7.11 which
gives the shape classes by the experimental events in which they were made and Table 7.12 in which a summary and totals of the events and the number in each morphological class are presented. There are about equal numbers of each class of angular block (49%) and flat-thin flake. The angular block material is classified by the stage in the reduction sequence, including where material is extracted from the rock outcrop.

From the experimental data I have tabulated the number of large flakes and blocks and present the data in Table 7.13. The results show the production of blocks of stone flaked during experiment which are large enough to be used for making preforms. These blocks are generated in the early stages of reduction and suggest suitable blocks are available, but the production is uncontrolled in that the original block is the intended preform output. In this circumstance, blocks in the Table can be treated either as waste or as potential axe preform material. The blocks selected are greater than 180mm in length because the weight and mass of the stone suggested that this was suitable as material for an axe preform.

In Tables 7.14 to 7.17 the flakes in different stages of reduction are shown separately, and show as charts in Figures 7.16 to 7.19. The results are most helpful where the experimental work has been most directed. The data recording for the late stage in reduction (Table 7.17) is not the purpose of the experimental stone knapping. What the extension of the experimental working of stone to the advanced thinning stage does is help to complete and confirm the whole reduction sequence. The early stages of reduction are well represented by fourteen experiments, and it is here that most of the data is recorded. The numbers of angular block material and flat-thin flakes are recorded in each reduction sequence and suggest a reduction from extraction (58% of total flakes), through blocking out (44%), to shaping (39%).

(2) Flake measures of LWT in reduction stages

Data was also collected on the whole flakes derived from the experimental work in order to compare the results of experimental work by Newcomer (1971) and Burton (1980) in flint material with the hard rock material used at Gulgong and Warren. This data is contained in Tables 7.18 to 7.21. For my study I chose the flakes which had been detached in one piece from the block, and were intact so that a three-way measure could be made.

Table 7.18 summarizes the squat and thin flakes in the stages of reduction. Tables 7.19 to 7.21 of the experimental stone from Gulgong describe the squat and thick flakes in the early stages of reduction. Table 7.19 gives the squat and thin flakes
in the extraction stage, Table 7.20 in the blocking out stage and Table 7.21 in the shaping stage. These are the events of the fourteen experimental pieces of stone used in the analysis, classified by their stage of reduction. This scheme allows for broken debris in the extraction stage at the quarry to include some reduction material from unwieldy blocks of stone. The trials at Gulgong in Reef Road produced this class of stone. So after the heavy reduction which I class as part of 'extraction', there is the 'blocking out' stage. At the blocking out stage, typically the stone is reduced with the thick squat flakes being produced. In this process of reduction, a lot of angular block material is produced along with some massive, thick squat flakes.

I began my test by looking at the early stages in reduction, which have thick, squat flakes, wider than they are long. The length, width and thickness were recorded and ratios of flake width to length and thickness calculated. The record of the experimental work in Table 7.18 has been placed into six classes which are divided along a continuum from squat and thick to long and thin based on length, width and thickness measures (LWT measures). Four of these classes refer to a relationship between the width and the length, and two refer to the thickness in relation to length. Squat is defined as length less than 0.67 times the width. These measures are designed to compare with the flake shapes and sizes from the experimental reduction sequence proposed (see Figure 7.1). Burton (1980) described squat flakes as having a length about half that of the width. In my observations and trials a length of two-thirds the width (0.67) seemed more appropriate for the collection of data to be analysed from the hardrock quarries. 'Long' is assigned when the length is more than two times the width. Table 7.18 also describes these flakes in terms of the relation of the length of the flake to the thickness. Flakes whose length is more than four times the thickness have been classified as thin flakes. Edmonds (1989) used the relationship of flake length to flake thickness as a register of control in knapping.

As expected, the squat flakes (<0.67) comprised as 51% of the total LWT measured flakes. Squat flakes are wider than long, with very few measuring long in relation to width. Only 5% are long by more than twice their width. The flakes from the blocking out and shaping stages are what Newcomer (1971) and Burton (1980) have described respectively as the massive flakes and thick, squat flakes. The 'thick' flakes are 58% of the total.

(3) Hinged flake terminations in the reduction stages

The type of flake termination is often seen as an indicator of the degree of control exercised by the stone knapper in tool making (Phagan 1976; Bucy 1974; but see Shott 1994). Certain knapping behaviours will result in the error free detachment of flakes, such as where feather terminations from the margin of a preform will cross the
surface and detach mass. Other actions will result in more time and resources being needed for detachment of mass, without there being any certainty of successful detachment. Mass which has not been detached can be difficult to remove. The undetached mass forms from an increasing number of hinge fractures along the margin of the preform. In some cases hinge fractures can be a calculated part of the knapping strategy. Crabtree (1972) describes a process of 'precision thinning' in which a series of hinge flakes are made from the margin and then removed from the other margin. The axes from Moondarra quarry in north-west Queensland are reported to be made on a large hinge flake which is subsequently reworked to form a distinctive discoid axe.

My expectations for the production of hinge flakes in the experimental trials were that they may or may not be produced from the process of reduction. At this point in the trials the expectations I had were partly conditioned by the skills of the knappers. The state of knapping skills leaves a dichotomy and degree of ambiguity which is difficult to control in an experimental situation. My assumption has been that the experimental knappers exercised a lower level of control than the prehistoric axe makers. This assumption is based on the knappers lack of experience in working with the raw material. Under these conditions I predicted a random pattern of detachments of flakes to be produced from the experimental trials. The results are not entirely random.

In Table 7.22, the hinge flakes from the three experiments are broken down by the extraction, blocking out and shaping stages of reduction. There are 10 hinges recorded which is 6.3% of the total of flakes produced in these stages with measurable flake features (LWT) (see Figure 7.20). These few flakes struck provide a limited basis on which to discuss the expectations for knapping control in the stages of the reduction sequence. Measurement details (LWT) of the flakes with hinges are given in Table 7.23. Predictions from the value-adding economic model are for hinge fractures to be more frequent in the early stages of reduction. The results of the experiments suggest hinging increases from extraction to shaping, although there is none recorded for the advanced thinning stages.

7.7 Experimental trials and comparison with archaeological data

My experimental work was designed to deal with two main questions. These are (1) to confirm the structure of stages in the reduction sequence; and (2) to assess the degree of control in knapping practices.
To deal with these questions I identified flake features in the raw material. In particular, flake features important in my analysis are: (1) angular block shape, compared with flat and thinner flakes; (2) squat and thick flake shapes compared to long and thin flakes; and (3) hinged flake detachments. From this data collected in the experimental workings, I structured the study of archaeological data to include the recording of these flake features.

I have used the theme of efficiency as one of the bases of the thesis. What is now required is the criteria for efficiency to be set up for evaluation. Predictions from the value-adding economic model will guide the choice of variables recorded. In the value-adding economic model, efficiency in axe making is identified through control in the knapping of flake features. I have treated features of the stages of reduction as a first step in the evaluation of efficiency. In contrast, the experimental trials used in my research are not designed to test symmetry. Symmetry is a guiding factor in the exchangeability of axes.

The experimental archaeology was designed to work through the reduction sequence stages. The experiments gave important data on the points at which significant steps in value-adding are taken. In the experimental knapping I recorded data on control in knapping. The control of knapping and efficiency traits are important within the economic model proposed for the movement of axes. In my approach to the evaluation of efficiency through knapping control, hinge fractures are an important indication of the degree of control.

Data on the angularity and squat shape of flakes was collected. The simple classification of stone on the basis of angular shape or flat shape was used in both experimental trials with the raw material and in evaluation of the archaeological material. This simple classification is described in its four parts in Chapter 4. The squat thick flakes, long thin ones and massive flakes of the reduction sequence are recorded from the experimental flaking. Collecting the data on these flake features forms a strong theme through the experimental work and the archaeological flaked debris.

7.8 Data from the research at Gulgong and Warren

The data from the quarries at Gulgong and Warren was collected with the objective of evaluating control in the making of axes. I have hypothesised this control in manufacture as having two distinct purposes: (1) efficiency in the making of the
preforms, and (2) symmetry in the shaping of the axes as products for exchange. Symmetry has been discussed in Chapter 5 and I evaluate efficiency in this section.

The source of data on the efficiency of axe making at the quarries in east Australia is in the archaeological material found (1) as flake attributes and (2) as axe preforms. First, the flake attributes will be discussed in relation to the archaeological material and the experimental data. Second, the axe preforms will be discussed. Expectations from the economic model have guided the choice of variables recorded as relevant to the problem. The variables recorded for the survey and excavation material shown in Table 7.3 and the features recorded for axe preforms shown in Table 7.2 have been discussed previously.

The first step in the evaluation of efficiency is to predict features of the stages of reduction in the reduction sequence. Whether the manufacture of bifacial stone tools takes place in all stages at the quarry can be established by the stage of reduction of the abandoned preforms. The quarries at Gulgong and Warren have scatters of blanks in various stages of reduction, much as is described by Holmes (1894a) for quarries in North America. The existence of abandoned axe preforms on the quarry sites is fortunate for understanding manufacturing stages. Without the abandoned preforms, the stages of axe making would have to be inferred from experimental stone working and flaking debris at the quarries. With the axe preforms abandoned in manufacture, the reason for abandonment and problems of production can be examined.

In preform manufacture and distribution where the activity is part of a value-adding economic transaction, the reduction stage analysis gives information on efficient behaviour and the degree of control exercised by the Aboriginal stone workers. This feature is important in the production trajectory. Control over the shaping and thinning part of the manufacturing process will reduce the error rate and so the amount of corrections necessary on the preforms. Control will also reduce the number of preforms abandoned in the late stages of reduction. The result of flake detachment at these stages is a flake scar on the axe preform, usually running from the margin of the biface to the medial mass. In a situation where efficient behaviour guides the axe making, then it is predicted there will be control over the flaking process and the resulting flakes. The expectation for the archaeological material is that recovery flaking will be avoided and there will be knapping practices which do not result in hinge flakes. My study of axe preforms from Gulgong and Warren records features of control in knapping in three stages of reduction.

7.9 Knapping control in the axe making
In addition to the recognition of stages of manufacture, experimental work has helped archaeologists gain insight into the degree of control exercised by ancient stone knappers in the production of various flaked tools. I now need to consider the extent to which these experiments have provided useful measures. My experiments have provided data on (1) the reduction stages; (2) the shape of flaked material, as either angular or block; (3) the character of the flakes struck, from the squat thick flakes to long thin flakes; (4) the features of raw material in terms of flaws and ripples; (5) the knapped features of flakes in terms of the condition of the PFA and fractures, such as hinging. These measures are used in the following section to test predictions about the economic model of transactions.

The degree of control exercised in the manufacture of stone axes will be important in discussion of efficiency and the distribution of axes through economic transactions. By 'control' I mean the knapping actions of the stone workers in relation to the detachment of stone from the workpiece. Many of these knapping actions have been described in the experimental archaeology trials and made up the events of the stages of reduction. The fracture process results in a path based on two waves of force created by percussion. One wave is longitudinal. In this case fracture takes place by tensile stress in the workpiece, that is the pulling apart of particles of stone at right angles to the plane of fracture (Speth 1972, 37). The other force wave is transverse, producing tensile stress in the work material at right angles to the plane of fracture (Faulkner 1972, 77).

Although Edmonds (1989) used ratios of flake thickness to flake length to investigate the degree of control, generally accepted flaking features found in core tool technology have not been unequivocally established for stone axe manufacture. But stone axe manufacture is a subtractive technology and much of it is a bifacial shaping and thinning process, where flakes produced conform to the types found in other tool types. So I take the conclusions of research in other areas of stone tool technology as relevant to stone axe making. In experiments using glass as a raw material, Dibble and Whittaker (1981, 295) attribute the type of flake termination to the (exterior) platform angle after initiation of the flake. The type of flake terminations recorded include hinge fractures.

Control in production can be registered through the incidence of stepped and hinge fractures. A hinge fracture at the distal end of a flake terminates the fracture at right angles to the long axis with rounding at the end. Step fractures also have right angled terminations, but without the distinctive rounding found in hinge flaking.
These flake terminations are recorded on flake debris at Gulgong and on abandoned preforms at Gulgong and Warren. For the preforms at Gulgong and Warren the total number of flakes struck from the surface is also recorded. The total flakes struck gives an indication of the amount of knapping work which has taken place on the preform, and can be related to the number of stepped or hinge fractures on the workpiece.

The presence of step and hinge fractures is not the only register of control in the knapping process. Two other features were recorded on the debris at Gulgong. One of these features is the condition of the PFA platform on waste material at the quarry. Where the PFA is crushed, the platform has been damaged by the force of the flake detachment blow. Intact platforms are recorded where found, and often provide a width measure for the distance of the impact point from the flake margin. The other indication of control is more tentative and concerns the ripples or undulations found on the ventral surface of flakes. These undulations may be due to inadequate force in detachment of the flake (Cottrell and Kamminga 1990). The occurrence of these ripples is recorded on flakes in the archaeological material.

In the interaction between the workpiece and the force applied, the fracture process is the basic element in the system of production technology (Moffat 1981). Phagan (1976, 9) identifies three groups of controllable variables. These relate to (1) the core (or preform), (2) the force, and (3) the interaction of stone. Some of these are important in my study of the production technology and nature of production in the stone axe quarries at Gulgong and Warren. Firstly in terms of the core, the controllable variables concern its geometry. According to Bucy (1974, 24), core geometry largely determines the shape of the flake removed. But in the production of axes, the need for a flake of specific shape is limited by the extent the flake removed will contribute to the shaping of the core as a preform. If the core shape is important, as for bifacial preforms, then the core geometry need only be controlled sufficiently to achieve fracture along an intended path. So for the production of stone axe preforms, it is the resulting shape of the core after flake detachment that is important.

Secondly in the force variables, Phagan (1976) considers the angle, the amount and the duration of force. I have assumed that the angle, (ie the direction of force) and the amount of force will influence knapping control in production. The effect of inadequate force amounts and poor force direction have been recorded on stone at Gulgong and Warren. Inadequate force amounts result in hinge fractures, sometimes with ripples along the fracture surface (Muto 1971, 58; but see Shott 1994). These flake attributes are recorded for flakes from Gulgong and Warren. Inadequate amounts
of force associated with step and hinge fractures, are also implied when flakes are thick in longitudinal cross-section. This flake attribute has not been specifically recorded for flakes from Gulgong and Warren, although flake thickness at the mid-point should give some indication of inadequate force.

The result of excessive force is observable on the impact part of the platform where the PFA is crushed (Figure 7.21). The crushing of the PFA destroys the surface of the platform, the bulbar apex and the ring crack. The condition of the PFA is recorded for worked stone at Gulgong and Warren as (1) 'PFA found' (2) 'crushed PFA', or (3) by means of a 'platform width' measurement. In contrast to the situation where inadequate force results in step and hinge terminations, the application of optimum amounts of force will result in feather terminations. Here there is no abrupt termination to the flake as is found in hinge and stepped fractures. As a result, I expect a high proportion of feather terminations and a low incidence of broken (stepped and hinge) terminations will indicate the presence of optimum control of force.

