CHAPTER 4

Gulgong and Warren quarries as case studies

4.1 Quarries as archaeological resources

In the late nineteenth century WE Roth (1897 (1984), 136) commented that too little interest was taken by observers in the place of manufacture of implements entering the trade routes of Aboriginal Australia. Stone quarries represent a nearly unique resource in Aboriginal procurement and as an archaeological resource, because they are well defined points on the landscape. To the casual observer quarries often appear as large quantities of undifferentiated and undiagnostic material (Crabtree 1975). This stone debris is invariably associated with this resource point for Aborigines. This class of material may be analysed in frameworks using methods developed within the discipline of archaeology, and these materials can give information on distribution processes. I define debitage as waste from production including all flakes whether conchoidal, block fractured or shattered, and including microdebitage. In fact a quarry is often identified as such by the waste material, because it is often far greater than would be expected from campsites where stone knapping has taken place.

In this Chapter my aim is to investigate the potential of two quarries at Gulgong and at Warren as case studies in which to compare and contrast axe making activity at the quarries. The Chapter supports my broader objective in the thesis which is to compare and contrast axe making and distribution from the quarries in a framework of exchange. In particular, the investigation of quarries should provide information on whether distribution of axes is an activity based on efficiency and organisation in production, or whether it is a casual activity characterised by procurement criteria not related to efficiency.

What analysis of the archaeological material at a quarry site can be undertaken that can be used in understanding the distribution of stone axes? The petrological characterisation of axes dispersed across the landscape can suggest patterns of distribution from their quarry source to find spots. Comparison of the spatial distributions from different sources indicates distances moved, density of distribution of axes sourced to particular quarries and their spread in relation to other sourced axes (Clough and Cummins 1979; 1981; Binns and McBryde 1972; McBryde 1978). Distribution is not the only information available from the quarry system. Attention to production is made possible by focussing on the activities at quarries.
Torrence (1986) names raw material sources, which includes stone quarries, as one of two relevant classes of site for exchange studies (the other being settlements). Raw material sources are described as the 'the only sites linking other parts of the exchange system' (Torrence 1986, 90). Given this, then activities at quarry sites should reflect constraints on behaviour imposed by the nature of the distribution system' (Torrence 1986, 110). The system of distribution works back through the quarries to give indicators of efficient behaviour in the archaeological remains at the quarries. Economic transactions operate under conditions of efficient behaviour in a relationship, such as where trade is for material gain.

Torrence's argument for monitoring factors affecting efficiency in the quarrying of stone for trade-driven production is connected to the question of why stone should be quarried at all. The results of extractive technology and reduction effort are prominent in the hard rock outcrops. The comparison of solid rock outcrop sources with procurement from loose cobble banks and pebble beaches suggests that intense means were used including leverage, firing and battering to access the raw material from rock outcrop quarries in workable units. In comparison the 'foraging' approach appears relevant to cobble sources of various sizes and raw material types, which may be found loose along the beach and coast lines (McCarthy 1941b; North 1964) or inland in water-rolled beds (see McBryde 1972: group 2C axes).

Other aspects of efficiency are prominent in problems of production. Production of the tools can take place in part or wholly at the quarries. Efficiency in production is important in quarry studies and this can be accessed through technological analysis of production and analysis of the quarries as stone resources. This is done within and between quarries as case studies, as well as for aggregations and groupings of quarry data. For example, the study by Ataman and Botkin (1991) at Tosawihi looked at the organisation of biface production in relation to distribution across the landscape. Their approach was to examine the data in terms of efficient processing of stone to reduce the cost of procurement.

The distribution of stone axes from quarry sources has been extensively researched by McBryde (Binns and McBryde 1972; McBryde and Watchman 1976; McBryde 1974; 1978; 1979; 1984; 1986) in eastern Australia, but the sources themselves have not been investigated for their content or context of production. Certainly valuable exceptions can be found to this situation (McBryde 1984; Baker 1987; Jones and White 1988; Hiscock 1988a; Cundy 1992). These give approaches to the problems of the organisation and technology of production. In one way the
approach of archaeology to an identified research problem does not suffer the restrictions of geographic or political boundaries. The technological problems of selection, extraction and production of stone tools are universal, but are perceived and solved in a cultural framework. The work of researchers at quarries in other parts of the world is valuable to studies in Australia (Bryan 1950; Houlder 1961; Bucy 1974; Sheets 1972; 1975; Torrence 1979a and 1979b; 1984; 1986; Arnold 1984; 1987; Bradley and Edmonds 1993; Edmonds et al 1992). Previous research gives some valuable guidance in two aspects which are important to my research: (1) firstly, as a baseline for action; and (2) second, for their comparative and contrastive properties.

Torrence (1994) discusses the utility and purpose of case studies for theory-building and theory-using in archaeology. Developing an argument on the use of 'difference' in theory-building, Torrence suggests the comparative approach is a valuable method for studying the variability between a range of cases. The method is described by Torrence as 'to begin with a general form of behaviour, and then try to understand its role in wider social and economic life by comparing and contrasting a wide range of cases' (Torrence 1994, 129). This approach through comparing and contrasting data seeks to maximise variation or 'difference' in the study.

In my study, the 'general form of behaviour' described by Torrence (1994) is making stone axes. This chapter uses the quarries at Gulgong and Warren as case studies in the extraction and manufacture of stone axes in eastern Australia (see Figures 4.1 and 4.2). My approach to testing the variability within the two quarries is to build a descriptive base of research material, and then to compare and contrast the sets of data. The objective is to draw out those features of the material record most valuable in testing the variation observed. The sites at Gulgong and Warren are means to compare and contrast the economic and social role of the quarries. In this chapter the comparison is done by means of surface study of the two sites.

Schiffer (1972; 1988) discusses how archaeological material has been formed into a record. To make inferences about past behavioural systems, it is necessary to distinguish which kind of processes are responsible for the identifiable patterns in the evidence. These may be past behavioural processes or intervening formation processes. Under these circumstances, the archaeological record is a record of everything that has taken place up to the present. In the mobile context of a stone tool quarry the formation processes discussed by Schiffer are an important influence on the potential for understanding human behaviour from static material remains. This problem has been recognised in quarry studies (McBryde 1984; Torrence 1982; Edmonds 1989) and is discussed in relation to Gulgong and Warren below.
4.2 Choice of Gulgong and Warren as study areas

There are two aspects to the choice of quarries in a research project on production and distribution of goods in prehistory, and where that project must have access to data for the purpose of contrast and comparison. These two aspects are: (1) visibility and, (2) the extent of the dispersal of material from the quarries.

(1) **Visibility** means some axe sources may not be amenable to study because the method of production does not leave material features for study in an archaeological context. For example, small outcrops of raw material exploited on a casual and opportunistic basis may not be recognisable as axe stone sources. Furthermore, the use of manufacturing techniques such as hammer dressing, pecking and grinding will reduce the available range of material for archaeological analysis of the organisation of production. The six axes from Gulgong includes one which is hammer dressed (Australian Museum #34966), although the preforms found on the quarry site are flaked and not dressed. Hammerdressing in production at the quarry would obscure the individual flake features and make some technological analysis inaccessible.

The question of visibility takes on an important aspect when geomorphological processes, such as downslope movement, are considered. McBryde (1984) discusses this feature of post-deposition in relation to Mount William and the greenstone quarries of south-east Victoria. Howitt (quoted in McBryde 1984) visited the site in the late nineteenth century and reported large mounds of stone, some of which appeared newer than others which were covered in grass. By the time of McBryde's survey in 1974 (1984, 274) there had been considerable downslope movement, the exposures were covered with grass and visibility was reduced. Edmonds (1989, 150) discusses the high mobility of screes in his study of the axe stone sources at Great Langdale in Cumbria. Slope movement can alter the contents and structure of assemblages at a quarry. The quarry at Gulgong appears to be exposed to processes similar to those at Mount William (McBryde 1984), Great Langdale and Killin (Edmonds 1989; 1992).

(2) My study of the stone axe sources is related to and depends on the extent of the dispersal of the material across the landscape. Two quarries, one with a restricted dispersal and one with an extensive distribution, were required to conduct the case study for the research project. The sites at Gulgong and Warren were suggested by McBryde as being potentially suitable for a study of procurement and exchange because the quarry sources were visible and still substantially intact, and because there were identified dispersals of axes held in museums and private collections. Gulgong
and Warren are also interesting because of the pattern of social interaction suggested by their dispersal across the landscape. Gulgong appears to be part of a western direction distribution from the Central and Northern Tablelands. The Gulgong axes are classified by McBryde as group 10 (Binns and McBryde 1972). They share a dispersal pattern and direction with the pebble axes of group 5 and the important group 2B from Moore Creek. McBryde (1979, 117) comments that the dispersal of the material from these sources crosses the area where the Warren quarries are located. These McBryde describes as being in an 'intermediate range' of dispersal. They are more extensive in dispersal than axes from Tia and Salisbury Court found on the Northern Tablelands, but more restricted than that of Gulgong and Moore Creek quarries.

As a means by which comparison and contrast can operate, the material on the surface of the quarry must be characterised. Random and casual observation of the material raised interesting questions about past operations at the quarries and the present distribution of material. I decided to undertake a systematic survey of the surface material at Gulgong and Warren.

4.3 Attributes and variables recorded at the quarries

The inspection of stones found on the transects was done as part of a classification system. The classification system provided for stone material found on the surface of the quarries to be described in a way that would facilitate the testing of hypotheses about behaviour in the quarries. The attributes recorded in the survey are outlined below and shown in Table 4.1.

(1) Stone is either 'worked' or 'unworked'. To be worked the stone must carry some features of intentional breakage. This usually results in features like impact points on dorsal or ventral surfaces (see Glossary). This classification gives an indication of the ease or difficulty of recognising the status of stone material in a quarry. In a quarry, it can be argued that all of the broken stone is in some way related to the working of the quarry. This situation is true of flakes from the reduction process and for stone material moved as unsuitable for axe making, or as part of any overburden. For purposes of technological analysis, flake features in size classes become important and these can only be found from material classified as 'worked'. The 'unworked' material will contain broken stone which cannot be recognised as 'worked'.

Some of the 'unworked' material will be recognisable as weathered stone from the rock outcrop. This weathered stone is usually small size material (less than 80mm length) with rounding at the edges from erosion and abrasion of the deteriorating stone.
CHAPTER 4

These are found on the surface of the site, especially below the unexploited rock outcrops, where the accumulation from natural fracturing is not disturbed. They occur in the excavation and are easily distinguished from the angular chips and flat flakes. So the distinction between 'worked' and 'unworked' stone is one in which 'worked', will include any stone smashed in pieces as part of the extraction and early reduction stage. They are not necessarily flakes or angular blocks ready for reduction to axe preforms. They are of irregular shape and most are angular and blocky in shape, with some that are flat and angular. From the point of distinction between 'worked' and 'unworked' the metric data was based on the 'worked' group of stones. Here there were flakes with the attributes sought in analysis and argument, with length, width and thickness (LWT) measures and the possibility of some measure of variability.

(2) Stone is classified by size. The four size classes chosen as a basis of classification and enumeration are: greater than 250mm; less than 250mm; less than 80mm; and less than 40mm. The classification of greater than 250mm and less than 250mm is the main classification of unworked stone. The reason for the class boundaries being set at the measures given above lies in some assumptions and tests of Aboriginal stone procurement and knapping practices. The boundary of 250mm was used because of the proposition about hand held working of the stone. A stone of 250mm length (L) is the reasonable maximum when reducing stone for an axe preform, where the stone is held single handed and struck repeatedly. The percussion can be by hammerstone or by block on block reduction. Above the 250mm size the blocks will need some heavy reduction, with more than one preform being possible from the blocks in many cases. The worked stone below 80mm length (L) and below 40mm length (L) is often flake material with strongly identifiable features and technological attributes. For example, flat, thin flakes less than 40mm in length are important in the late stages of preform reduction where thinning flakes are most frequent. These size classifications are potentially relevant in the reduction sequence for making axe preforms. The technological attributes may be sufficient to extend the understanding on the nature of production at prehistoric quarries in Australia.

(3) Worked stone was classified as one of the following:

(i) a block from which flakes had been struck;
(ii) a preform partly shaped;
(iii) a flake with measurable flake features; or
(iv) a flake with no measurable features.
(i) Blocks from which flakes had been struck were recorded along the transects and length measured. The 'block' was identified by no bifacial flaking and characterised by very few flakes struck (less than 6) (see Figure 4.3). Blocks present a problem in recognition because of establishing a threshold to distinguish this material from that which is unworked and unregarded. The problem is in deciding at what point the block has in some way been tested or selected for incorporation into the production trajectory. Ultimately the cut-off point where such blocks are recognised by the surveying archaeologist is somewhat arbitrary. So the criteria I have established in this survey is one of block size and more than one flake struck from the block.

(ii) Preforms partly shaped were recorded by length, width, thickness (LWT) where there was some bifacial work at the width margins, with mass removal flaking or end shaping (Dickson 1981). Mass is removed from the middle of the faces and at the distal end, that is the bevel edge on a ground-edge artefact. Figure 4.4 shows two illustrations of axe preforms from Gulgong. A further characteristic was that of having more than six flakes struck, together with possible pronounced irregularities not yet removed in reduction. The flakes are usually removed by the artefact being handheld and struck with a percussor, although anvil working may occasionally be used.