In contrast, if there is a high proportion of hinge fracturing, then the question is, why? Phagan (1976, 96) suggests hinges are more common when certain types of flake were produced. For example, a wide long and thin flake can easily go wrong. In practice it can be difficult to control the amount of force such that it is generated and contained within an optimum range. Control is easier with relatively small amounts of force, but can become a problem where intended flake size detachments are large. The adequate use of impact is a problem in hand axe manufacture and results in a high proportion of hinged and stepped flakes in production debris at the Gulgong and Warren quarries.

As described by Phagan (1976), controlled lithic fracture relies on the relationship between core mass, the fracture area of the intended flake, and the mass of the percussion flaking tool, such as a hammerstone. Direction and amount of force are important influences. To produce a fracture in the workpiece, the transmission of force from a hammerstone into a core must have the effective force applied in a particular direction and in adequate amounts. During force application the core must be stable, but in much implement production the core mass is relatively small in relation to the flake removal force required. In this case core or blank stability can become a problem, so inertia may be needed to improve the fracture process. The inertia of an object is directly proportional to its mass, with the consequence that larger mass has greater tendency towards stability and requires a larger force to move it. Consequently, the increased core or blank mass and the greater stability will give greater inertia that can stand the required force for a successful flake detachment.
Reduction strategies have been developed to overcome the problem of inadequate mass. Mass can be increased by a number of means ranging from tightly hand-holding the workpiece, or wedging the core or blank in a tree stump, to the use of the anvil technique. In the anvil technique the core becomes the mass in motion and the speed of the strike is directly dependent on the mass of the core or preform. Of these techniques, tight hand-held working has been attempted with experimental material from Gulgong. Phagan's comments on the problem of control in knapping are accepted as relevant to the anvil technique (Phagan 1976, 30). The other aspect of the interaction of force and mass, the size of the hammerstones used, will be discussed in Chapter 8.

In summary, the value-adding economic model predicts a low incidence of hinge fractures for axe making at Gulgong and Warren. If these fractures are production errors, rather than the natural fracture pattern, then efficient behaviour traits suggest there will be a low error rate. The incidence of hinge fractures is proposed as a measure of efficiency which can be recorded from the archaeological material at the quarry. Hinge fractures are not the only features which can give guidance on the degree of control and efficiency in behaviour. The condition of the striking platforms, where the PFA is crushed or intact, the presence or absence of ventral ripples on flakes, and the stepped fracture terminations also gives some guidance. These features are used in testing the efficiency of preform manufacture at the quarries.

7.9.1 Results from preforms recorded on transects at Gulgong and Warren

My purpose in this section is to: (1) compare the reasons for abandonment of preforms between the two quarries in relation to the stages of reduction; and (2) test the extent of hinge flaking found in the stages of reduction at the quarries. These features are important in efficiency found in the material from Gulgong and Warren. My experimental trials suggest stages of reduction are not achieved at the same rate for every preform (see Tables 7.14 and 7.15). Instead, the reduction is flexible and depends in part on the chosen workpiece. As a result some stages on one block will take longer and present more problems than the same stage on another block of raw material.

My expectations for hinging on the preforms is that knapping control as a factor in efficiency will determine the number of hinge fractures at the stages of reduction. Comparison between the stages of reduction is based on the results of hinge fractures in the experimental trials.
Study of the preforms found across the quarries gave data on 293 preforms at Gulgong and 199 preforms at Warren. These preforms have been classified according to the technological and stone knapping features appearing on their surface; the results appear in Table 7.24. The features on the surface identify the point where abandonment in the production trajectory has taken place. I have recorded the reasons for abandonment as (1) transverse snap, (2) edge damage, (3) mass removal, and (4) raw material flaw.

In this classification most axes at Gulgong (56%) were abandoned because of edge damage. This reason accounts for 40% at Warren, which is about the same as for transverse snapping (41%). Edge damage is due to excessive or misplaced stone removal, which makes the recovery and further symmetrical reduction of the preform impossible. Technologically this problem can be minimised through the use of appropriate knapping techniques. Unremoved mass on the middle area of the face of preforms at the quarries was recorded for 23% at Gulgong and 19% at Warren. The recording of mass remaining on the preform with no other apparent reason for abandonment suggests this can present problems in removal sufficient to warrant abandonment. The reason is the subtractive process has not resulted in a mass of stone removed. Instead there is mass in the middle part of the face for which the knappers have decided there is no means of removing without causing damage, which would then result in abandonment. However, Hayden describes mass removal work being done on grindstones (Hayden 1987).

The exposure of a flaw in the (otherwise) homogeneous formation of the rock cannot be recovered through knapping (Figure 7.22). Up to the point where raw material flaws are exposed, there is nothing on the surface of the stone by which I have classified the preform as abandoned. At Gulgong 9% had raw material flaws. In contrast, at Warren there were no raw material flaws exposed through flaking on the preforms at Little Mount quarry. This result was expected at the volcanic blockfield and homogeneous rock outcrops at Warren, where I did not observe flaws in the rock and loose stone. The existence of flawed material on preforms and flaked debris is a useful property for the archaeological analysis of stone. The importance of raw material flaws will be discussed in relation to hammerstones (in Chapter 8). Whereas these flaws are found at the Gulgong site, the use of them in analysis is not available at Warren.

The other notable feature of the recorded preforms from Gulgong and Warren is the difference in transversely snapped preforms on the two sites. At Warren 41% preforms are transversely snapped, where at Gulgong 12% are snapped.
This summary of the main features of abandoned preforms at Gulgong and Warren must now be placed in a more rigorous framework for analysis. I did this by recording the preforms as they occurred in the surface survey transects taken across the sites at Gulgong and Warren. The sample from the transects across the quarries provided 217 useable preforms from the total of 341 at Gulgong, and 125 preforms along the transects from the total of 199 at Warren. The data collected on this basis for Gulgong and Warren is given in Tables 7.25 and 7.26, in which my classification of the reason for abandonment given in Table 7.24, is cross-referenced to the stage of reduction deduced from the experimental work described previously.

7.9.2 Results from preforms at Gulgong and Warren on hinge fractures

In the evaluation of efficient behaviour for making of axes, I have proposed that the degree of control exercised by stone knappers can be measured by the extent of hinge fracturing. Hinging is not the only flake termination regularly found in archaeological material. Flake terminations can be feather or stepped. In my study of the flaked surface of preforms at Gulgong and Warren, I recorded the total number of flakes struck from the preform at the point when it was abandoned, and the number of stepped and hinged fractures found. In my analysis I have concentrated on the extent of hinge fractures. My reason for this is related to the causes attributed to the hinging and stepping found on stone. Edmonds (1989) study of the Great Langdale axe quarry in Cumbria combined stepped and hinge fracturing together for the purpose of analysis. But in one way, damage found on flaked stone (such as shatter and crushing) will more often look like stepping than any other form of termination. This creates an ambiguity in the flaked stone material which cannot readily be resolved, even through experimental trials. The classic stepped termination described by Cotterell and Kamminga (1990) is not easily identified in many archaeological assemblages and the cause of the damage remains ambiguous. Notwithstanding the cautions attached to the causes of hinge fracturing (see Shott 1994), I have therefore used the incidence and extent of hinging as the indicator of knapping control.

The summary Table 7.27 shows differences in the incidence of hinged and stepped fractures between the two quarries with a high incidence of hinged flaking marks on the preforms from Gulgong. This must be compared with Warren where only 6.6% of fractures are hinged. These results are important, as my expectations regarding efficiency are for the degree of knapping control at Gulgong to represent the distribution of axe preforms as an economic transaction. The low incidence of hinge fracturing on preforms at Warren further contrasts with my expectations from the value-adding economic model of exchange. The high incidence of stepped terminations on
preforms at Gulgong and Warren (89.6% and 72.0%) also creates ambiguity in interpreting the results. These results indicate that a more detailed analysis is required.

The number of hinged fractures for all preforms recorded are shown in Table 7.28. The preforms recorded at Warren have no more than two hinges on each preform and the great majority (94%) are without hinging. At Gulgong a wide range of variation in the incidence of hinging was observed.

The data from the transects confirms the more general observations. The numbers of hinge flakes on preforms from transects at Gulgong and Warren are given in Table 7.29. At Warren there is a paucity of hinge fractures and all of these occur in the classes with one or two hinges on each preform. In contrast, the preforms from Gulgong are spread across the range of hinge classes, although this spread is not even. These results for the transects are grouped in frequency classes in Table 7.30. In Table 7.30, 75% of the preforms from Gulgong have from 1 to 4 hinge flake scars, and 15% have no hinge fractures recorded. Only 10% of the preforms at Gulgong have more than 4 hinge terminations and most of these, that is 7% of the total have 5 hinges. In terms of the axe making process at the quarries, knapping control results in a high incidence of hinged flakes at Gulgong and a lower frequency at Warren. At both quarries most preforms have stepped fractures.

Although hinge fractures are an indication of the degree of knapping control, hinge fractures are not always the cause of the abandonment of a preform. Abandonment is the result of mass removal problems, edge damage, and transverse snapping (see Table 7.24). The hinge fractures on the surface of the blank register the need for correction in thinning and finishing before edge grinding (Bucy 1974, 7), but they are not the reason for abandonment of the preform. Nevertheless, hinge fractures provide a register of efficiency. The amount of hinge flakes at Gulgong found in terms of the stages of reduction should give a good measure of control. The shaping and thinning stages of reduction at Gulgong contain a higher percentage of hinged flakes than the early stages and a higher percentage of preforms with more than four hinged flakes (see Tables 7.29 and 7.30). The flake mounds are mainly debris from extraction and blocking out.

If hinged flaking occurs in later stages of reduction, then the low incidence of hinged flakes in the flake mounds at Gulgong is to be expected. The extraction of stone and the early stages of reduction is characterised and numerically dominated by angular blocky material and this is the majority of stone in the flake mounds. The reason for the low incidence of hinged flakes is that the reduction stages where the hinged flakes occur

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(that is in the late stages of reduction) are worked at points adjacent to the flake mounds. Here there are many small flakes eroding out of the hillsides (see Table 7.33). The flakes are mostly flat and thin and a high percentage are hinged compared to those in the flake mounds. Hinged flakes are rare in the flake mounds, where extraction material is found and the blocking out process takes place. Hinged flakes from the late stage of reduction are found in the surface scatter of small flakes which erode from the hillside adjacent to the flake mounds.

What does it mean for control in the knapping process to have signs of hinge flaking on preforms? Bucy (1974) comments that hinge flakes are produced by hard hammer percussion, and this fits with what is known of late stage reduction at Gulgong. The preforms may have hinge marks due, not to inadequate control, but to insufficient force being applied through the hammerstone. In other words this application of force was restrained rather than overloaded with the result that fewer preforms would be damaged in the late stages. The flaked axe preform would have had ridges and portions of the stone where it was difficult to remove the material. As a circulating item of the material culture, the acceptability of a preform is not impaired by the hinged flake marks on the surface.

In summary, the high incidence of hinged fractures on the preforms at Gulgong, and the low number recorded at Warren contrasts with my expectations for knapping control at the two quarries. The value-adding economic model suggests that efficient traits in axe making will reduce the number of knapping errors and this is expected as a strong feature for Gulgong, when compared with Warren. Yet at Gulgong, there is not only a high incidence of hinge fractures on the preforms, but 4 out of every 5 of the preforms show the repeated production of hinges.

7.9.3 Results on control from the surface survey and excavation of GFM1 at Gulgong

In this section I am moving the discussion of hinge flakes and knapping control from preforms at the quarries to the flakes found as debris. In three of my experimental trials on material from Gulgong, I recorded the incidence of hinge fracturing. The results are given in Tables 7.22 and 7.23. The stages of reduction and size of the hinge flakes were recorded. There were only 10 complete flakes with hinge fractures (6.3%) recorded from 158 flakes capable of LWT measures. Most of the flakes were thin and less than 50mm in length, with a long, rather than squat, shape. Hinged flakes were recorded in the blocking out and shaping stages of reduction. My expectations for hinging as an efficient trait in axe making could not be tested in the later thinning stage
of reduction because only one experimental trial was conducted in the last stage of reduction and no hinged flakes were recorded.

Additional data for study of the hinged flakes recorded at Gulgong came from (1) the excavation of four squares on the main flake mound, GFM1 (EG5 in Chapter 4) and (2) the surface collection of flaked stone from the 10 x 5 metre area adjacent to the main flake mound (SG6 in Chapter 4). The purpose of drawing data was to compare the results from these two points at the quarry where there appears to be different stages of axe manufacture taking place. I will begin with the results from GFM1 and then discuss data from the 10 x 5 metre surface area.

(1) Results from excavation at GFM1. Very few hinged flakes were recovered from the excavation squares at GFM1 (EG5). The summary of excavation squares at GFM1 gives worked debris totalling 9154 pieces (above 20mm in length) counted and classified in my analysis. From this worked debris I have identified flake attributes from which variables used in my analysis are drawn. In Table 7.31, I have presented the numbers of worked stone pieces recorded with hinges, ripples (or undulations) and PFA attributes, such as crushed, or intact.

Hinges are recorded here as 1.9% of the total of worked stone. Only 0.7% of the flaked material from the excavations had ripples on the ventral surface. A few are on flakes with hinging and this may suggest their association with questions of control of force in knapping, but the role of these undulations and ripples is uncertain. The value of undulations as an indicator of knapping behaviour requires experimental study (see Cotterell and Kamminga 1987; 1990).

The crushed PFA is a flaking feature often associated with hard hammer percussion of hard rock material (Bucy 1974). In my study of the nature of production at quarries, the behavioural traits associated with the condition of the impact point in stone flaking is recognised as valuable. The indication of the adequacy of force in stone flaking can be recorded as a crushed PFA, or as one intact with a certain platform width. Crushed and intact impact points are found in all four squares excavated at GFM1. In Table 7.32, I present a comparison between one excavation square and the total for four squares excavated.

The incidence of PFA was high in the worked stone from GFM1. Most important is the comparison of the frequency of crushed PFA with intact platforms. There are 39% of the flakes with PFAs which were crushed in detachment of the flake from the block or preform. There are a few flakes (9%) with a platform sufficiently
intact to measure the width at the point of impact. This percentage of the PFA refers to the stone debris that can be identified as a flake with flake measures of LWT and not for the total of all debris recovered from the excavation.

In the square 2C there was a large number of artefacts with PFA features. 31% of the worked stone for the square had PFA features. This high figure must be compared with 8% for the total of the GFM1 excavation. In this collection of worked quarry stone, 14% of the flaked stone in the square is a crushed PFA. This figure can be compared to the total of crushed stone for the four squares, where only 3% of the worked stone is crushed.

The low count of hinged flakes in the worked stone from the excavation squares at GFM1 is to be expected, because hinging occurs in the later stages of the reduction process. The few hinged flakes recorded are found in flake mounds with reduction debris which will be mostly from the point of extraction. The four excavation squares at flake mound GFM1 (EG5) are located on the uphill side of the main flake mound. This part of the flake mound has two anvil blocks at the edge, and my series of excavation squares run from the edge of the flake mound to one of the anvils. The debris comes from direct hammerstone reduction and anvil working. This low incidence of hinged flakes in the Gulgong flake mounds must be compared with the flaking features found on the preforms at the quarry, and in the flaked material from the 10 x 5 metre area. On the preforms the hinge scars are numerous, and often recorded on the surface area flakes.