(iii) A flake with measurable flake features was characterised as one in which the point of force application (Crabtree 1972) (PFA) is found, the bulb of percussion is formed, and the margins can be (mostly) identified (Figure 4.5). This gives a three-way length, width, thickness (LWT) measure which is used to recognise variation of material in the archaeological record. The PFA is the point of contact by the percussor (hammerstone) on the platform of the stone where the cone on the bulb face truncates.

(iv) A flake with no measurable features can be recognised as a flake but it is not feasible to measure three ways for length, width and thickness (LWT) in the way in which flakes can fully be measured. In this case the length measure is taken along the longest axis.

(4) Length, width, thickness (LWT) measures were taken of preforms and featured flakes. The metric measures for the various classes of stone are summarised below:

<table>
<thead>
<tr>
<th>Measure</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>All worked stone: Blocks; Preforms; Flakes, and flakes with LWT</td>
</tr>
<tr>
<td>LWT</td>
<td>Preforms; Flakes with flake features for LWT measure</td>
</tr>
</tbody>
</table>
The LWT measures for axe *preforms* is based on the long axis at mid-point across the bevel (distal) and butt (proximal) ends. Measurements at right angles on this long axis are taken for width and thickness. These are made at the mid-point and quarter-points on the long axis. The measurements at the quarter-points become relevant where the preform is not at its widest or thickest at the mid-point (see discussion on symmetry in Chapter 5). The widest or thickest part of the blanks are recorded at the quarter-point closest to the maximum point. Where the length is at its maximum away from the midpoints of the proximal and distal ends, then this is recorded as a maximal length.

The LWT measurements for *flakes* are based on the length. Length is measured along the perpendicular from the platform width or impact point. The width and thickness measures are taken at right angles from this long axis at their widest points. A three-way measure is where the flake is complete, so the length, width and thickness can be recorded.

### 4.4. Methods of surface study at Gulgong and Warren

The surface study of the two quarries at Gulgong and Warren was done to provide a description of the sites from the different survey techniques used. Table 4.2 gives a list of the surface studies at Gulgong and Warren. The surveys (and excavations) at Gulgong and Warren have identification numbers which will be used with description of the work done on the surveys. With the exception of survey SG5, all the research work was done at both Gulgong and at Warren, although there are necessary differences in approach between the two sites. The purpose of the surface surveys are discussed below.

The methods used to record and collect data from the surface of the two sites at Gulgong and Warren are different and depend on conditions at the sites. Some surveys are specifically constructed to study a particular aspect of the site and others are designed to give a general description. In summary, my approach to fieldwork at the quarries is to seek information from the following main sources: (i) rock outcrops, for selection and extraction of raw material for stone tools; (ii) flake mounds with flaked stone and debris; (iii) axe preforms and hammerstones; (iv) archaeological features, such as grinding grooves and anvil stones. These four main sources will be used for information on the organisation and technology of production at the two quarries.
I did the quarry survey and data collection by the following methods:

(1) SGW1 (Surface Gulgong and Warren). A surface survey based on transects randomly chosen across the sites gave a map of surface stone at Gulgong and at Warren. These maps were drawn from data collected in Tables 4.3, 4.4 and 4.5 for Gulgong and Tables 4.6 to 4.11 for Warren. The Tables record the stone along the five metre wide transects across the sites and are used to map the stone material and features of the two quarries. Mapping the surface stone material was designed to record the concentrations of axe preforms, flakes, stone debris and other archaeological features. The maps of the quarries are shown in Figure 4.6 for Gulgong and Figure 4.7 for Warren, and Figure 4.8 photographs show the surface of the quarries. The recordings from the surface survey give a basis for planning the research program. The random transects and the material recorded is discussed in the section on the archaeological surface surveys for Gulgong and for Warren (section 4.6).

All stone greater than 20mm in length was recorded and this was done at one metre intervals along the transect. The recording of stone was done for worked material with flake features and for unworked material in size classes. The size classes are less than, and greater than 250mm in length for the unworked stone. This classification recorded the availability of suitably sized stone (ie >250mm) for axe preform preparation. Chapter 6 discusses selection of stone at the quarries. Worked stone was recorded and actual size measured for categories of: blocks with signs of flaking; preforms; flakes with platform measure; and flakes with no platform measure. The length, width and thickness measures (ie. LWT measure) were recorded for preforms and flakes with platform measures or identifiable impact points. The size as a length measurement was recorded for blocks with signs of flaking and flakes with no platform measure.

(2) SGW2. The surface density count of stone across the sites at Gulgong and Warren used metre squares as the basis of data collection (Figure 4.9). The randomly chosen metre squares were designed as a further means of characterising the sites. Characterisation is done in one way with the random transects across the site (SGW1). The random metre squares concentrated on the flake mounds at Gulgong and across the whole of Little Mount at Warren. At Gulgong the approach was to use the survey stations established for the topographical survey of the site. These stations were used as the point from which the random compass readings and distance along a tape were recorded. Table 4.12 gives the results of the surface survey for Gulgong. At Warren the compass and tape measures of random density squares were recorded from a cairn.
stone at a high point on Little Mount. Table 4.13 gives the results of the surface stone density per square metre for Little Mount.

The stone in the squares was counted in size classes and any preforms were recorded. The size classes of stone recorded are: greater than 250mm; less than 250mm; and less than 40mm. I recorded the number of stones in each class. The number of blocks, preforms, hammerstones and their length, width and thickness (LWT) measures were also recorded. Based on random selection metre squares the survey at Warren resulted in there being an equal chance of suitable stone and stone working being found at any point on the surface. At Gulgong the metre square samples confirm high density in what is seen as the extraction and working areas and nothing outside.

(3) SGW3. I have recorded the features of over several hundred axe preforms and hammerstones from Gulgong and Warren. Apart from measurements of their dimensions, flake characteristics were recorded and the blanks attributed to some stage of reduction in the production process. The dimensions of the preforms were measured by establishing the length from the midpoint of the butt to mid-point of the bevel end. The width was taken half way along this line and at right angles to it. Thickness is then at right angles to the point where length and width cross.

The results have implications for the nature of production at the quarry because questions of adequacy of force and raw material behaviour can be addressed. Hammerstones are part of the output at the quarry. Some hammerstones are based on abandoned preforms, some material has been prepared solely for hammerstone use and some are exotic to the quarry. The procedure and results are discussed in Chapter 7 and 8.