(2) Results from surface area SG6. Table 7.33 gives the results of the collection and recording of worked stone from the 10 x 5 metre surface area adjacent to the main flake mound at Gulgong (SG6). The hinged features on the worked stone was recorded for whole flakes and other flakes and hinged features recorded on these. Of the 892 pieces of small (<80mm length) worked stone, 65 (7.3%) have hinged fractures. My purpose in collecting data from this surface area adjacent to the main flake mounds was to evaluate the features of the flakes in relation to the work done in this area. I expected that the flakes would indicate features of the late stages of reduction on the site, which are not represented in the material on the main flake mounds. In the advanced thinning stage of reduction many small flakes are produced Newcomer (1971) and Burton (1980) describe them as typically between 50 x 20 x 5mm (LWT) and 50 x 50 x 5mm (LWT). The 50 square metre surface collection area had a density of small flakes (mostly less than 50mm in length) of 17.8 per square metre. The worked stone collected from the 50 metre square was mostly (78%) flat thin
flakes. Of the worked stone 15.6% were complete flakes in that a 3-way length, width and thickness (LWT) measure was possible.

My expectation was that hinge flakes would be found in these thin, flat, flaked pieces, and that they would give data on knapping control in the late stages of reduction. One in five (20.1%) of the flakes with LWT measures had hinge terminations. The percentage of hinged flakes from all the worked stone is much lower (7.3%) and this may be expected from the inclusion of material for which it is difficult to recognise the type of termination. The hinge terminations suggest control in knapping was not sufficient to avoid production errors, and that they are found in the late stage of reduction. The hinge flake marks will remain on the surface of preforms through the production trajectory to the grinding stage. Where they are away from the bevel edge, the hinge fractures are likely to remain on the surface into use life.

In summary, the data relating to control and efficient traits in manufacture was evaluated through flake features recorded from the flaked debris and abandoned preforms at the quarry. A high percentage of hinged flakes was recorded on the abandoned preforms at Gulgong. This high incidence of hinging was not found at Warren. The flakes in the excavation square and on the surface at Gulgong and at Warren carried features associated with control in knapping.

7.10 Conclusion

In Chapter 7, I continued the analysis of value-adding economic transactions in axe production at Gulgong and Warren. My enquiry into whether axe making was efficient was done by looking at the stages in the reduction sequence after extraction, particularly in blocking out and in shaping. Efficient production is value-adding and is therefore expected with the economic model.

My expectations for this process at the two quarries are repeated: At Gulgong I expect the value-added model of efficient transactions to result in efficient knapping behaviour in relation to preform production. The error rate in flaking on the stone will be low, especially the incidence of hinge fractures (in comparison to Warren).

At Warren expectations from my model is for abandonment to take place in all stages of reduction. There is no propensity to manufacture into late the stages of reduction, compared with the factors influencing axe making at Gulgong. There will be no
behaviour associated with efficient control in knapping; error rates will be high, with frequent hinge fracturing on the flaking faces of preforms.

What has been learned from the test of the economic model for efficiency in axe making at Gulgong and Warren?

The experimental trials carried out to test predictions on preform shaping and the production of flake debris at quarry sites were limited in their goal, but valuable in outcome. I identified efficiency in axe making through flake features, and the more general process of value-adding was followed through the reasons for abandonment of axe preforms. The traits indicating efficiency in behaviour in the flaked debris from the experimental trials were elusive, especially the hinged fractures. The subsequent analysis of the flake material from the archaeological surface survey and excavation was based on the most relevant flake features. Control is the important concept in the organisation and technology of axe making. These flake features are the relevant variables which are 'warranted' as evidence for the argument.

I used the experiments to identify stages in reduction and problems in the reduction of raw material from the sites. From the stages of reduction in the experiments I could set up criterion for recognising the stages of reduction for preforms found at the quarry. The stages of reduction could then be related to the reason for abandonment of the preforms in these stages.

The reasons for abandonment of preforms at the quarries are important in evaluating value-adding decisions in axe making. At Gulgong the model was partly maintained by the early abandonment of tested stone at the blocking out stage. But this is also found at Warren where the value-adding model was not expected to operate. The early stages of reduction (blocking out and shaping) have more damaged preforms from which a knapping recovery has not been made. At Gulgong and at Warren 4 out of 5 of the preforms along the transects are abandoned in the early stages of reduction. The testing of the raw material by heavy stone reduction results in abandonment before additional value-adding work of finishing is undertaken by the stone knappers. This tendency to test material in axe making is emphasised in the data on transverse snapping. The heavy impact knapping which results in transverse snapping occurs in the early stages of reduction. For example, most of these at Warren (96%) occur in the blocking out and shaping stages of reduction. Only 4% of the transversely snapped preforms come from the last stage of reduction.
CHAPTER 7

The tests of control in axe making did not confirm Gulgong as a quarry where manufacture was a value-adding economic transaction based on efficiency in knapping actions. Gulgong did not have low production error rates when measured by the hinge terminations on the preforms. Hinge terminations occurred in the late stages of reduction at Gulgong, that is, the point where knapping should be most controlled. These results suggest that efficiency was not a guiding factor in axe making at Gulgong, and in these circumstances the expectation of the economic model of transactions for axe distribution from Gulgong is not supported by the results.

Very few hinge fractures were recorded on the preforms at Warren, where knapping control on efficiency criteria was not expected. Where knapping practices are not directed towards producing axes as goods in a system of trade for gain, the regular production of error on the preforms should be specifically located on the surface. The hinged flaking errors at the stages of reduction are few and yet distribution of axes from the source is limited in extent and they are not symmetrically shaped.

The organisation and technology of production suggested by the study of axe making is not consistently efficient but parts of the axe making activity at the quarries are skilful. This skill is not efficient, except in a conservation sense of not destroying a preform in the subtractive process. A difference in value-adding potential at the stages of reduction is only one aspect of consistency in relation to efficient behaviour. In the axe-making process there are points where control in knapping is important for production of symmetrical axes. These points are where control decisions are made in the organisation of production. Where skill is the benchmark, these points will be recovered by controlled knapping. Where efficient behaviour guides the axe making, then the recovery of errors will depend on the value-adding prospects for the action. In these circumstances not all error situations in the preform will be recovered.
CHAPTER 8

Tool kits and specialisation in axe making

8.1 Hammerstones in tool kit technology at quarries

In Chapter 6 tool kits were evaluated in relation to problems of extraction at the quarries. Fire, lever poles and heavy hammerstones were proposed as means for detaching stone selected as axe material from the rock outcrops. The use of fire in stone tool technologies is important, but often difficult to identify. Holmes commented that 'the extent of its application in mining work can only be conjectured' (1919, 156). Since Holmes there have been ethnographic studies where firing was used to extract stone (see Cook 1982; Binford and O'Connell 1984; Petrequin and Petrequin 1993). The work of the Petrequins' in Irian Jaya records the use of lever poles for extraction in association with fire and heavy hammerstones.

By themselves, one of these tools will not achieve the required detachment. The combinations are simple. Firing was followed by leverage with poles, and then initial breaking down done with heavy hammerstones; or heavy hammerstone detachment of stone, was followed by leverage and more heavy hammerstone work. The use of leverage in extraction is associated with another physical principle, that of wedging. Apart from fire, detachment is achieved through wedges made of wood or stone before steel tools were available (Cook 1973; Hayden 1987; Horsfall 1987).

In this chapter I evaluate the role of hammerstones in tool kits used for making axes. Tool kits tell us about the technology adopted by particular human groups to achieve particular tasks. My study of tool kits is connected to the question of specialisation. Specialist tool kits are associated with skill in making objects, economic specialisation, and efficient behaviour in the production of goods. So the identification of specialist tool kits, and particularly hammerstones, as specialist equipment, is important in the evaluation of efficiency as a factor in economising behaviour found in the production of axes (Torrence 1986; 1989; Ericson 1981; Costin 1991).

Tool kits are important in the technology of axe making. The degree of specialisation in the tool kits of stone workers was used by Torrence to evaluate the extent of efficient behaviour in making stone tools (Torrence 1982; 1986). From the case study of obsidian tool making at Melos, Torrence concluded that standardisation, as well as routinised production and craft specialisation did not operate at Melos. In
contrast flexible approaches to production techniques of the industry at Melos were identified by Torrence.

Hammerstones are part of the tool kits of axe makers at Gulgong and Warren. A number of features make them useful for study. Hammerstones are more common on archaeological sites than is often supposed (see Bucy 1974; Bamforth 1986). They are more visible archaeologically than other items of the tool kit, and have more variation in their salient features than found with other tools in the kit.

Hammerstones are implements used in the making of stone tools by percussion techniques, both direct and indirect (Crabtree 1967). Direct percussion may be free-hand or anvil rested, including the casting of one stone against another (Holmes 1919). The direct percussion technique using a hammerstone is common in Australia for the making of flake tools from cores and in the shaping of stone axes. The principle of operation of a hammerstone is for the rounded or pointed part of the surface of the stone to form a point or small surface area of impact on the surface of the workpiece (Hayden 1977b). The workpiece may then have flakes intended for use detached from the platform core, or from platforms on an axe blank in shaping and trimming to a preform. The use of hammerstones is known from the Oldowayan assemblages, where Pelegrin (1990) argues the need for a degree of 'motor know-how' by the stoneworker sufficient to control the aim and the strike.

Professor Sven Nilsson conducted experimental trials on hammerstones in the early 19th century, and is quoted by Holmes (1919, 283) as saying the hammerstone was 'the greatest of all Stone Age Tools'. The importance of this statement lies in the ability of a hammerstone for making other implements, and in particular flaked stone tools. Other tools, such as digging sticks are also important in the subsistence and economies of hunter-gatherer societies. But digging sticks are used directly in food gathering and do not produce other implements. In studying the technology of manufacture this distinction is important.

Some tools are multi-purpose and others are adopted into another use when circumstances require. For example, stone adzes and axes of both steel and stone are used in this way to make other implements. Adzes can be used for shaving wooden objects, such as the hardwood digging stick found in parts of Australia (Davidson, 1935; Gresser, 1962). Similarly stone axes have been used for shaping stone, for chopping, and as portable anvils for small cores carried for flaking. The essential feature of hammerstones as tools is in the specific and repeated use of them for the purpose of making other tools.
Hayden (1987) describes the use of stone hammers in a tool kit of stone and steel used by workers to make metates and manos in Guatemala. The hammerstones are in various shapes and sizes, some weighing as much as 20kg and others of few kilograms. All the large hammerstones are of the same type of raw material found in the metate quarry, but the small ones are of a more dense basalt material (Hayden 1987, Table 2.1). The hammerstones were abandoned on site and not cached. Holmes (1894a; 1919) also observed many hammerstones left at quarries in Mexico and the United States.

The stone for some hammerstones seems to have been selected opportunistically from the material resulting from extraction for metate manufacture (Hayden 1987). Sometimes broken metates or flawed manos were used. Worn and exhausted cores for flake tools are reported as having been used as hammerstones both in Australia and Europe (Gresser 1962; Semenov 1964). Small hammerstones of different and tougher material were also selected with care and shaped for use (Hayden, 1987). Steel tools were also used in metate making (Cook 1982; Hayden 1987), especially as levers and splitting bars, and steel axes as wedges and hammers for trimming off flakes. In some cases these steel tools were cached on site at the quarry and may be considered as specialist tools used specifically for metate production. On other occasions or in other circumstances the tools were removed from the work area at the quarry. Removal seems to be less for property protection and more because the tools were needed for use in other places (Hayden 1987). In these circumstances curation does not mean that these tools are found away from their place of use (Binford 1979; 1981). Curation resulted in hammerstones being kept for further and future use in the several places where they were regularly used. This situation has implications for the comment and observation often made that hammerstones are rare on archaeological sites (Bucy 1974; Bamforth 1986; 1990).

With a different emphasis from Hayden, Bradley and Sutren (1990) have studied the exotic hammerstones found at Great Langdale axe quarry in northern England. These volcanic hammerstones are divided into two broad groups both of which were found in the nearby lowlands. Hammerstones from each of the two volcanic groups were found in different places across the quarry face at Great Langdale. This raises a question of the control and possible restriction of access to the different quarry faces. The association between restricted access to a resource, such as an axe quarry, and the development of specialist production and the distribution from that resource is not evaluated at Gulgong and Warren through the hammerstones. The data available in the hammerstones at Gulgong and Warren is used to compare and contrast
the tool kit technology at the sites. I do this with particular reference to the evaluation of efficiency in axe making.

8.2 Predictions for value adding and efficiency in hammerstones

My expectations for the use of tool kits in making axes is based on the framework I proposed in Chapter 2. In Chapter 2, axe making at the quarries is based on output as an economic transaction. In this framework value-adding is related to the exchangeability of the axe as an output and efficiency in axe making is a factor in the control of production cost.

Hammerstones used at quarries in the manufacture of stone axes are important in evaluating the technology in production. Hammerstones used for the casual procurement of stone and manufacture of axe preforms will differ from those used in conjunction with specialist activity on the quarry site. How these expectations will differ between specialist and non-specialist activity is not just a matter of exotic, curated tool kits compared to local, expedient material. Local, expedient material may be used where actions are simple and laborious, but the whole process requires considerable planning and skill. There may be specialist activity involved, and this prospect is tested on the data available for hammerstones used at Gulgong and Warren.

I expected a quarry tool kit to provide an infrastructure of technology used in axe making. Within this technology there will be a choice in the tools used. The choice will determine both the parts of the reduction sequence, where used, and the frequency of their use. My expectations were for hammerstones to be used extensively in axe making at Gulgong and Warren. The reason for this expectation was that the use of hammerstones from the available tool kit gives control over the reduction process in axe making. The control found with hammerstones is better than found for other items in the tool kit, although the use of these others are appropriate in other circumstances. The control relevant to the relationship between the hammerstone and the axe in manufacture, is that of knapping control. This knapping control causes efficient behaviour in axe making. The achievement of efficient actions depends on the availability and use of appropriate hammerstones. The skill in selection, and organisation of the use of hammerstones by the knappers reduces the error rate in axe making.

My expectations for hammerstones at the quarries were that (1) they would reflect the value-adding economic basis of the transaction for axes, and (2) there would be efficient traits in the hammerstones and tool kits at the quarries. At Gulgong I
predict from value-adding economic transactions that some axe preforms are transferred to use as hammerstones rather than being reworked as preforms for distribution as axes. The decision is based on an alternative cost for hammerstones being made from material on site or brought on to the site. The generally tighter criteria for the axes passed into trade-driven distribution systems than for non-trade uses can be expected to result in more material being available for hammerstones. There is a consequence to the decision process for making axes for trade and this to produce rejects which pass into other parts of the production trajectory, such as hammerstones.