(4) SGW4. The rock outcrop survey at Gulgong and Warren of the available raw material was designed to evaluate raw material properties that may have influenced the Aboriginal selection of raw material (Figure 4.10). The results were then compared with worked stone in the flake mounds. My method of data collection was to identify the extent of the site and the number of separate rock outcrops. The result was a ranking of raw material in the rock outcrops in relation to their suitability for selection as axe stone. These results are discussed in Chapter 6 on selection and extraction at the quarries.

(5) SG5 (Surface Gulgong). In the main area of working at Gulgong (Area B.X) rock outcrops were surveyed to collect data on raw material properties. The
small outcrops of stone in the flake mounds were studied for any differences within the raw material used for axe making. Within this area of flake mounds all the available material appears to have been used for axe making. There are only a few small rock outcrops, some of which may have been used as anvils. My method was to identify the number of rocks outcropping and loose boulders in the main flaking area. These rocks were scored for features as follows: raw material type, either coarse or fine grain, as for the survey of rock outcrops across the whole site (SGW4); signs of extraction on the face of the rock; any flaws in the rock which limit the potential of the raw material for use as axes; and the proximity of flaked stone to the rock. The results of this survey are discussed in Chapter 6.

(6) SG6. I collected and recorded stone from a surface area at Gulgong where flakes **eroded from the hillside** adjacent to the flake mounds (Figure 4.11). The small flakes (mostly <40mm) are under represented on the surface of flake mounds. So a study area was selected to record these small flakes in a cleared area (see Figure 4.7). The purpose of the recording is to investigate knapping behaviour in axe making at the site. In particular, flakes from the late stages of reduction are interesting because of errors and their relationship to control in knapping. The results are discussed in Chapter 7. My method was to collect and record the stone (mostly small flakes) in a 10 metre by 5 metre area. The material eroding from the hillside was collected and recorded in two sessions six months apart. The features recorded are the same as those for the material in the excavation squares. Apart from the basic distinction between worked and unworked stone, flake features relating to the platform and to the impact were recorded. Where flakes are complete, then length, width and thickness can be recorded, along with any hinged terminations. Flake shape as angular blocks, or flat and thin are recorded.

(7) **SW7 (Surface Warren)**. The surfaces of **rock ledges** at Warren were one of the few places at Warren to have concentrations of flakes on the surface and one of these was selected for recording and study. This study at Warren is comparable to the Gulgong surface study of flakes eroding from the hillside adjacent to the flake mounds. My method was to record the stone in random metre squares across the flat ledge of stone. I recorded the same flake features on the ledges at Warren as are recorded for Gulgong in the 10 metre by 5 metre square. The results are discussed in Chapter 7.

4.5 Methods of depth study at Gulgong and Warren

4.5.1. **Excavations at Warren**
(1) EW1 (Excavation Warren). The shallow ground of the quarry mount at Warren was test pitted in four places (Figure 4.12). The test pits were chosen by looking for depth on a site where there are few places with a depth of sediment greater than 10cm. At 10cm or before, the test spike was stopped by either bedrock or buried stones. Four places were selected for 50cm x 50cm test pits. These went down between 15cm and 25cm with no flaked stone pieces found below ground level. The result was that no worked material was found below ground and there was no excavation program.

It is not known what has happened to the flakes from the production of axes. One possibility is that the fragments of stone decay quickly under ground because the feldspar breaks down to clay. The sediment was the material of the rock matrix, with the quartz crystals from the matrix of the rock free in the ground. The other possibility is that flakes are buried off the edge of rock ledges, where knapping is known to take place.

4.5.2. Excavations at Gulgong

(1) EG1 (Excavation Gulgong). The rock outcrops away from the flaked stone mounds presented an opportunity to determine the extent of the site and to seek spatial patterning in the production process at the quarry. Test pits were dug across two rock outcrops considered to be of low potential for selection as raw material. The result was a few exotic flakes and no indication of flakes associated with the later stages of reduction. The map in Figure 4.7 gives the location of the rock outcrops used and the two series of six test pits dug. Table 4.15 gives the stone from the test pits at the rock outcrops (RO 22 and RO 25). Stone was classified as worked or not worked, and put in size classes of greater than 30mm in length or less than 30mm. The proportion of worked stone to total stone in each square was low. With one exception the percent of worked stone was less than 10% of total stone. The exception to this was a scatter of worked stone in square South 2 at RO22. The scatter of worked stone was mostly less than 30mm in length and may have represented a knapping event in the late stages of reduction, rather than a work area for axe making. No blanks or large blocks were found in association with the collection of worked stone, although RO22 did produce two quartz flakes. From this study of material below surface at the isolated rock outcrops, I decided to concentrate on excavation at the main part of the quarry (Area B).

(2) EG2. I dug testpits in a hollow at the top of the quarry ridge at Gulgong (Figure 4.13). McBryde (1984) at Mt William, Houlder (1961) at Mynydd Rhiw in North Wales, and Bradley and Edmonds (1993) at Great Langdale in Northern England
observed hollows at quarries which may have been old workings. The test pitting of the hollow at Gulgong did not reveal signs of raw material extraction, nor small flakes associated with reduction in the later stages of production. The map in Figure 4.7 gives the location of the four test pits. The results of the work are discussed in Chapter 5 on extraction of stone at the quarries.

(3) **EG3** A large flat block of stone appeared to have anvil working marks on the surface (but not on the sides) and stood among a sloping area of large stones (Figure 4.14). This situation presented an opportunity to see if material below the surface of a predominantly extraction and blocking out area (Area B.Z) was any different from material at the surface. This extraction area showed a different size range from that of the flake mounds (in Area B.X). The possibility of anvil working debris of predominantly small size was lost when the excavation turned into a hole below ground. The result was a higher proportion of large stones >200mm and a greater number of large blocks above >400mm than the stone in Area B.Z. Flakes in the range 50mm to 200mm were few and most stones were angular blocks.

The anvil block was of interest because it is a large block on top of a mound of large stones and boulders. The surface is pitted and battered, but not the sides. There was another surface stone positioned and marked like an anvil stone. This is located on the north end of the quarry Area B.Z. The other anvil stones were recorded in a rock outcrop survey of the surface of the flake mound Area B.X. Some of the rock outcrops and large boulders are pitted and battered in the way described at other quarries where this method of reduction was used (see McBryde 1984; Baker 1987; Pearson 1981).

The role of anvil working in the stages of reduction is not clearly known. Certainly the late stages of reduction see the increased use of the hammerstone in direct percussion. This does not mean that the anvil was not used. Just as the use of a grinding or abrading technique may be found in some reduction sequences, so anvil striking or battering will be used to address some feature or problem in the reduction of the stone through preform. The role of anvils in the axe making toolkit is discussed in Chapter 8.

(4) **EG4.** I excavated to some depth at a possible extraction face for what appears to be high quality raw material (Figure 4.15). The excavation was an opportunity to test the expectation that angular block material would predominate in the debris at this point. This is contrasted with the flat flakes expected in the flake mounds. The result was a high percentage of angular block material in the excavation square. A large hammerstone of coarse grain material from a nearby geological unit was found in
the angular debris at the face. The map in Figure 4.7 gives the location of the extraction face excavation square, and the results are discussed in Chapter 6 on extraction.

(5) EG5. Several questions were formulated in relation to the mounds of flake debris in the main procurement and reduction area at Gulgong. Four squares in the gridded area GFM1 were excavated, and the attributes of all the stone excavated from here was recorded for debris above 20mm. The excavation results are discussed in this Chapter.

In summary, the surveys and excavations discussed here are used in building the descriptive base of the quarries. From this descriptive base, the sets of data can be compared and contrasted. The surface surveys and excavations described here may be used for discussion of either aspects of the reduction sequence and the nature of production, or building a baseline of information for evaluating the two quarries. Surveys and excavations used in evaluating specific aspects of axe making are found in the relevant chapters. The chapters are on selection and extraction (Chapter 6); axe-making at the quarries (Chapter 7); toolkits (Chapter 8). The results of those surveys and test pitting which were designed to give a baseline of data about the quarries, are discussed below. I will discuss Warren first and then Gulgong.

4.6 Survey of sites at Gulgong and Warren

4.6.1. Warren: the archaeological surface survey of Little Mount quarry

Little Mount is 650 metres long (north-south), 250 metres at the widest part (east-west), and 205 metres above sea level at the highest point. Initial observation suggested artefactual material scattered widely across the site with few concentrations of debris and abandoned axe blanks. Gresser (1962) refers to the Warren mounts as sources of stone in a region where there was no other stone. He believes that under these conditions, there will be 'crude implements' and 'not a wide range of types' (Gresser 1962, 532). These are found particularly around Coonable, Nyngan and Warren districts. To this Gresser comments that appearance does not seem to impede their functional efficiency. I decided to characterise the site by recording the artefactual material on the surface.

Random transects across the site were used as the basic surface survey (SGW1). This survey was done by recording all worked stone and archaeological features in a series of 15 random transects five metres wide, running east-west across the site. The results are given in the series of Tables from 4.6 to 4.11 and in Figure
4.7. The stone and outcrops of bedrock were recorded by metres distance along the transects. The results of the transect survey confirm the scatter of worked material across the site in a frequent occurrence of patchy distribution. The preforms are not necessarily close to flakes or hammerstones, and there appear to be very few flakes in all size categories considering the number of blanks recorded on the site. One exception to this situation seems to be the rock ledges where scatters of flakes are found, although these appear to be knapping events rather than the debris of intensive production. There is the possibility of prehistoric stoneworking being buried on the Mount. Some guidance on this was sought by digging test pits. The results of the test pits were void of archaeological material below the surface. This made study of the surface even more important in characterising production at Warren and as the basis for comparison at Gulgong.

The surface of the Little Mount site has plenty of raw material available for use as axe stone. In low outcrops and flat fissured slabs the material is found emerging from the surface of feldspar-clay and quartz that has eroded from the country rock of quartz feldspar porphyry (QFP). The mounts are solid blocks of QFP, which can be seen from the faces blasted and cut into the rock mass in the modern quarry at the south end of Mount Foster. With raw material ubiquitous at the site, stoneworkers could select suitable stone loose on the ground. There are some places where stone might have been extracted by being struck from the bedrock, but mostly the stone detaches from the bedrock along natural fissures. Very little leverage is needed to make this raw material available for axe production. The contrast is with the problem at Gulgong where extraction is a more intensive activity for the stone workers. So a blockfield of uniformly available material is the most appropriate means of characterising the raw material resource at Warren. Edmonds (1989) described a blockfield formation of material at Great Langdale and related this to the question of extraction technologies in the Neolithic of Britain. The blockfield feature of the quarry at Warren was investigated by a series of 216 random metre squares. Table 4.13 gives the location of the metre squares and results of the survey, in size classes of stone and type of artefact. The recorded pattern suggests the ready availability of suitable raw material across the site without the need of a sophisticated extraction technology.

The absence of manufacturing debris in the form of flakes led to the concentration on rock ledges where flakes are to be found on the surface. There are four rock ledges on the Mount with enough material for study. One is located at the north end and another at the south end of the Mount. The other two are unevenly spaced along the east and west sides (see Figure 4.7). On the rock ledges at Little Mount the flakes survive in good condition. There is no cortex on the flakes as can be
found from flakes not on the rock ledges. The area to be studied needed sufficient small flakes to give data on flake attributes and dimensions. Other recorded and observed scatters of flakes are small, usually less than two metres by two metres. One rock ledge was chosen for study from the four areas.

4.6.2. Gulgong: field survey of the topography and physical features

A field survey was undertaken for the site and the long ridge of the outcropping rock. The survey was designed as a topographical base plan on which the archaeological resources of the site could be plotted. Contoured heights and distances were established for the site and features of archaeological importance surveyed into the plan. Figure 4.16 gives contours for the site and Figure 4.17 the archaeological features on the contoured map. The scale plan of the site was used as the basis of planning for the archaeological surface survey of the quarry.

The stone axe quarry at Gulgong is part of a hillside (height 610 metres) which forms a low ridge to the north. The topography and main features of archaeological importance were surveyed into a plan of the quarry site by means of a number of (pegged) survey stations. The quarry and associated flaking floors is found for 900 metres along the ridge, although exploited stone is concentrated in one main area of about 50 by 40 metres. The slope and general topography suggested surface mapping by means of stadial tachaeometry would be appropriate. The slope of the hill is given in Figure 4.18 for Transect #10, which runs through a dense part of the stone mound. For the survey work a Wild theodolite was used, with a program in a Hewlett-Packard programmable calculator to get the reduced vertical heights.

The result of the survey was to establish four areas to the site and these are shown and numbered A, B, C and D in Figure 4.19, which shows the Gulgong quarry site in its local context. Area A on the 'Norbiton' property of the Watt family is the low ridge in the south-east formed of weathered rock outcrops and isolated axe blanks and flake scatters. Area A rises to join Area B which is the main part of the quarry. Area B goes for approximately 200 metres north along the top of the hill and down the slope on the east face. There is a shallow saddle (50m. wide) with no rock outcrops and few examples of worked stone dividing Area B from Area C. Area C sees the return of the site to a ridge, with a steeper fall on the east side. The rock outcrops are weathered and discontinuous, with occasional signs of stone working. Area D is a continuation of Area C across Reef Road on the Willard family property. This northern extreme of the site runs for approximately 100 metres and sees the ridge dropping gently to the north.
Rock outcrops are prominent and a few flake scatters and axe blanks are to be found in this part.