In terms of efficiency in production of preforms the hammerstones are predicted to be specialist tools in that they are made for the purpose and of the most appropriate impact material. Efficient production of traded axes requires few errors in production and damage leading to abandonment of the preform. For low error rates in production of axe preforms control requires these tools be special purpose. The use of specialist tool kits in axe making at Gulgong has two dimensions: (1) where abandoned preforms from the production process are used then there will be some reshaping to make hand tools suited to stone knapping, with an improvement in knapping performance and reduction of hand trauma; and (2) where the hammerstone is exotic stone, the tool will be maximised in its effectiveness for knapping by its shape and point of use in the preform reduction sequence.

In contrast to Gulgong, predictions for Warren were that hammerstones would be casually acquired from the site and they would be discarded as expedient tools.

In some ways the testing of the economic model is incomplete from the analysis presented in Chapter 7. This incompleteness is because the study of stone debris and axe preforms is dealing with a lot of material which has been through one stone knapping event and then is deposited as debris. Some of this debris will be recycled through subsequent selection, but most not. The human impact on the stone is most repeated with preforms for axes, and for hammerstones. The origins of hammerstones at a quarry can tell us about the approach to technology and efficiency in axe making by the stone workers.

My field collections from the axe quarries at Gulgong and Warren show patterns of recycling. At Warren and Gulgong axe preforms abandoned in the subtractive process are often found with pitted and battered edges (see Figure 8.1). The pitting and battering observed on the preforms were not part of the process of axe manufacture. Rather preforms were reincorporated as tools in the production cycle. An interesting aspect of the way in which this relates to the question of tool kits is in the regular, but
unintentional, production of these abandoned axe blanks as hammerstones. Certainly some hammerstones made from the site materials at Warren and Gulgong are formed out of stones with shapes outside the range of likely axe blank shapes (see Figure 8.2). These may have been adopted specifically as hammerstones, but others are modified from axe preforms abandoned in working. The problem in predicting a specific technology for making 'the greatest of all Stone Age tools' is that many hammerstones are by-products of abandoned stone from axe making. From a stock of abandoned axe preforms found on a quarry site such as in Gulgong and Warren, pieces can then be chosen for hammerstones. The tool kit is partly supplied from axe production.

The redirection of axe preforms is not the only source of hammerstones used at Gulgong. The hammerstones made of a geological unit of coarse material found on the site was not a by-product of the reduction sequence, but made specifically as hammerstones. Extracted blocks with hammerstone marks, flawed material and stones not selected for reduction are found at the quarries. My expectations for the use of this type of stone as hammerstones at the quarries are related to mechanical efficiency. Efficiency in axe production would suggest this material be adopted where the rock properties differ between the hammerstone and axe preform and that this improves the detachment of flakes from the axe stone. The different crystal structures of rock used as hammerstones, and that of the core or axe preform may give an improved detachment.

Some hammerstones from Gulgong are composed of exotic material which cannot be sourced to the quarry. For hammerstones at sites, this is not unusual. Away from quarries all hammerstones are of exotic material and often of material different to that of the workpiece. The interesting feature here was that they are found broken or damaged on the quarry, along with hammerstones made from the same type of material used to make axes. Most are water-worn pebbles or cobbles. Some show signs of other use-lives. For example, one (and possibly a second) have surfaces ground flat against the curvature of the pebble in the manner consistent with top stones or mullers used for grinding seeds in Australia.

For use in an axe making quarry, there will be some limited importation of appropriate hammerstone material. My expectation for the use of tools such as hammerstones at quarries was that axe making based on economic transactions involves the importation of suitable pieces of rock as hammerstones. The importation of exotic stone to the axe making site should give a more efficient manufacture of preforms than would be found with quarry material, in terms of knapping control and low error rate.
In one way transportation of heavy stone as hammerstones acts as a limiting factor, as some hammerstones for extraction and heavy reduction weigh up to 20 kg. Items of material culture with these weights are transported for great distances in Australia. For example, pituri is reported as leaving the Mulligan-Georgina area in 30kg packs (Horne and Aiston 1924). The indivisible weights of grindstone slabs from the Toko Ranges are of the same order (Mulvaney 1975). There is no evidence of these heavy weights being carried onto stone quarry sites. At the quarries heavy hammerstones are drawn from the local available stone and the reduction process relies on the inertia of the block against the workpiece.

From this situation I hypothesised that, beyond initial extraction using the 20 kg blocks of local stone, there is a choice and set of alternative courses of action available to the stone knappers. For some stages of reduction, hammerstones could be imported to the quarry site or they could be drawn from the available local stone. In a situation where the choice made by the axe makers is based on economic transactions, then the stone is selected in a trade-off. The trade-off is between using the partly formed pieces abandoned from the making of preforms or importing selected exotic stone. The exotic stone used as hammerstones would have to be procured and transported from other places and because of this and the access to resources, may itself be the subject of an economic transaction.

In contrast, the use of local hammerstone material is part of a flexible reduction trajectory for stone in which the effort in making an axe preform is recycled into the stone being used for a hammerstone. This may be adequate for the technical requirements of a hammerstone, but does not mean there is not better material to be found in other rock sources. So the efficient approach to axe making is not followed in this case, and there is likely to be a flexible pattern of resource use from the available material at the quarry. The number of production failures may increase, because the degree of knapping control with local material may not be as high as with the specialist and purpose-specific tools made from imported stone. The trade-off gives a larger stock of partly-formed hammerstones from the knapping regime and the tool-kit adopted. To test the efficient use of hammerstones as tools for axe making at Gulgong and Warren, the hammerstones must first be placed in relation to the tool kits expected at quarries.

In summary, the economic model of transactions can be evaluated through the tool kits found at quarries. Axe making based on economic transactions at the quarries will use special purpose tool kits. Predictions for control in axe making is based on efficient behaviour in knapping, and suggests the use of hammerstones is particularly
important in the process. In particular, there will be special purpose hammerstones used in axe making. In contrast, a flexible production trajectory is possible where stone partly worked for an axe preform is redirected in use, and is used as a hammerstone in the tool kit.

8.3 Hammerstones in the tool kits at Gulgong and Warren

Table 8.1 describes the tool kit projected for making axes at the quarry through the reduction sequence of manufacture and maintenance. This expected tool kit for each stage of reduction in the production trajectory will be compared with the tools found in association with axe making at Gulgong and Warren.

As discussed in my reduction models in Chapter 7 (Figure 7.1) and shown in Table 8.1, the tool kit expected in the reduction sequence following the extraction of stone contains hammerstones of various sizes, anvil blocks and stone slabs for grinding. The tool kit varies along the production trajectory, from the blocking out stage of reduction to grinding the artefact. Whereas the anvils are used at the early stages of reduction along with heavy hammerstones, the grindstones are used for the bevel edge in the late stage. In a flexible reduction sequence, anvils are interchangeable with hammerstones over a range of reduction and may be used at later stages to facilitate reduction. This approach to reduction obviates the need for hammerstones in some part, but the use of anvil blocks limits knapping control and increases production errors. As a factor in control in axe making and as an efficient trait in knapping behaviour, the use of anvil reduction is limited in the later stages of reduction. Along the reduction continuum, small hammerstones are substituted for large hammerstones, and the anvil blocks are used less often. These hammerstones may consist of exotic stone imported to the quarry (Bradley and Suthren 1992). When one tool in the kit is replaced in favour of another will depend on individual features of the axe preform, and the need for flexibility in the approach to the reduction sequence.

In the use-life of a stone axe, maintenance takes place away from the production point at the quarry. The process of maintenance at the campsite and in the field shapes the trajectory of the axe, either to maintain symmetry or to be recycled into other uses. The maintenance tool kit includes small hammerstones for rejuvenating the bevel edge, and portable grindstones and whetstones (Hayden 1989). These tools are not likely to be found at quarry sites. The small hammerstones may be used in the late stages of axe making, but are curated and carried away from the quarry to be used in maintenance activities. The portable grindstones and whetstones are not at axe making quarries,
unless there is a retooling program incorporating the quarry site (Torrence 1983; Gramley 1984).

In Table 8.1, hammerstones are predicted to be the most frequent type of tool. They are expected in production stages from extraction to maintenance and rejuvenation, but most items of the tool kit are specific to particular stages of axe making and maintenance. Hammerstones are also specific to stages of reduction and so there is more than one type in the stoneworking tool kit. For example, the heavy hammerstones used in extraction which weigh four kilos or more must be used with two hands against the worked stone. There are also small pebbles used in the late stages of reduction, which are used for hand-held reduction of the workpiece. The heavy hammerstone used in extraction would not form any part of the reduction practice used for the thinning stages.

**In summary**, data on tool kits used by stoneworkers at quarries gives guidelines on what tools are to be expected at the axe quarries.

### 8.4 Properties of hammerstones

The interface between the workpiece in shape and raw material type and the hammerstone size, shape and raw material type is crucial to the knapping process and the making of a stone tool. The properties of a hammerstone are important in terms of lithic technology, fracture mechanics and manual feasibility. For example, the force loading needed to detach a flake will relate to the hammerstone through size, shape and crystal structure of the impact implement. Hammerstones of various sizes are used for detachment in different parts of the reduction sequence and for different tasks. For example, hammerstones for the flaking of cores are often small pebbles, whereas axe blanks require more substantial hammerstones.

Hammerstone shape is important in two aspects. Firstly, the holding and use of an impact tool creates trauma in the hand and the knappers grip must be changed to relieve this. Secondly, for particular techniques of work on stone one shape of hammerstone may be more successful than another. For example, the removal of flakes from an axe preform requires impact with a rounded edge, usually created by battering, whereas the hammerdressing by pecking on the surface of an axe will require a stone with a more pointed shape at impact. The grain size and crystal structure is important where the hammerstone must lock on to the workpiece for flake removal. In some cases the raw material of the workpiece is suitable in grain size and crystal structure for
the hammerstone as well (Baker 1987). In other cases, a raw material of different grain size and crystal structure will be used as a hammerstone.

Because of the various origins of hammerstones, the means for recognising worked stone used for this purpose needs guidelines. In the raw material I recorded as blocks and preforms there are worked stones with features inconsistent with reduction in an axe making trajectory. I recognised anomalies in the supposed preforms and the worked stone at the sites, by the shaping and flaking pattern found on them. To identify hammerstones in the preforms and other worked stone at Gulgong and Warren, some well-defined recognition criteria were needed. The problem was aptly put by Hayden (1987), where the trihedral point identified by him on the large hammerstones at the metate quarry was offered as an ideal form for a hammerstone type. But as Hayden points out, this ideal is less strongly formed in other worked stones used as hammerstones by the metate makers. So there is some need for the criterion used for recognition to be sufficiently encompassing to cover the range of hammerstones used, without there being too much ambiguity between what is solely an axe preform and what has been used as a hammerstone.

Hayden's (1987) study of criteria for selecting picks (pics) used by modern Maya metate makers gives a basis for determining the properties of hammerstones. The criteria may be summarised as: (i) The hammerstone material must indent the stone of the workpiece; (ii) it must keep a good cutting edge and not crush on impact; (iii) this cutting edge must be capable of shaping and resharping, so the material must flake to an edge but holds it under impact; (iv) the breaking of a hammerstone under impact is also related to the degree of internal flaws and fracturing; (v) the picks must be shaped or capable of shaping to be hand held, either single or double handed, and the grip must avoid hand trauma or allow repositioning, otherwise it will not be chosen (The preferred shape of a triangular cross section was not always found in the pics); (vi) size, like shape, is important ergonomically for the operation of hammerstones, and Hayden observed large boulders being selected and broken into smaller pieces.

Hayden concluded his ethnographic observations that hammerstones were selected with care. The stone in the case of small single or two-handed hammerstones, had a different toughness and hardness than the stone material that came into contact. The hammerstone material showed much greater compressive strength than the grindstone material (see Hayden 1987, Table 2.1). The applicability of these hammerstone properties for the stones at Gulgong and Warren is evaluated in the data for recognition of stone used at these quarries.
8.5 Criteria for recognition of hammerstones at quarries

When the field survey of Gulgong and Warren quarry was done and the axe preforms were studied, I observed features on the stones which were inconsistent with making preforms for axes. For example, many of the axe preforms had battering and marks which did not form part of the knapping pattern found in the reduction stages for an axe preform. The observed battering on the parts of these preforms and type of flake fractures suggested hammerstones had been used for making of axe preforms. In the case of Gulgong these stones were too irregular in shape to be axe preforms, and sometimes were made of a coarse material not used in axe making. The battered stone blocks I observed had very often started as axe preforms, but at some point in production, they had been damaged and then abandoned. These damaged preforms were only abandoned in terms of no longer being part of the reduction sequence for axes. The damaged stones were taken up by the stone axe makers as hammerstones and used in the reduction of axe preforms.

For a quarry such as Gulgong, where material for hammerstones comes from the same source as the preforms, there is a problem of recognition. The large blocks used as hammerstones in extraction are likely to be selected on a casual and opportunistic basis. The shaping to a trihedral point found with large hammerstones at Hayden's quarries in Guatamala is not found at Gulgong. The reason for this lies in the technology of extraction and stone reduction, and the organisation of stone procurement. In the technology of extraction at the metate quarry, the sharp (ideally trihedral) point removes large flakes of waste stone. In Mexico at the metate quarries studied by Cook (1982), the removal of these flakes is done by pointed iron bars. As Hayden points out, the type of reduction on the metates requires this shape of impact implement. But at the Gulgong stone axe quarry the large blocks used for heavy reduction do not need to be (trihedrally) shaped to a point. Detachment from the impact of the hammerstone can be achieved by inertia on a flatter and more blunted distal end surface than with the large hammerstones for metate quarrying. This form of detachment was confirmed by my experiments at Gulgong (summarised in Table 7.22).

The other reason for the differences between the metate quarries and Gulgong axe quarry lies in the use of large blocks of detached raw material as stone for making axe preforms. Recognising large hammerstones (above 10kg in weight) is a problem with quarry sites. Hayden (1987) recorded large hammerstones of the same raw material type as the metates used in the early stages of manufacture. Some of these were metates abandoned in the early stages of manufacture (see Cook 1982).
Under these circumstances large blocks of stone capable of withstanding repeated battering as hammerstones will also be implicitly tested for suitability as axe stone. Within this work regime any stone which gives way through flaws and incipient fracture planes will probably not be selected for axe stone and will often break up to the point that it is no longer recognisable as a hammerstone. The result is a low level of visibility for the large hammerstones at the quarry. Few will be found either intact, or with only minor damage. This damage is usually a large flake or two detached from the distal or proximal end without any pattern associated with the reduction of extracted blocks for axe preforms.

Exceptions did exist, and these combined with my experimental trials provided some guidelines in the recognition of large hammerstones at Gulgong. For example, two hammerstones were recovered from the excavation of the extraction face (see Chapter 6). One near the surface was small and made on the same raw material type as the preforms (see Table 8.2). The other hammerstone was large (4.75 kg and 295mm long). This one was made from a geological unit of the local coarse grain material found on the quarry site, but not used for axe preforms. The hammerstone was found with battering and some large flakes detached from the distal end.

Semenov (1964) offers evidence for the use of stone as hammerstones from two features of an implement used in this way: (1) the margin is battered and blunted by blows and (2) there are lighter blows on the mass and bulges of the surface. Bucy (1974, 26) describes the battering of hammerstones on portions of the surface as having characteristic flake scars. The flake scars often have either split cones or several small bulbs of percussion along edges and prominent parts of the mass.

The criteria I have established for the recognition of a hammerstone at Gulgong and Warren are a development from the features recognised by Semenov (1964) and Bucy (1974), and are guided by the discussion in Hayden (1987). My criteria for recognising hammerstones are (1) battering along the margin (that is, the edge) or the ends of the worked stone (Figure 8.3); and (2) in some cases heavy reduction damage to develop at either, or both, the distal and proximal ends (Figure 8.4). The battering along the margins is a series of small conchoidal fractures and platforms, somewhat like that received by cobbles against rocks in the sea-shore. Where they are preforms from the trajectory of axe making and then adopted as hammerstones, the flaking features of the preform shaping are overlaid by the battering. The heavy reduction damage at the ends of the worked stone block is like the damage described for the large hammerstone blocks at the metate quarries.
The hammerstones weighing less than about 4kg are likely to carry signs of battering. This is because the smaller ones can be held as single handed tools, or where they weigh more than 2kg they can be held as small two-handed tools. These types and sizes of hammerstones can be impacted with the axe stone by rapid and repeated short blows. It is this action which results in a battered edge or end to the hammerstone. The battering on the hammerstones at the quarries were recorded as occurring on the stones at 1, 2 or 3 points (Figure 8.5). The details of the battering recorded are given in Tables 8.2 and 8.3 for Gulgong, and in Table 8.4 and 8.5 for Warren, and summarised in Table 8.6.

The cases of three battered points will always include one end and one edge. The hammerstone is used by turning it to different striking faces, which suggests the hammerstone is a tool which develops and changes in use. It may be rejuvenated by flaking and resharpening (see Hayden 1987), but there is no sign of this on the hammerstones from Gulgong and Warren. Nevertheless the hammerstone does get worn. At Warren, Towle (1939) reports rounded, disc shaped hammerstones where the entire edge would have been created by battering. Figure 8.6 illustrates hammerstones from Warren rounded by battering.

The larger hammerstones are less likely to be battered along the edge, and more likely to show heavy reduction damage at the ends. The second criterion of heavy reduction damage is more appropriate as a means of recognition for these large hammerstones. The effect of the damage is for large flakes to be removed and this will often obliterate the signs of repeated battering.

I recorded large hammerstones greater than 250mm long and the weight for those greater than 2kg because: (1) The 250mm length follows the idea used for axe preforms to be hand held as blocks for reduction, and (2) the 2kg weight allows for the movement from the upper limit of single hand held hammerstones being at a maximum of about 1.5 kg, and a range of two handed hammerstones at above 2kg in weight. Table 8.7 presents data on the large hammerstones recorded at the sites.

In summary, criteria for recognising hammerstones at the quarries can be established. These criteria come from what is known of their working properties and use in other stoneworking situations.

8.6 Hammerstones in the revised production trajectory for Gulgong and Warren
My initial expectations for the quarries led to a simplified reduction sequence for the manufacturing stages of axes (see Figure 2.1 in Chapter 2). The need for a tool kit to make axes, and the generation of stone debris, including abandoned preforms, suggests it is an incomplete picture of the process of axe making. At the quarries stone is shaped as preforms to be distributed as symmetrical axes. Many of these preforms are damaged and do not attain, or retain symmetry. Under these circumstances the axes may be withdrawn from symmetrical reduction and may be recycled into some other use, such as hammerstones for making axe preforms. My initial observations at the Gulgong and Warren quarries suggested there may be some reuse of the preforms rejected during manufacture.

In one way it should be possible to predict that a trajectory of axe making would incorporate hammerstones, as well as symmetrical axes. The output of a production trajectory gives material shaped to be an axe, or the stone could serve as a hammerstone. In Table 8.1 the expectations for tool kits shows some hammerstones at the quarries should be made from the type of rock used for axe preforms. A number of these hammerstones of the same type of stone used for axe preforms will be derived from the production trajectory.

As a result the hammerstones used at the quarries are often the same type of stone as the preforms, and are part of the same reduction process. As blanks pass through the reduction sequence, their shaping to axe preforms will sometimes result in damage. At this point the preform may be used as a hammerstone in the production of axes. The conversion of axe preforms to hammerstones can take place at any stage in the reduction sequence, and occurs at both Warren and Gulgong (see Figures 8.7 and 8.8). On this basis, the reduction sequence in the production trajectory will contain hammerstones as by-products of every stage of reduction.

The production trajectory shown in Figure 2.1 of Chapter 2 describes the production of axes and the paths of processing for the axes. The production trajectory for the making of axes and their distribution into use-life describes the selection and working of raw material along a path of increasing symmetry into use-life. Throughout the production trajectory which I proposed, the axe makers evaluate the progress of the axe in terms of its symmetry. At some points, and on the occurrence of some events, axe preforms are withdrawn from the trajectory of symmetrical shaping in axe making. The destinations possible from the events occurring in the production trajectory, are described in Chapter 2 (Tables 2.2 and 2.3). The trajectory divides at points through selection and extraction to maintenance and rejuvenation in use-life, and some axes do not follow a direct path of symmetrical shaping and then into distribution. The preforms
withdrawn from the trajectory of symmetry are abandoned in my classification of preforms on the quarry sites.

The effect of using the damaged axe preforms as hammerstones is to extend the production trajectory proposed for axe manufacture to include the hammerstones. So, one possible outcome of initiating the reduction of a block to an axe preform is to produce a hammerstone. The production trajectory then includes the output of hammerstones. These redirected axe stones are found at both Gulgong and Warren. In both quarries, the abandoned axe stones adopted as hammerstones have their origin from all stages of the reduction sequence at the quarry. At both Gulgong and Warren there are stones from the stages of extraction, blocking out, shaping and advanced thinning (Figures 8.9 and 8.10). At Warren there are also a number of transversely snapped preforms used as hammerstones. These have been discussed in section 8.5 on the criteria for recognition of hammerstones at the quarries.

8.7 Analysis of hammerstones at Gulgong and Warren

The expected features on hammerstones are the basis for classifying worked stone as hammerstones. Most of these are from the production trajectory of axe making and at some point have been adopted as a hammerstone. The range of worked stones on which the hammerstone features can be recognised establishes the origin of hammerstones at the two quarries.

My classification of worked stone as hammerstones gives their origins as (1) made as hammerstones from the same raw material as that of the axe preforms (see Figure 8.1); (2) adopted from abandoned axe preforms and cores for flake tools, with little or no modification to the worked stone (Figure 8.11); (3) made as a hammerstone from raw material type found on the site, but not of the same geological unit used for making axe preforms (Figure 8.12); (4) exotic stone imported to the site of different raw material type from that found at the quarry.

The hammerstones adopted from the abandoned axe preforms were taken up as hammerstones at stages in the reduction sequence of axes. The preforms were at either (1) the blocking out stage, or (2) the later shaping and thinning stages. The blocking out stage I have described as 'from block to hammerstone' in the classification, and the later stages I have called 'from preform to hammerstone'. The hammerstones adopted from the abandoned cores are described as 'from core to hammerstone'. These
classifications are found in the data from Gulgong and Warren, and details are given in Tables 8.2 and 8.3.

8.8 Hammerstone features at Gulgong and Warren

The complete results are presented in Tables 8.2 and 8.3. The hammerstones as a proportion of all the tools recorded are given in Table 8.8. The hammerstones represent 13% of the 403 axe preforms and hammerstones recorded for Gulgong. At Warren the hammerstones represent 18% of the total of 288 impact tools, consisting of axe preforms and hammerstones. The results from the transect recordings for Gulgong and Warren give lower percentages compared to the whole sites, at 10% and 14% respectively.

More detailed information on the hammerstones recorded at Gulgong and Warren is provided in Tables 8.2 to 8.5. Location (or find spot), dimensions of length, width and thickness, as well as weight, type of material, points of battering, and their origin and trajectory as hammerstones are described. I recorded 53 hammerstones from Gulgong, and (coincidently) 53 from Little Mount at Warren in order to give as much information as possible on the hammerstones found at the site. This approach becomes valuable when the exotic stones are considered.

When the hammerstones are broken down into the transects 25 hammerstones at Gulgong and 21 at Warren are listed in Tables 8.4 and 8.5. Every type of hammerstone found in the whole site recording was also found in the transects, with the exception of exotic stones at Gulgong, where only one exotic hammerstone was noted on the transects, a piece of broken quartzite cobble. These were the most common exotics found at the quarry, although there was one quartz piece.

Battering. The criteria followed for recognising stone used as hammerstones were quite useful. In particular, the test of battering marks on the stone could be systematically used and is summarised in Tables 8.2 to 8.6. Battered margins and ends were recorded as either 1, 2 or 3 points on the hammerstone. Battering was mostly at only one point, most commonly at the distal end or at one of the edges. The proportion of the stones with only one battered point are the same between the whole site and the transects for Gulgong and Warren, with 80% for both at Gulgong, and 70% and 68% respectively for the whole site and transects at Warren. Very few of the hammerstones have three battered points, with 5% at Gulgong and 2% at Warren recorded for the whole site. There were no hammerstones with three battered points recorded along the transects at Gulgong and Warren.
The criterion of edge battering marks use for the hammerstones weighing up to two kilos was not reliable for recognition of larger hammerstones. In these latter cases irregular and heavy reduction damage acted as the guide. Table 8.9 records the few large hammerstones identified at Gulgong; there are none at Warren. Of the hammerstones recorded across the whole site at Gulgong, only 5 are greater than 250mm long. All of these weigh more than 2kg, and another 4 hammerstones less than 250mm long weigh more than 2kg. Two of the hammerstones were found in excavations. One was in the square excavated against an extraction face (see Chapter 6). The hammerstone was made of coarse grain material not used for axe making but found outcropping at the Gulgong site. The other hammerstone found by excavation was in an area of the flake mound with reduction debris and anvil stones a few metres away (see Figure 8.13). The other large hammerstones were all found on systematic surveys of the surface.

At Warren there are no hammerstones longer than 250mm, or greater than 2kg in weight. This is to be expected because the selection of stone for axes takes place from among blocks which are then reduced by removal of cortex from some faces to give an appropriately sized workpiece for axe making (see Chapter 7).

Exotic Stone. In one aspect of sampling and recording hammerstones at the quarries, there is a bias because only one exotic stone is recorded along the transects at Gulgong, but there are 11 in the recording for the site as a whole. To increase the data base all hammerstones sighted were recorded. This bias requires the exclusion of the exotic stone from the tabulated analysis, and this is done in Table 8.6. The exotic hammerstones are important material in the study of the late stage of axe making at the quarry. Leaving the coarse and fine grain hard rock material from Gulgong quarry in the sample, the results suggest that the larger sample in the whole site sample can be used for comparison between the whole site and the transects. Table 8.6 gives a summary of the more detailed Tables 8.2 and 8.3. For the whole site when exotic hammerstones are excluded, 83% of the sample is fine grain material and 17% coarse grain. This figure compares with the sample from transects where 87% was fine grain rock, of the type used in the making of preforms at Gulgong, and 13% was coarse grain material not used for making axes.

Stages of reduction. The hammerstones recorded at the quarries must be related to the stages of reduction, as a means of evaluating efficiency in use of the stone selected. In Table 8.8, I have divided hammerstones from the whole site at Gulgong and at Warren into six weight classes. The weights of the hammerstones are divided
into groups on the basis of the hammerstones used in the stages of reduction and for different knapping operations. Experimental data is not abundant on this aspect of knapping in the reduction sequences for stone axes and core tools. Cleghorn (1986) uses the same set and size type of hammerstones for his thirty replication experiments in research at Mauna Kea in Hawaii, but does not give their sizes. The hammerstones used in my experimental trials varied in weight depending on the task and the decision of the knapper. The experimental knappers tested a number of hammerstones, some of which proved unsatisfactory and either broke or were abandoned in favour of others.

One hammerstone adopted for knapping Gulgong material by Patrick Gaynor (PG) survived the whole series of experimental trials. This hammerstone weighed 1.5kg and was of a hard, tough and dense material, and not of the same type as the axe preforms being shaped. This particular hammerstone was used in the early stages of blocking out and in reducing irregularities in the shape of stone after extraction. Use for this purpose suggested that in spite of its great toughness, it was not a suitable weight for the early stages of reduction. It was however most effective in the shaping stages of reduction. This use was of some surprise, because the suggested weights for the shaping stage of reduction are twice that of the 650 gm weight for the other major manual impact tool, namely the steel axe (Dickson 1981). The butt end of a steel axe is favoured by stone knappers today as an all-purpose percussor for flaking stone. When Roy Barker (of Gongolgon, NSW) visited Warren axe quarry at Little Mount in November 1993, this was the tool he used. In the late stages of reduction and for knapping flakes from microsilaceous cores, the hammerstones are usually small and dense. The size is understandable for the fine flaking associated with this type of production and makes the hammerstone a portable item of the tool kit.

The six weight classes of hammerstones are unequal in their divisions. The divisions are 300gm and 350gm in the smaller size classes (1, 2, and 3), and 500gm in the larger size classes (4 and 5). The upper weight class (6) covers all stones above 2kg. My reason for this is to evaluate the association of hammerstones found at the quarries with their use in the stages of reduction. The divisions are based on available information from the literature and trials done with hammerstones (Torrence 1982; 1986; Dickson 1981; Bradley et al. 1992). The association of hammerstone weights to the stages of reduction is based on the weight groups given in Table 8.10.

My groupings are (1) the advanced thinning stage in groups less than 300gm, and from 300gm to less than 650gm; (2) shaping in groups from 650gm to less than 1kg and from 1kg to less than 1.5kg; (3) blocking out from 1.5kg to less than 2.0kg; (4) extraction more than 2.0kg. The data is biased because large heavy hammerstones
are not included. Hayden (1987) describes heavy hammerstones weighing more than 10kg, whereas the heaviest in my sample was 6.1kg (see Table 8.2). The effect of this was to give an evaluation of the size of hammerstones used in the stages of reduction from thinning and shaping to blocking out. The stones weighing above 2kg for use in extraction are for trimming and testing the extracted block. Detachment of axe stone has already taken place from the rock outcrop and it is in this initial detachment that heavy hammerstones of 10kg are likely to be used. The hammerstones I used for experimental trials in detachment at Gulgong and Warren weighed more than 10kg. So the data in Table 8.10 relates to hammerstones used after stone is detached from the rock outcrop. The hammerstones from Warren support this in that most axes on the site are reduced from small blocks of raw material readily available on site. Under these circumstances few large heavy hammerstones would be expected.

In Tables 8.11 and 8.12 the type of raw material for hammerstones and by implication its source is presented for both sites. At Warren all hammerstones are the same material type as that used for making axes. At Gulgong some hammerstones are exotic material from off the quarry. At Gulgong for the type of raw material used for making axes, half (18) of the total count of 35 stones are used solely and (probably) made specifically, as hammerstones. Half (17) of this total of 35, were adopted from the worked stone abandoned in axe manufacture. When the coarse grain material found on site (but not used for axes) and the exotic stone is added in, the number of stones specifically made as hammerstones and not adopted from the production trajectory increases to 68%. At Warren fewer hammerstones (38%) were made specifically as hammerstones and most (62%) come from the production trajectory for axes and for cores.