The long ridge is high enough and steep enough in some parts to form a hillside on which large boulders form the steepest part of one area of the quarry at Gulgong. I have called this area of the quarry Area B.Z (see Figure 4.19). It is in this area that boulders and large flakes predominate over the flake sizes found on the flake mound (Area B.X), sixty metres away across a shallow gully in the quarried area. The area of the flake mounds has very few large boulders, and some small rock outcrops which have been worked for axe stone. The transect data for the surface survey at Gulgong shows areas high up the hillside (in Area B.Z) where the five metre wide transects are mostly occupied by boulders longer than one-half metre. Between these boulders (some of which were not of the favoured fine grain axe material) there are flake scatters with flakes and features associated with the early stages of breaking down and blocking out of the axe blank.

The rest of the flake mound area (Area B.X) is broken and worked stone of some depth and running up and down one-third the length of the hillside at this point. The flake mounds are divided from each other by narrow pathways, mostly made in the moveable mound of stone that formed the hillside at this point. These pathways give an arbitrary distinction to the surface, which must be taken into account in any characterising of the contents or form of the quarry. In effect, the whole hillside is a flake mound and this has been sub-divided into mounds, mostly by the passage of European cattle. The influence of erosion from human traffic is commented upon by Edmonds at Great Langdale (Edmonds 1989) and Killin (Edmonds 1992) quarries. The continuous nature of the flake deposit, and its likelihood of a depth sufficient to give a quantity of broken material set on a steep hillside, gives rise to some questions about the general stability of the site at Gulgong. The mass of stone formed there could be moved downhill by some natural event or process. However what appears as the most prominent feature is the continuous mound of broken stone spread at some depth (nearly one metre in excavations) across the hillside.

4.6.3. Gulgong: archaeological surface survey of the quarry

My systematic survey of the surface focussed on Areas A and B of the quarry from the survey plan (Figure 4.19). This systematic survey was done by a random sample of transects from a base line running north on the east side of the quarry. Twenty transects were laid out at right angles to this baseline, each transect being five metres wide and these are shown in Figure 4.20. Areas C and D were surveyed by the
same method, using twenty random transects across the Area C and five transects across Area D.

Information recorded in the surface survey was as an enumeration of every stone on the ground at one metre intervals along the five metre wide transect (SGW1). The count of stone along the transects is given in Table 4.3. To get an indication of the density of the stones on the surface, I converted the surface count into stones per square metre. The calculated density is shown in Table 4.5. These I found to be zero in some places below the face of the quarry to several hundred per square metre on the flaking mounds. The result of the surface density study was mapped in five density classes. The survey gave the limits of the scatter of stone on the surface of the quarry and was used in defining the limits of the mounds. Edmonds (1989, 181) established the limits of flake exposures at Great Langdale by similar means.

The transects show the contents of the surface at Gulgong. This numerical recording of the various classes of stone was used to outline the density of stone at the quarry in Areas A and B and is given in Figure 4.21. I have mapped the density of stone at the quarry on a continuous basis across the site. The progressively higher density of the inner circles in the flake mounds are exaggerated only to the point of emphasising the general character of the flake mound. Most of the high density readings are in the middle parts of the flake mounds, but there are dense scatters recorded on the edges of the main flake mound.

My survey of individual flake ledges in the main flake mound resulted in the map shown in Figure 4.22. The purpose of this study was to characterise the quarry surface in another way from the general formulation found from transects and shown in Figure 4.21. The individual flake ledges in Area B.X were surveyed from the surface and classified by size and type of stone. The number and size of stones in the defined ledges were counted in size classes from boulders to small flakes. The five classes were given as: small flakes less than 60mm in length; large flakes more than 60mm in length; small stone; large stone; and boulders.

The survey was partly driven by the search for the surface scatters of particular flake types. The flakes in question were the small flakes associated in great number with the thinning and finishing stages of axe making. The flake mounds gave very little evidence of small thinning flakes. These small thinning flakes were found in a surface study of a square 10 metres by 5 metres adjacent to the main flake mound (see Figure 4.20). This main flake mound was recognised as being a series of ledges, mounds and
scatters of flaked stone. These features were often created or developed by cattle making tracks.

This survey of the ledges and flake mounds gave some idea of the degree of variability to be found in the density of stone in different areas of the quarry. Generally my map holds for ever increasing density of stone towards the more central parts of the flake mounds. There were concentrations of stone greater than 25 per square metre and these were recorded in my survey of the ledges on the main flake mound in Area B.X (Figure 4.22).

The length of the transects at right angles to the baseline was set at a standard 250 metres to run west across the quarry or the associated outcrops. I extended the transects to the east of the baseline for 50 metres. In two cases I surveyed 100 metres west of the baseline. This increase in the length of the transects was done to take account of the possible downhill movement of stone off the hillside and to seek flake scatters and reduction areas away from the main areas of debris.

Transects were also run from a 500 metre baseline along Area C, again in a series randomly drawn. The length at right angles to the baseline was 150 metres across the ridge of the rock outcrop running along the hill. Observation suggested Area C was not an area of extraction or stone axe reduction, such as was strongly associated with the material at Area B. The transect survey confirmed the absence of archaeological material, with only one extraction point possible on the faces in this area of the site. Subsequent and prior inspection of the face did not reveal any other signs of working on or among the rock face and outcrops. The extraction marks are about ten metres from a small flake scatter containing debris associated with the early stages in reduction of a block for an axe preform. The second flake scatter found in Area C is much larger and contained axe preforms and smaller flakes, including those compatible with the later thinning stage of reduction. These features are shown on Figure 4.20 with the transect baseline for Area C.

Across the road cutting through the quarry at the northern end is the lowest part of the ridge formed of the stone used for Gulgong axes. This Area D is less than 100 metres long and forms a continuous outcrop about 25 metres wide. From this outcrop signs of extraction can be seen in a two places and a thin scatter of debris, mostly reduction flakes, can be seen on the rock ledges. The density is not great and the flakes seem mostly associated with the late stages of reduction. This part of the quarry at Gulgong was surveyed by random transects at only five points, pro rata to Area C with 20 transects over 500 metres. The five metre wide transects were 50 metres long across
the ridge of the outcrop. A few blanks were recorded close to the base of the outcrop and a surface area search revealed a few more.

Generally this part of the quarry is different from the main part of the quarry at the flake mounds (Area B). On its own the area (Area D) is less interesting and not very informative about axe production. There are no flake mounds and the rock faces have not been worked for extraction. When Area D is contrasted with Area B in the organisation of production, the archaeological features of less rich parts of the site (such as Area D) become valuable.

4.6.4. Gulgong: excavations in the flake mounds (GFM1)

The excavations at the flake mound GFM1 are the basis of my analysis of the stone debris found at Gulgong. GFM1 is the largest flake mound at Gulgong and for much of its area the surface is completely covered by debris. To what extent this debris represents extraction waste or material from the later stages of reduction can be estimated from the surface stone by means of the size and shape. However more information on the making of axes at the quarry could be gained from the depth of material deposited in the flake mounds. I therefore excavated the site at GFM1 to increase this information (Figure 4.23). GFM1 is in the main flake mound area, Area B.X at the southern end of the quarry site. The map in Figure 4.20 shows the location of the excavation in Area B. An area of 10 metres by 10 metres was gridded into 2 x 2 metre squares in a part of the flake mound near the top of the hill. Figure 4.24 shows the gridded area of the stone mound (GFM1). This area of the flake mounds was chosen because it included part of the flake mound and covered the surface between the dense flake mounds and two outcropping rocks of the type of stone used for axes. Figure 4.25 shows the excavation square GFM 1C at the base of a rock outcrop. The outcropping rocks had rounded tops and carried flaking and battering signs on these parts. The sides and faces also had what may be flaking marks from extraction of stone for use in axe making.

I decided to undertake a limited program of excavation in the gridded area. I excavated a line of four 50cm x 50cm squares. These squares were placed from the top of the flake mound (GFM1) to one of the rock outcrops made of material suitable for axe stone. I wanted the limited excavation program to provide information on several aspects of activities at the quarry:
(1) The character of the stone in the squares; in particular the amount of stone which can be recognised as worked in comparison with unworked stone, and the features of the individual pieces of flaked debris.

(2) The organisation of production, in that extraction and the later stages of axe making may have been spatially separated, or may have taken place in an overlapping pattern in the same area of the quarry.

(3) The time period over which quarrying has been undertaken and changes in the nature of axe making over the period of exploitation.

(4) The influence of natural processes in the present formation of the site, because the stone mounds forming the site are on a hillside and may have moved after the period of cultural formation.

On the basis of the surface recording of archaeological material, I decided to test my developing expectations for axe making at the quarry by excavation. I did this testing by seeking data in the categories in Table 4.16, which gives a list of the attributes and variables measured from the material excavated at GFM1.

(1) The character of the stone in the excavation squares was investigated by selecting every piece of stone 20mm length or greater and recording its length in millimetres along the longest axis on the surface of the stone. The average length of the stone in each level of the squares in GFM1 is given in Table 4.17. This basic measurement of length was associated with other metric and non-metric recording, where these features were considered relevant for characterising and analysing the stone assemblage.

In Table 4.17 the initial non-metric classification of the stone from the excavation at GFM1 was as 'worked' or 'not worked'. The conditions for classifying stone as worked or not is discussed earlier in the Chapter (4.3(1)). Table 4.18 is summarised from Table 4.17 and shows that the majority of stone in the four squares is recognised as worked. In GFM1 62% of all stone was classified as worked, and this is 6600 pieces above 20mm in length. Square 1C has 80% of the total stone classified as worked. The square is next to a rock outcrop which was probably used as an anvil, and under these circumstances there may be fewer unworked stones associated with site debris and more flakes from axe making. In square 1C, 86% of the stone is in the small size from 20mm in length to 60mm, and these are more likely to be associated with the later stages of axe reduction. The classification of stone as worked gives a
substantial base on which to seek particular stone features. For example, a particular feature on stone such as hinging only has to appear on 3% of the worked stone material for there to be over 200 pieces available.

The fundamental distinction between stone which can be recognised as being worked and that which is not worked is the basis of further analysis of the stone. Although both worked and unworked stone is measured for length and so put into a size class based on length, the worked stone gives greater potential for analysis. Worked stone can give length, width and thickness measures, which is the basis of the classification of flakes for the stages of the reduction sequence. Table 4.19 LWT gives the number of flakes in the levels of the squares where flakes have LWT measures. The surface survey along the transects recorded flakes, where they were complete enough for length, width and thickness measures, and where the recognisable flake was not complete and had no platform measure. From the surface information of flakes, I had some expectations of complete flakes available for measurement in the excavations. My initial interest was in the identification of flakes which are long and in flakes which are squat. In establishing which flakes could be described as long and which are squat, I was able to draw on the literature for experimental axe making. In Newcomer (1971) and Burton (1980) experiments to replicate axes gave long flakes (flakes whose length is twice that of width), and squat flakes (flakes which are wider than their length). I defined a squatness in flakes where the length is two-thirds (0.67) or less of the width. The results for the squares is given in Table 4.20. These results showed that 76% of all flakes were squat flakes and the remaining 24% were long flakes.

The experimental flaking by Newcomer and Burton was designed to give details on the characteristic flakes found in the stages of reduction for axe making. Because of the importance to reduction sequence stages, I discuss Newcomer's and Burton's experimental flakes in relation to my own experimental results in Chapter 7. Their experimental work suggested some of the squat flakes would be thick and some of the flakes would be massive. My expectations for characteristics in the assemblage at Gulgong matched these flake descriptions. A flake is thick where the thickness is more than 20% of width. Flakes are massive where length is at least 100mm and width is more than two-thirds the length. Thick squat flakes are found in the excavations and are 15% of the total flakes recorded. Massive flakes are also found in the excavated flakes, but they are few in number being only 6% of the total flakes. The average length of these massive flakes is 117mm, that is greater than the 100mm proposed, but the expected thickness was often not found in these massive flakes. Only 2% of the total flakes are thick massive flakes, that is with a thickness greater than 20% of the
flake length. There were no very thick massive flakes, where the thickness is more than 50% of the length.

There is a high frequency of small flakes throughout the whole assemblage. My expectations for squat flakes were for characteristic squat flakes to have LWT dimensions of 67 x 100 x 20mm. Of the squat flakes recorded for the four excavations, 75% are small sized in that the width is less than 60mm. The same pattern exists for the long flakes recorded, where 60% of the long flakes are less than 60mm in length. In the long flakes the small size class does not conflict with expectations. Thinning flakes from the late stages of the reduction sequence are characterised as long flakes of less than 60mm in length. These results are discussed in more detail in Chapter 6, where they are important for the evaluation of the stages of reduction.