When data for the transects at Gulgong and at Warren are considered, there is an increase in the difference between the two quarries. Table 8.13 gives the origin of the hammerstones at Gulgong and Warren by the type of raw material used. At Gulgong, hammerstones made specifically of the type of raw material used for axe making forms most (57%) of the hammerstones recorded in the transects. The figure at Gulgong for hammerstones not adopted from the production trajectory increases from 43% to 64% when the coarse grain material not used for axes, and the exotic stone is included. At Warren 68% of the hammerstones on the transects come from the production of axes and cores.

At Gulgong nearly one quarter of all hammerstones are below 300gms which is less than 5% of the range of weights. The stones described as specially selected as hammerstones are not predominantly in the less than 300gm group. Table 8.11 for
Gulgong gives 25 of the stones specially selected as hammerstones, with 18 in this group being made of the type of material used for axes. The other 7 are made of the coarse grain material, which is found at the quarry but not used for axe making. Of these 25, only 6 weigh less than 300gm, with two of these being made of the coarse grain material. The other 7 hammerstones weighing less than 300gm are made of exotic stone. This situation is to be expected with small hammerstones because of their importance in the late thinning stage of reduction. The hammerstones are the type likely to be used in the late stages of reduction, where thin flakes are removed. The value of dense tough stone in thinning and finishing the axe preforms will encourage their use.

Some of these exotic stones may have been damaged and left on site, but others may be taken away. In this group of 13 hammerstones weighing less than 300gms, nearly half (7) are exotic stone not found at the quarry. The remaining 4 exotic stones at Gulgong are in the group between 300gm to 650gm. The heaviest exotic hammerstone weighs 560gms. The rest are small compared to the hammerstones made of coarse and fine-grain hard rock from Gulgong. Several in the sample recorded are broken. Extrapolating from the broken piece, there are only two which could be close to 650 gms. The damage occurs as a break across the piece, not as subtractive flaking from a block. The missing parts of the whole can be reconstructed from the remnants because the surfaces are smooth and curved or flattened. The exotic hammerstones are mostly made on pebbles with smooth surfaces. Two of these exotic hammerstones (#44 and #45 in Table 8.2) were recovered from the excavations at the flake mound (GFM1). These water worn pebbles had sides ground flat, and battered or broken ends. One was originally a top stone on a grinding dish, hence the flat ground faces, and then it was used as a hammerstone. The other may also have been a muller stone. These two were found in the excavation near the top of the hill, but within the flake mound area by the anvil stones and raw material rock outcrops.

At Gulgong there are no stones from the production trajectory for axes in the group less than 300gm, although there are two in this group from Warren. Warren produces small axes but Gulgong does not. The difference in the size range of axes made at Gulgong and Warren would explain why there are no small size stones abandoned from the preforms at Gulgong.

In summary, the results of stones analysed from Gulgong and Warren suggests the hammerstones have several origins and some are adopted from the production trajectory. The sample is large enough to give data in all classes of analysis for both quarries. The size classes of hammerstones, the origins of the hammerstones and the relationship to the production trajectory are available from the data recorded.
8.9 Conclusion on implications for axe making at the quarries

My expectations for axe making at Gulgong was based on value-adding economic transactions at the quarry where stone knappers would use special purpose tool kits. Torrence (1986) used this approach at the quarries on Melos. Control of knapping as an efficient activity would suggest that the hammerstones would be specially produced for axe making. In particular, there would be special purpose hammerstones of exotic stone imported to the quarry.

The quarries at Gulgong and Warren both have hammerstones made from the raw material from the quarry and adopted from the production trajectory for axes. The hammerstones recorded at Gulgong have few made of exotic imported material. There are no hammerstones of exotic material at Warren. Many of these exotic hammerstones are broken and in a curated technology where tool kits are not all 'site furniture' (Binford 1979; 1981), then the exotic hammerstones are likely to have been brought to the quarry and taken away with the knappers. This situation creates a problem for the analysis of tool kits and the importance of particular tool types at the quarry, since small exotic stone removed from the quarry may give a biased picture. The breaking up of large hammerstones also affects the sample of hammerstones at the quarries.

The implications of the results from Gulgong and Warren are valuable in relation to my expectations for axe making as an economic transaction. A flexible approach to manufacture will favour the adoption of abandoned axe preforms. Many of the hammerstones come from the production trajectory, and so do not establish these tools as specialist tools. These are not special purpose tools but adapted from the manufacturing of axes. The preforms and blocks I recorded at Gulgong and Warren did not show any subsequent reworking, apart from the battering at the edges and ends.

The stones used directly as hammerstones can be said to have been associated especially with the task, rather than having been abandoned from the production trajectory for axes. This stone was drawn from the reduction sequence at the point of extraction from the rock selected for axe making. But the amount of modification on these stones used as hammerstones is also often minimal. Even the modification through battering is no more frequent than is found on all hammerstones at the quarries. There is none of the shaping for reduction of hand trauma described by Hayden (1987) for metate making in Guatamala. Nor did the selection procedure favour stones which reduce hand trauma when compared to all other stone available at the quarry. The stones adopted from the abandoned axe preforms are more suitably shaped for
hammerstones than are those found as specific hammerstones, which do not come from the production trajectory for axes.

There are exceptions to the general lack of preparation and suitability of hammerstones as hand held tools. Exotic hammerstones are small-sized and suitable for the purpose of thinning in the advanced stage of reduction. These exotic stones reflect the skill of knappers in selection and use of stone. The exotic muller stone at Gulgong is one example of a tool compatible with the interaction between the knapper and the axe preform. Some of the other exotic stones are like this.

The heavy hammerstones are expected to be made from the stone found at quarries, and not imported. Efficient reduction for axe making suggests the heavy hammerstones between 500gm and 2kg could benefit from being made of exotic stone and imported to the site. The hard, high impact exotic stones would perform well in the earlier stages of reduction. Large exotic hammerstones (above 2kg in weight) are not found at the quarries, and were not likely to be removed from the sites as a curated technology.

Hammerstones made as preforms and adopted from the production trajectory are important at the quarries. These hammerstones were used in the stages of reduction from blocking out to the advanced stage of thinning. The hammerstones were probably used as part of a stock and changed frequently in the work of reduction. This use of a range of hammerstones was probably to relieve hand trauma from the repetitive pounding. Because the hammerstones were mostly drawn from the axe making sequence, they were more suitable in shape than irregularly shaped blocks, although they were not intentionally shaped or reworked as hammerstones.

The hammerstones found at Gulgong and Warren could not be described as exhausted or broken; they could continue to be used as tools in knapping. The battered edges were still functional and few showed signs of deep flake damage at the ends. Those made of quarry material are left on the surface of sites and none have been found in large-scale caches but the storage of single items at surface points remains a possibility (Hayden 1987; Hiscock 1988b). The suggestion is that hammerstones were treated casually, because of the recurring supply from axe preforms found abandoned in the production trajectory. The hammerstones were suitable for the task, but were not designed into the tool kit as a means of giving efficient results in the knapping of stone for axes. The origin of hammerstones and their pattern of use suggests flexibility in the tool kits for axe making at Gulgong and Warren.
My evaluation of hammerstones has emphasised the importance of flexibility within lithic reduction systems, rather than for goal-oriented reductions (cf Torrence 1986; 1989; Amick, Mauldin and Binford 1989). Axe preforms abandoned in manufacture at some stage in the reduction sequence between blocking out and the advanced stage of thinning are not left unused. In order to perform as percussors in axe making, hammerstones must fulfill certain specifications but they are not specially made to conform to these specifications.

The tools used at Gulgong are not special purpose in the design or production, but (at both Gulgong and Warren) they are adopted and recycled from the production trajectory and the material culture of the stone knappers. Apart from the top stones for grinding and then being used as impact tools, there are the fine grain hammerstones. These fine grain stones are all at first part of the axe preform production trajectory and then become hammerstones. As blocks and preforms they leave the production trajectory and become in effect production equipment in the making of axes. The flexibility of approach to axe making is confirmed by the range and origin of the hammerstones used. Abandoned axe preforms, cores and exotic muller stones are incorporated in a flexible approach to the tool kit used in axe manufacturing. As stones from the production trajectory, the hammerstones from Gulgong and Warren have very much the same features, and my expectations for trade-driven axe making at Gulgong were not confirmed.
CHAPTER 9

Lessons from axe making for trade and distribution systems

9.1 The lessons of axe making

In this Chapter I discuss what has been learned about the distribution of stone axes in east Australia. I return to the thesis problem stated in Chapter 1, that is, whether axe-making and the distribution of axes in east Australia is an economic transaction based on trade for gain. The conclusions derive from the study of two quarries at Gulgong and Warren.

A subsidiary issue addressed in Chapter 4 and relevant to my analysis in Chapters 5, 6, 7 and 8 was the accessibility and quality of data from quarries (see Holmes 1894a; Crabtree 1975; Torrence 1986). I have argued that the mass of unorganised and (apparently) undiagnostic stone in a quarry is a complex archaeological problem from which to draw out data relevant to a framework of axe-making behaviour. But a quarry is not too complex to understand and evaluate, given there is a relevant theory to use. This is important for the potential of quarry studies and the opportunities given by the many quarries known in Australia (Hiscock and Mitchell 1990; 1993) and in other parts of the world (Cleghorn 1986; Clough and Cummins 1979; 1981). An approach based on formal economic theory is valuable to explain behaviour which can be tested and then used to find a better fit for the data.

The material at the quarries was evaluated through features proposed in my framework for axe making and distribution: (1) symmetry as the recognition feature for the exchangeability of an axe; and (2) value-adding as a decision making process in making and distributing axes. The symmetry in shape which I link to exchangeability required there be recognition and acceptance by the consumer. The purpose of this was a goal related to social interaction between groups. In contrast, efficiency (as cost reduction) operates to control knapping behaviour and establishes the trade (for gain) potential of the transaction which was to obtain goods under mutually advantageous conditions.

I will deal first with predictions for symmetry as they compare between axes from Gulgong and Warren, and then my expectations for value-adding and efficient behaviour as they affect the two quarries.
9.1.1 Symmetry at Gulgong and Warren

In Chapter 2, I made predictions about the axes from the quarries at Gulgong and Warren. My predictions were for symmetry to be found frequently in preforms from Gulgong, and for symmetry to be found less frequently from Warren. The prior recognition factor for exchangeability was discussed in Chapter 5 and distinguished between the two quarries by:

(1) The strong trend expected at Gulgong, where axes were distributed over long distances in a system linked with other eastern axe quarries and (possible) exchange centres;

(2) A weaker tendency, but basically one of no symmetry in the axes at Warren, where the distribution system was one of predominantly local usage. Asymmetrical shaped axes are not acceptable for trade in the distribution system. The possibility of some minor influence from regional exchange systems could result in a few incidences of symmetrical shaping in the axes at Warren.

Data on symmetry was collected with the objective of evaluating the differences in control in making the axes between Gulgong and Warren. At Warren there was a more restricted distribution of axes from the quarries. Symmetrical shaping of the axe will be less important at Warren than for Gulgong. The hypothesis that axe making was a value-adding activity intended to regulate an exchange transaction, suggests that symmetrical shaping was found more strongly at Gulgong than at Warren. Because axe making at Gulgong was (under these expectations) more directed to material gain in the transaction of goods and their dispersal in a more extensive system of distribution, the incentive for symmetrical shaping was greater at Gulgong than at Warren. The intended local use of axes at Warren would not be an impetus to shaping axes symmetrically.

The purpose of symmetry is recognition and acceptability by the user in an exchange transaction. From the measures made, I find that symmetry in plan is easier to attain than in mass distribution (along the side from the bevel edge to the butt) and cross-section. Symmetry in plan is easily attained at Warren, but symmetry in the distribution of mass is more frequently attained in preforms from Gulgong than from Warren and is more frequent in all stages of reduction. The difference is in direct contrast with the expectation of the easier reduction process for raw material from Warren compared to the difficult and irregular shaped material at Gulgong. The different attainments of symmetry between the two quarries are due to the action of knappers and their acquired skill, rather than the working properties of the raw material.
The main reasons for the loss of symmetry on preforms in axe making are abandonment because of problems in mass removal and edge damage. In spite of the difficulty of knapping Gulgong stone there was a progressive movement to symmetry through the reduction sequence.

In summary, recognition and acceptability is needed for a good distributed in an exchange system. Symmetry in axe shape gives the good exchangeability, and although Gulgong was more difficult to work when compared to Warren, knapping at Gulgong more frequently results in symmetry. The symmetry resulting from shaping mass and section requires knapping skill, and this was demonstrated in the stone working at Gulgong. The tests of symmetry at Gulgong did support the expectations for symmetry as the criterion for exchangeability.

9.1.2 Value-adding decisions at Gulgong and Warren

The two possible outcomes for the value-adding economic transactions model of efficient production are restated from Chapter 2:

Either, (1) the quarries produced axes under conditions of value-adding economic transactions if both symmetry and efficiency of production are present.

Or, (2) the quarries did not make axes under conditions of value-added economic transactions, that is if both symmetry and efficiency are not present.

I will discuss each of these possible outcomes and then return to the outcome resulting from the tests in my thesis.

My conclusions on the possible outcomes differ from the view of Bradley and Edmonds (1993) on the most fruitful approaches to evaluating the nature of production and distribution in the small scale societies of prehistory. Bradley and Edmonds questioning the usefulness of analyses based on 'modern economic principles' in problems of exchange in prehistory leads them to propose a social reproduction model (Mauss 1925; Gregory 1982) by which to understand trade in axes. Social reproduction tackles the problem of production, distribution and consumption as circular process based on the social control of the means of production, in contrast to the linear process and universal maximising approach of formal neoclasical economics. Their approach through social reproduction emphasises the relations of people with goods in the process of replacement by production and exchange. My interest is in testing formal economic models. The process is linear with emphasis on the production
of goods, an approach which restates the point of manufacture (quarries) of a good (axes) as giving a better evaluation of the nature of the conversion process and the decisions involved.

The value-added economic model of transactions is useful for evaluating the making of axes at quarries, that is, as points from where they enter into a distribution system. Were axes at the quarries made under conditions specified in the value-adding model of economic transactions? To repeat my expectations for the two quarries analysed here:

The quarry at Warren was part of a limited distribution system in a place where other stone was scarce and the stone was distinctive but not especially suited for use as a high impact tool. Under these conditions I predicted there would be no efficient axe making nor a value-adding decision process. In contrast the quarry at Gulgong was part of an extensive distribution of axes connected with a bigger distribution system from axe quarries in that part of east Australia (see Chapter 3). I have argued that the axe making at Gulgong quarry was based on efficient knapping action and a value-adding decision process.

The result of tests and analysis of data was that axe making at Gulgong was not done on the basis of efficient knapping practices within a value-adding economic transactions model. At Gulgong my prediction of trade based on efficient knapping behaviour is rejected. But the role of value-adding as a decision process for transactions has some utility in the evaluation of axe making and the distribution of axes. I will evaluate the results of and reasons for this conclusion by reviewing the relevant aspects of my research.

**Gulgong.** I predicted that selection of raw material would identify stone suitable for axe making. The value-adding process then results in stone for axe making being available with known properties. The decision-making process in the selection of suitable stone now has the uncertainty associated with choice and wide-ranging testing reduced to known stone resources. From the selection of one type of raw material, there is an efficient control over the knapping performance and quality in output of the stone to be used.

My prediction was that extraction at Gulgong was as a value-adding economic transaction, which detached stone in a useable form. The process was expected to maximise the amount of raw material available for making axes. Efficient behaviour at
this point in axe-making was expected to need less axe making effort to maximise the number of pieces available from any one extraction event, and would reduce wastage and the need to extract more stone for the same number of axes produced.

The operation of the value-adding model of economic transactions resulted in the selection of raw material being focussed on a closely specified rock source. Stone with the potential for 'sustained economic exploitation' (see Torrence 1986) must meet criteria of technical acceptance: that is, in the performance properties of stone selected for axes. The performance properties of rock were evaluated through tests of tensile strength and impact and abrasion. From the selection point in the procurement of raw material the stone used was a single geological type, for which the working properties were both consistent and known.

The concentrated extraction of stone conformed with the expectations for value-adding, and gave opportunity to develop efficient traits in axe making (although these may not have been followed by stone knappers in the later stages of reduction). Extraction by the stone workers controlling the quarry should result in more efficient use of the available resources. The stone workers adopted extraction techniques appropriate to the task, and so maximised the units of axe stone material available from the selected raw material.

Gulgong had features of value-adding economic transactions with known working properties, and knowledge of this gave concentrated and intense exploitation in an efficient and organised manner. The choice of one type of raw material gives the basis for the production of stone tools. Efficiency in the economic transactions model operated because the selected raw material had performance properties known to the Aboriginal stoneworkers, and did not have to be reevaluated by the axe makers every time they wanted axe stone. The regular use of a standard raw material used through the selection of specific stone in outcrops increases the efficiency of ownership and control in a quarry. The owners or controllers will regulate material gains more effectively where the specific nature of the resource is known, and this makes the stone resource more closely controlled and highly valued.

My expectations for axe making at the quarries were that the value-added model of transactions would result in efficient knapping behaviour in relation to preform production. The error rate in flaking on the stone would be low, especially the incidence of hinge fractures.
Gulgong did not have low production error rates when measured by the hinge terminations on the preforms (and when compared to those at Warren). The high incidence of hinged fractures on preforms contrast with my expectations for knapping control. Hinge terminations occurred in the late stages of reduction at Gulgong, which is the point where knapping should be most controlled. The value-adding economic model suggested that efficient traits in axe making would reduce the number of knapping errors. Control over the hinge fractures was expected as a strong feature for Gulgong; yet there was not only a high incidence of hinge fractures on preforms, but four out of five preforms show a repeated production of hinges. These results suggest that efficiency was not a guiding factor in axe making, and to this extent the expectation of the economic model of transactions for axe distribution from Gulgong is not supported by the results.

The reasons for abandonment of preforms at the quarries were important in evaluating value-adding decisions in axe making. At Gulgong the model was partly maintained by the early abandonment of tested stone at the blocking out stage. For example, transversely snapped preforms are found mostly in the early stages of reduction. The testing of the raw material by heavy stone reduction results in abandonment before additional value-adding work of finishing is undertaken by the stone knappers.

Value-adding economic transactions predict that some axe preforms are transferred to use as hammerstones rather than being reworked as preforms for distribution as axes. The decision is based on an alternative course of action, with the cost for hammerstones being made from material on site, or brought on to the site. The generally tighter criteria for the axes passed into trade-driven distribution systems than for non-trade uses can be expected to result in more material being available for hammerstones. In terms of efficiency in production of preforms the hammerstones are predicted to be specialist tools in that they are made for the purpose and of the most appropriate impact material.

The stone analysed from Gulgong suggests hammerstones can come from the production trajectory, and from several other origins. The combination of tools and techniques found in toolkits at quarries is expected in technologies where flexible approaches to problems defy standardisation associated with economic specialisation. The control of knapping as an efficient activity would suggest hammerstones be specially produced for axe making. At Gulgong (and Warren) hammerstones were mostly not specifically worked as percussion tools in axe making. There are some used
as hammerstones directly from extraction, but these are used with minimal modification and are not shaped to reduce hand trauma, something I expected in a specialist tool kit.

In a specialist tool kit there would also be importation of special purpose hammerstones made of exotic material. Gulgong has few hammerstones of exotic material, and there are none found at Warren. The problem is that in a curated technology toolkits are not all 'site furniture' (Binford 1979; 1981), then exotic hammerstones are likely to be brought into the quarry and taken away with the knappers. If this is the case then the exotic hammerstones, especially the small ones, are not as likely to be found on site. Large exotic hammerstones are not found at these sites, although they would be useful in heavy reduction.

The hammerstones found at Gulgong and Warren have implications for axe making as an economic transaction. Hammerstones emphasise the importance of flexibility within the lithic reduction systems, rather than for single goal-oriented reductions. The hammerstones used were suitable for the task according to the tests applied. At Gulgong preforms of fine grained material leave the production trajectory and become production equipment in the making of axes. But hammerstones were not designed into the tool kit as a means of giving efficient results in knapping stone for axes. The tools used are not special purpose either in design or production, but are adopted and recycled from the production trajectory and material culture of the stone knappers.

**Warren.** The prediction for selection of raw material at Warren does not follow the value-adding economic model of transactions found at Gulgong. Selection was expected to be casual from the available raw material, and would be chosen from rock with qualities which vary across the range at the site. Expectations for extraction at Warren were in line with selection of raw material on a casual basis, where there was no system of trade for gain operating to structure behaviour on an efficient basis.

Compared with Gulgong, Warren is not a place of concentrated and intense exploitation, and identification of suitable raw material was not a question of choosing between several sources or raw material types. At Warren the raw material is equally available across the site in the form of loose blocks, and selection is a matter of indifference because of this equal availability. The raw material is available as a single geological rock type with no flaws. In these circumstances, the problem of quarry organisation and the balance of decision-making shifts from the problem of raw material
selection in terms of rock properties to the question of extraction and initial preparation of axe preforms.

Warren was not operated on a value-adding decision basis of economic transactions. As expected stone extraction was easy and was done in a casual manner for which sophisticated techniques are not needed. Loose blocks of the raw material can be extracted by percussion and leverage.

My expectation from the model was for abandonment to take place in all stages of reduction at Warren. There would be no propensity to manufacture into the late stages of reduction, when compared with the factors influencing axe making at Gulgong. There was no expectation of behaviour associated with efficient control in knapping; error rates were expected to be high, with frequent hinge fracturing on the flaking faces of preforms.

Abandonment of preforms did take place at all stages of reduction. But there were few hinge fractures at Warren, a quarry where knapping control as an efficiency criterion was not expected. Where knapping practices are not directed towards producing axes as goods in a system of trade for gain, the casual approach to knapping control should give regular production of error on the preforms. The hinged flaking errors at the stages of reduction are few and yet distribution of axes from the source is limited in extent and they are not symmetrically shaped.

In contrast to Gulgong, predictions for Warren were that hammerstones would be casually acquired from the site and they would be discarded as expedient tools. The stock of hammerstones used at Warren were from the abandoned preforms on the site, with modification only through use as impact tools.

**In summary,** my predictions for selection of axe stone and axe making at Gulgong and Warren was for Gulgong to have operated on the basis of the value-adding economic model of transactions, with efficient knapping guiding the behaviour. In contrast Warren was not part of a system of distribution where axes were traded for material gain and value-adding economic transactions were not expected. My tests and evaluation of axe making at the quarries did not confirm all these expectations. The selection of axe stone and axe making at the two quarries was done with care and knowledge of the impact material, and skill in the shaping of stone for axes. The toolkits used are not specially manufactured, but are drawn from the process of axe making.
9.1.3 Conclusion on value-adding and efficiency

I will review the value-adding process and efficiency in behaviour through the discussion of axe making and toolkits at the Gulgong and Warren quarries.

My predictions for selection of axe stone and axe making at Gulgong and Warren was for Gulgong to have operated on the basis of the value-adding economic model of transactions, with efficient knapping guiding the behaviour. In contrast Warren was not part of a system of distribution where axes were traded for material gain and value-adding economic transactions were not expected. My tests and evaluation of axe making at the quarries did not confirm all these expectations.

The extraction of stone for axe making follows the predictions for Gulgong and Warren, on the basis of selection of suitable stone from a single exploitable source, and this process gave a value-adding framework in which there was the potential for efficient behaviour. In the stages of the production trajectory for axe-making reduction begins to diverge from the expectations and criteria for efficient behaviour.

Value-adding can take place at extraction after the point of selection. At the point of extraction the technology exercised by the stone procurers can be applied to the stone resource at the quarry or the consumers can be allowed access to the identified stone at the quarry. From my analysis of Gulgong quarry the selection and extraction stages of the reduction sequence satisfied conditions for the value-adding model of transactions with efficiency in stone working. Value-adding decisions are made at the various stages of reduction in the axe making process. An extracted piece of raw material was either further processed through the stages of reduction, or it can be transferred to consumers. This decision-making process can go on through the stages of reduction in axe making and did at Gulgong. The axe making stages of blocking out, shaping and advanced thinning have to be completed before a preform can be passed into the distribution system as an axe.

Contrary to prediction from my model and the trade-driven distribution system, efficiency was not a guiding factor in axe making at Gulgong. Nor was it at Warren, but at Warren it was not predicted from the model. The efficiency criterion of low error rates expected for axe making as an activity in this process (from stage 3 to stage 5) was not supported by results from these stages. Although the error rates were not low as expected for Gulgong, they were not the only cause of abandonment of preforms at the quarry. The efficient traits were related to the cost of production. High error rates made
finishing for transfer into a trade distribution system more difficult to achieve and caused more preforms to be diverted into other end-uses from the production trajectory.

The organisation and technology of production suggested by the study of axe making was not consistently efficient but parts of the axe-making activity at the quarries were skilful. A difference in value-adding potential at the stages of reduction was only one aspect of consistency in relation to efficient behaviour. In the axe-making process there are points where control in knapping was important for production of symmetrical axes. At these points control decisions were made in the organisation of production. Where skill was the benchmark, these points would be recovered by controlled knapping. Where efficient behaviour guides the axe making, then the recovery of errors depended on the value-adding prospects for the action. In these circumstances not all error situations in the preform are recovered, and some of the preforms are used as hammerstones.

Efficient behaviour in axe making requires a specialist tool kit, with hammerstones made for the purpose and exotic stone for some parts of the reduction process. The results of analysis of hammerstones suggest they are linked into decisions about making axes in the production trajectory and its outputs at the quarries. Where hammerstones come (in part) from the stock of abandoned axe preforms there is a relationship between the two outputs. Decisions about production of axes for distribution through a system based on trade for gain are going to influence the amount of stone available as hammerstones from the reduction sequence in the production trajectory.

The value-adding economic model distinguishes behaviour at Gulgong and Warren and also gives a line of connection between decision-making at the quarry: that is, the process and organisation of production, and the supply of axes into consumption. The decision process at an axe quarry is a series of possibilities which have to be assessed and balanced by the owners or stoneworkers in relation to their economic benefit and social relations with other groups. But the test of efficiency in axe making did not work, in that hinge fracturing does not register trade for gain. From the results of tests a further evaluation of axe-making is needed. The evaluation can be done through reassessment of the distribution patterns from the two quarries, which was the source of the hypothesis.

9.2 Axe making at Gulgong and Warren and patterns of axe distribution
The two quarries did not operate in the same system of distribution. I will discuss Warren and then Gulgong.

**Warren.** The production of axes at Warren was not based on value-adding economic transactions for the purpose of trade for gain. The evidence from the quarries and dispersal of material suggests axe making was permitted by direct procurement and a limited transfer of the goods between groups in the region. What form of exchange these transfers took is not certain. Some form of local or regional exchange is possible between local groups from Warren and those more distant from the quarries, who come from within a contact area stretching towards (but not as far as) Brewarrina in the north and Narromine and Dubbo in the south. On occasions these groups would have travelled to the quarries and meetings take place. A stone arrangement survives near the quarries at Warren, although its exact purpose is not known. The food and camp resources along the creeks and between the quarries and the Macquarie Marshes were sufficient for groups to meet and stay. The campsites around the quarries contained grindstones and whetstones from sources in the region.

Ceremonies are temporary aggregations of people where more than one activity takes place in the framework and duration of the meeting (Ericson 1981; Stanner 1933-34). Under these circumstances, permitted access for direct procurement of stone and axe making would take place and some of the axe production could be used for exchange among groups in the region.

Where axe making is not tightly organised in the way found with economic value-adding and efficient behaviour, then the pattern of procurement, manufacture and dispersal will be variable and flexible. The different arrangements for stone procurement at the quarry can only operate by agreement with those who own or control the quarry (Perles 1992). Given Tindale's and Howitt's suggestion that a stone resource (such as that at Warren) gave the Aboriginal owners much to defend, then some arrangements would be necessary to allow different forms of acquisition for axes (Tindale 1974; Howitt 1904, 311). Once these arrangements are in place the variety of possible flexible combinations between these closely connected groups could have been developed.

I conclude that the making and movement of axes from the quarries at Warren defined an area of relationships that bounded the distribution of quartz feldspar porphyry axes. But this was not an area of complete exclusion because other hard rock axes were found in the region; as would be expected, goods cross human interaction boundaries.
**Gulgong.** On the other hand Gulgong is one of two long transfer quarries in eastern Australia (the other being Moore Creek) from where the axes travel over long distances. The exchange system for axes in east Australia may include nodes of exchange (McBryde 1986; 1987) where transactions take place.

The value-adding process can be seen and supported for axe making at the Gulgong quarry, but within this decision-making pattern and conversion of raw material efficient behaviour was not found at all stages of reduction. The value-adding approach used was a flexible decision-making process in the economic system found in Aboriginal Australia. The production trajectory outlined in Chapter 2 resulted in the manufacture of axes for distribution in the system under conditions of trade for gain. The possibility within the value-adding framework is for decisions to be directed towards another set of relationships, based on the nature and difference between the groups in contact with the axe makers.

Decisions have to be made by any group of people both in relation to their physical environment and their social relations with others (Whitelaw 1986). These decisions require both judgement and information, and on this basis the material of the quarries are converted along a production trajectory into a distribution system of transacted goods. The stone axe producers make decisions about value-adding production in the light of information about demand for (symmetrical) axes for exchange and the other uses of stone passing through the production process.

Traditional Aboriginal society was one of structured relationships between individuals and between groups. Through this situation who requests the axes or the stone was as important as the axe making regime followed at the quarry and determined in which direction and under what conditions the axes will be transacted. The arrival and request by a close 'relative' to the axe makers would involve a decision process about the supply of stone. But the arrival and request of people from another group who are in a relationship of both 'trade' and possible aggression ('war') would involve a different decision process about the transaction of the same stone resource. In both cases diplomacy, kin connections and other family relations will structure the transfer of stone axe material in a way not expected in a value-adding model of economic transactions.

Under these conditions the exchange of goods was not trade for gain, but it was systematic through those who come with requests and through the transport of axes by the makers away from the quarry to special places where (among other events) goods
are transferred between people in an exchange transaction. The system of 'trade partners' described by Tindale (1974) for people in separate and distant groups in Australia created social relations which satisfied the movement of goods between people. The goods passed between a trade partnership must be acceptable for them to be exchanged, which in the case of axes would be achieved by the recognition of symmetrical shaping of the stone.

I conclude, the value-adding economic argument is important for evaluating axe making at the quarry but the model is limited in application to distribution systems in the small-scale societies found in Aboriginal Australia. The goods may be technically scarce (i.e., absent otherwise from the material culture) but unless there is a knowledge of the goods in the group where they are absent, then there will be no demand. The axes were produced and distributed into a system of exchange, but this was not done on the basis of trade for gain.

9.3 Formalist models as explanation for distribution from quarries.

The high risk strategy adopted to test hypotheses from a strict formal economic model in relation to trade resulted in a negative conclusion, but a valuable one. I have tested the hypotheses from the model and find that it does not work for these sites. The reasons for this outcome may be that (1) my method of testing is inappropriate; or (2) there are no appropriate methods of testing; or (3) the methods are appropriate but do not work for all sites.

To investigate (1) and seek other appropriate methods of testing would be another research project and I do not believe that the methods are inappropriate (see Chapter 2). I do not support the view in (2) that there are no appropriate methods of testing. The outcome of my study is that (3) the methods are appropriate, but do not work for all sites. The axemakers at both quarries did not make axes as economic transactions under conditions of efficiency and value-adding, but the model may be tenable. This needs to be tested elsewhere on a larger range of sites, to further refine conditions under which the model may apply. Universal economising behaviour found in formal economic theory and stated in my economic model of transactions, gives an evaluation of outcomes in terms of efficiency in stone knapping behaviour, and value-adding in decision-making at the stages of reduction. But in small-scale societies, economic organisation was not based on performance measures as the distinguishing feature.
To explain economic behaviour formalist theory needs a measure of value along a scale of exchange. This measure of value is like a currency, in that it has equal divisions of small denomination to reflect the close distinctions in value made by producers and consumers between their appreciation of different goods. Value-adding decisions about the point at which to transfer axes out of the production trajectory can offer some guidance about the transactions, but not a closely defined currency. Axes (as preforms) at various stages of working were part of a production trajectory which transferred them into the distribution system. But finer calculations require a measure of value where small gradations of scale in value can be calculated in relation to the good offered for exchange. This graded measure of value did not exist between the people involved in these axe transactions.

The mechanism for exchanging goods in Aboriginal Australia has been described by McCarthy (1939) as barter. The meaning of 'barter' as the moneyless transaction of goods on agreed terms of value by the participants does not mean there is a commercial market trading situation (Dalton 1975). Barter is associated with the long distance movement of goods. By this means tribes can negotiate the exchange of goods where contact is not regular, nor are goods circulated through the ceremonial exchange system. The result of barter is the exchange of commodities in a manner that alienates the objects from the parties. Alienation is one of the conditions found in trade for gain and the formalist economic use of commercial money exchange. It does not require a continuing cycle of exchange to be maintained. In trade for gain, once the transaction is completed, all economic and social obligation ceases.

To what extent an activity conforming to 'barter' can be identified in the exchange transactions of Australian Aboriginals will depend on the possibility of distinguishing barter from reciprocal exchange. Both forms of exchange have an element of calculation in the transfer of goods and the conditions of the transaction are the subject of (direct and indirect) negotiation between the parties. The dynamics of reciprocal exchange suggests the activity is meshed in broader social relations. Trade partners are established early on in life and are cultivated and maintained through social life. Small-scale reciprocal exchanges operate in local contexts and intra-group transfers, such as exchange through ceremonies and these events took place over most of Australia (McCarthy 1939, 177). The ceremonial exchange cycles described by Stanner (1933-34) for the Mulluk-Mulluk and by Thomson (1949) in Arnhemland incorporate most items of the material culture. These events have goods exchanged on a reciprocal basis, with a ritualised pattern of behaviour where goods were transferred, held and then passed on. The return of obligations operates through the kinship
system, and results in the circulation of goods. This is done as part of social negotiation, which includes rights of access to resources.

There is some evidence of behaviour adding value to the good where the transport of goods is by the owners of the resource, as is found with pituri in north-west Queensland (Watson 1983). But transport, by either owners or procurement by users, is an inconclusive test of value-adding as an economic model. My argument follows the view that the point of manufacture gives a better evaluation of the nature of the conversion process and decisions involved, than does any other part of the distribution system. The processing of the pituri plant in north-west Queensland is done from specific groves and produces a good of high repute in which there are stages, from harvesting at the correct time, to techniques of curing. The result is a high quality good put into circulation. To achieve the output required knowledge and decision-making, because resources were used and acceptance was needed from the other users.

The production trajectory (outlined in Chapter 2) was predicted to produce axes for distribution under conditions of trade for gain, and other outputs not in the distribution system for trade. They were all part of the same productive activity at the quarry and (most importantly) are the subject of decision-making in their use as material resources. The strict formalist approach to maximising returns from efficient behaviour does not operate in small-scale societies, but the element of calculation is to be found in all exchange transactions and transfers, and this may give guidance on the role of value-adding decisions in these societies. Economic systems in the small-scale societies of prehistory undertook material provisioning using productive factors perceived to be available in those societies. The economic activities of those societies (like the movement of goods) were the subject to control, which took place through ceremonial centres and trade partnerships in Australia. Under these conditions the exchange of goods was not trade for gain.

9.4 Conclusion on axes quarries and distribution systems in east Australia

The results of my evaluation supports McBryde's suggestion that scarcity cannot wholly explain the reason for the movement of goods across the landscape and between groups. She concludes that Australian Aboriginal exchange is something that 'cannot be interpreted simply as an adaptive mechanism for ensuring acquisition of materials not available in the local environment, though obviously it often achieves this' (McBryde 1984, 267). McBryde (1986) offers an other view to that of the formalist economic argument by a wider explanation of the transfer of goods in an economic
system. In McBryde's view the exchange system transfers goods incidentally to the social relations that give social alliances which were established or confirmed by the exchange of goods. The social factors which operated to move goods, such as stone axes, across the landscape were the social alliances which existed between Aboriginal tribes and groups in Australia. These social alliances give a direction to the movement of goods.

The quarries at Gulgong and Moore Creek in NSW are part of a large scale distribution system, as are greenstone axes from Mount William in Victoria and the output of quarries in Queensland (see Figure 9.1). With the known distribution of axes from the systems based on long transfer quarries extended by including systems in Queensland, these major distribution systems cover east Australia from south-east Victoria and (probably) north to the Gulf of Carpentaria and Cape York (see Binns and McBryde 1972; McBryde 1986; 1987; Connah, et al. 1977; Davidson, et al. 1992; Sharp 1974; Roth 1897 [1984]).

One system covers north-west Queensland and was centred on distribution from the axe quarry at Moondarra (near Mount Isa). Hiscock (1994) has studied the quarry material and preforms at Moondarra and the axes from the source in museum collections. The finished axes were more standardised than earlier stages of manufacture, and axes from Moondarra were more standardised than other axes in the Queensland Museum collection. These standardised axes are distinctive and distributed from the quarry through the Selwyn-Leichhardt region and south in the direction of Wilcannia (Mootwingee) in the north-west of NSW. Major distribution quarries are distinguished by some features, which may be symmetry in shape or standardisation in manufacture, when compared to quarries with local distributions (such as Tia in NSW). Local quarries where there is no system, such as economising behaviour in axe making, where reduction is haphazard and wastage high, are recognised by their restricted distribution.

The major distributions from the long transfer quarries enclose the Wilcannia/Mootwingee area, from Moondarra in the north, Gulgong and Moore Creek in the east, and the Mount William complex in the south (Davidson, et al. 1992). The movement of axes from these long transfer quarries appear to be directed towards an important ceremonial area at Mootwingee (Witter personal comm. 1995). Exchange nodes are likely to be associated with the place and events in the area around the location. These centres or nodes are known from inland Australia and the long distance 'trade routes' described for the movement of people and commodities (McCarthy 1939; McBryde 1987). The movement of people in and out of the nodes was necessary to
achieve these transactions. Groups moved around and passed through one area to another, often along well-defined routes.

The distribution of axes in these regional networks drives much of the research about trade in east Australia. Movement of people may have been based on a seasonal round or on the occurrence of an event (Roth 1897 [1984] 132). The element of calculation common to transactions of goods underpinned the relations between groups. Although the basis of the movement of goods across the landscape is not one of formal economic transactions, the altruistic or motiveless gift or exchange had no place in the systematic movement of goods. The basis of the transactions in an exchange system may not be the gains from efficiency or economising actions, but the purpose of the activity will be known and agreed between the parties. These calculated elements may not barter or match goods on a regularised and specific rate of exchange, but they will be negotiated between the parties. The quarry at Gulgong was part of a distribution system for axes which converged with other distribution networks through exchange nodes. But Warren was not part of the distribution system from long transfer quarries.

In any archaeological study of past systems other viewpoints are possible and other explanations are likely. My study has offered a partial model of reality in which a formal economic approach to the production and distribution of goods in the material culture of Aboriginal groups of east Australia was evaluated. A theory-driven approach to axe distribution systems will require evaluation of the nature of production at the quarry, needing the archaeological analysis of quarry material done at Gulgong and Warren. My approach has reasserted the importance of points of manufacture, namely quarries, for evaluating the nature of the conversion process and the decisions involved in the distribution system of axes. The economic model of axe-making behaviour at the two quarries gave a connection between decision-making at the quarries and the supply of axes into consumption.
GLOSSARY

Key: Based on Crabtree 1972 (C), Bradley 1975 (B), Dickson 1981 (D), Davidson 1990 (ID), Palgrave 1985 (P).

Anvil. Stone used to support the workpiece being struck with a percussor (hammerstone). (D)

Axe. Hand-tool used for hewing, cleaving or chopping wood. Fixed on a handle it is hafted. Also hatchet when light and one-handed. Can be a stone head alone or hand-chopper (celt). Also a hand-axe, as a flaked instrument made as a core tool. (D) Handaxes are recognised as stone artefacts from which flakes have been removed from both edges. (ID)

Bevel. Ground surfaces that meet in the median plane to form the edge of an axe. (D)

Biface. Stone shaped on both sides to form an edge. Artefact bearing flake scars on both faces. (C) (D)

Blank. The early stages of the manufacturing process before the preform is reached. A blank is not a finished implement. The stone is modified to a stage of the reduction sequence where the shape or form of the final product is not disclosed in the blank. It has the morphological potential to be modified into more than one implement type. (B) (C) (D)

Block on block method or Anvil technique. Where the work piece is struck against a block, anvil or stationary object to fracture the workpiece and detach flakes. The method of removing flakes by swinging the work piece against the anvil. (C)

Chopper. Heavy core tool presumed to be used for chopping. May be uniface or biface; hand-held tool for chopping wood with a flaked or ground edge. (C) (D)

Core. Nucleus or parent piece of stone from which flakes are struck and one or more detachment scars are shown. (C) (D)

Debitage. Residual material from stone tool manufacture, which shows technological traits through stages of manufacture. (C)
Debris. Waste flakes and material with no definitive characteristic, such as from quarrying stone. (C)

Deformation. Change of shape under applied force, on a range from elastic to plastic. Deformation is elastic where capable of returning to original shape after removal of the deforming force. Plastic deformation goes beyond elastic limits to give mechanical damage. (C) (D)

Demand. The point on a scale of values where two parties (the buyer and seller) agree on the exchange transaction for the good.

Dorsal. Outer surface. Part of the face of the core prior to detachment. See Ventral. (C)

Economic. Human activity aimed at the allocation of scarce resources between competing ends.

Edge damage. Where knapping mistakes result in the excessive removal of stone from the margin of a preform and upsets the continuity of reduction along that margin. Usually results in abandonment of the preform.

Efficiency. The ratio of the value of an output in production to the cost of the input. In economic terms these inputs must have costs and alternative opportunities. The input may be a combination of factors of production, such as land, labour and capital. A measure of output per unit of input, where an optimum allocation of input will produce extra output.

Feather termination. A technique which produces a flake which terminates in an edge with a minimal margin. (C)

Flake. A piece of stone removed from a larger mass by the application of force. Isotropic material will have a platform and bulb of force at the proximal end. (C)

Flexibility. The amount of bending without breaking exhibited by some lithic materials. (C)

Hand-held percussion. Holding the workpiece in the hand and striking with the percussor (hammerstone) in the other hand. May be freehand or hand-rested. (C)
**Glossary**

**Hinge fracture.** A fracture at the distal end of a flake or blade which prevents detachment of the flake at its proposed terminal point. The termination is at right angles to the longitudinal axis and the break is usually rounded or blunt. (C)

**Homogeneous.** Raw material which has the same structure throughout, in which there is no plane of weakness to impair the conchoidal fracture process. (C)

**Isotropic.** Stone having the same properties in all directions, with no preferred planes of cleavage. (C) (D)

**Mass removal.** A quantity of matter forming a body (C) prominent on the medial part of the faces of a preform, which is removed in the successful shaping of a preform.

**Median line.** An imaginary line pertaining to the middle part of the artefact from the proximal to the distal end on either face. (C)

**Morphology.** The three-dimensional form of an object; size, shape, and volume. (B)

**Optimality.** An objective among people in economic systems were the best or most favourable point is sought to give the greatest satisfaction possible, within known constraints. In (neoclassical) economic analysis the optimal distribution between people aims at a situation of competitive equilibrium. (P)

**PFA (Point of contact).** Area of forceful meeting of the percussor on the platform of the workpiece. The quantity of energy exerted by the moving body (hammerstone) will initiate a movement of another body from inertia at that point. The point of contact by the percussor on the platform of the stone where the cone on the bulb face truncates. (C)

**Preform.** Stone modified to a stage of the reduction sequence, but not finished. The artefact requires more reduction and has the morphological potential of being modified to one implement type. (B) (C)

**Rational behaviour.** The assumption of rationality in human decisions and actions underlines (neoclassical) economic thought, and says that in choice situations people will act with reasoned self-interest. The choices based on information are expected to maximise utility, and should be both cogent and systematic. It follows that an assumption of 'irrationality' in behaviour is less useful than one of 'rationality' in
economic analysis, both as a prescription of how people should act and how people will actually behave. (P)

**Ripple.** Compression ring as a wave appearing on the plane of a fracture. Undulations and waves are similar. (C)

**Stage.** Knapping goal in a reduction sequence. (B)

**Step fracture.** A flake or flake scar that terminates abruptly in a right angle break at the point of truncation. It is caused by a dissipation of force or the collapse of the flake. (C)

**Transverse snap (End shock).** Transverse crosswise fracture due to the stone exceeding its elastic limits. (C)

**Tenacity.** Resistance to fracture. (C)

**Thinning flakes.** Removed from a preform to reduce the thickness. (C)

**Value.** A specific term in economic theory as the portion of an object or good which can be transferred from one person to another. The transfer is by means of an exchange transaction and established by reference to some scale or system external to the particular good or object.

**Ventral.** Plano side or inner surface of flake or blade detached from a core. See Dorsal. (C)