The stone recorded by length in millimetres is also grouped into size classes. Table 4.21 is a summary of GFM1, and includes measurement of flake size categories. The classification of stone in the three flake size categories is given in detail for the excavation levels of the squares in Table 4.22. The size classes exclude stone less than 20mm in length and are: 20 to less than 60; from 60 to less than 100; from 100 up. The majority of stone is always in the 20 to 60mm length class and this majority is to be expected because in these stone tool technologies small stones will predominate. Numerically there will be even more small stones less than 20mm in length than is found in the 20 to 60mm class. The proportions of stone by count is valuable in the range of larger stones available at the quarry. The size of stone postulated as an appropriate working size for a blank on which to preform an axe is scarce absolutely and relatively to all other stone. Of the total stone recorded in GFM1 only 6% (669 pieces) exceed 100mm in length. Stone of about 250mm or larger is viable for axe making. Most of the stone greater than 100mm in length is less than 150mm in length. In other words, it is not a suitable size for selection in axe making at the quarry. The PFA (point of force application) incidence on flaked debris at the quarry is recorded in Table 4.17. The PFA was recorded in three conditions: first, as measured from the complete flakes where the PFA is intact; second, when the PFA has been crushed; and third where it is found on a fragment of flaked stone. The force of impact is important in the condition of the PFA. This force is a question of knapping control and efficient behaviour in the making of axes. There is high relevance to the economic model which I intend to test.

**Flaking on two sides** of a piece of flaked debris is important in relation to the stage of reduction, which is likely to have produced that flake. The **dorsal ridge** count and pattern of cross-knapping can give valuable data on control in knapping and
suggest economising judgements in the work of the stone knappers. Control in knapping is accessible through the type of termination on the flakes in the debris. I have recorded the hinge fractures on the flaked debris because they are important in control aspects of impact and efficient behaviour in axe making. Stepped fractures are also recognised in experimental reproduction (Cotterell and Kamminga 1987; 1990). In the fragmented state of most of the mass of stone at a quarry stepped fractures are often difficult to recognise, and easily overlooked in recording. The number of stones flaked on two sides and those with dorsal ridges are shown in Table 4.17 of GFM1.

**Flawed** stone is also given in Table 4.17. There are very few stones with flaws in the excavation. Nevertheless they are there and suggest the flaws have to be recognised in stone knapping and appropriate action taken. These incidence of flaws becomes important where axe preforms are being shaped and thinned. If there is a flaw, the axe is weak at that point.

I distinguished the cortex found at Gulgong quarry from the weathering found in the excavation squares. Whilst I did not expect stone with cortex to be used for making axes, I expected stone with cortex to be in the stone mounds. All around the flake mound area of the quarry there are rock outcrops with cortex blocks of stone, both large and small. The number of stones with cortex is given in Table 4.17.

(2) I have investigated the organisation of production through classifying the shapes of stone. Table 4.17 in summary of the excavated stone gives four shapes of stone. Stone is either thin, flat, or a chipblock and this stone can be angular or not. This means the stone can be chosen as having either one or two of the attributes, such that flat can also have an angular shaping, but flat cannot also be a chipblock. The stone classification is based on shape features and on length (as the longest side) in relation to the shortest side in an LWT format. Thin fragments have a long face more than four times the most narrowest face, and may in some cases be eraillure flakes. Flat fragments are less than four times the shortest side but more than twice this narrow side, and chipblocks have sides approximately equal, with one face not more than twice as long as the shortest side. Angular material has faces which are not the same shape. The shape of the broken stone was recorded on the basis of shape or shape combinations and are important means of recognising types of stone in relation to stages of reduction. These stages lie broadly between the early extractive and preparation stages and the later shaping and finishing stages. The expectation of debris at a quarry is that there is a large proportion of angular blocks and that these are from the early stages of reduction.
I calculated the density of stone in the four squares as one means of evaluating the possibility of there being spatial differences in the organisation of work at the quarry. Table 4.22 gives the density of stone found in the four squares excavated at GFM1. The calculations show that the most dense accumulation of stone is on the flake mound proper in square 4C. The other three squares are above the flake mound, and below a rock outcrop which may have been used as an anvil stone. There is much more sediment in the squares than found in square 4C. At .04155 per cubic centimetre 4C is .016 per cm3 above the average for these squares, and gives an estimated 41,500 pieces of stone per cubic metre. I estimate this density of stone per cubic metre in 4C would apply as a density estimate for the flake mounds as a whole.

The estimate of density of stone is based on the number of stones counted greater than 20mm in length. The size of the stone affects the density where the proportions of stone size classes differs between the squares. Table 4.21 gives a summary of size classes of stone in the GFM1 squares. Square 2C is an exception to the average of 75% of stone in the squares being in the size class from 20mm in length to 60mm. Square 2C has only 60% of its stone count in the size class from 20 to 60mm in length. The fewer stones in the 20 to 60 mm length class in square 2C would account for the low density per stone in this square when compared with the other squares.

(3) The time period over which the axe making activities took place cannot be established by reference to the stone working at the quarry. To establish this a material such as charcoal is needed for dating. In a quarry this can be difficult to find in a context which is reliable. The problem comes in part from the mobility of dateable material, such as charcoal, where there is no good matrix in which to hold the charcoal. The flake mounds of the quarry have very little sediment and plenty of opportunity for low density material like charcoal to move around. In effect the flake mound is a flushing system in which charcoal can move around. In this situation it is fortunate that the squares uphill of square 4C are bedded with a matrix of sediment. It is in square 2C that charcoal was found in a sufficiently firm context to be used for dating. Figure 4.26 shows the section drawing of square 2C and the location of charcoal. A sample of the burnt wood was sent for radiocarbon dating and resulted in an uncalibrated date of 1970 +/- 50 years BP (University of Waikaito: Wk 2959).

Whilst only one date was taken for the site at Gulgong and nothing was available for Warren, the date obtained does not conflict with current views on the interactions between groups in eastern Australia. The view that ceremonial
aggregations and exchange interactions developed an intensity and regularity during the late Holocene fits with the radiocarbon date for axe making at the quarry.

(4) The influence of natural processes in formation of the mounds of stone is important for evaluation of the cultural behaviour likely at the site. The movement of stone mounds has been documented at other quarries (McBryde 1984; Houlder 1961; Edwards 1989) and raises the question of whether this process is occurring at Gulgong.

Table 4.24 gives stone in square 4C greater than 20mm length compared with less than 20mm length by weight in kilos. The table points to the possibility of small stones moving through the gaps and channels in the mounds of stone where there is no sediment or matrix to hold the stone. From the total of 137.64 kg of stone taken from the square only 2.88 kg is less than 20 mm in length. Numerically this 2.88 kg may represent many pieces of stone, in many small thin flakes. There is an increasing percentage of small flakes found in the lower levels of square 4C, which suggests the small flakes are moving down to the base of the square from the higher levels of the flake mound. In all the excavation of GFM1 4C only 4 kg of sediment is recovered with the 138 kg of stone. Table 4.24 shows the percentage of small stone in each of the excavation units as a whole of that unit. Level 4 at the bottom quarter of the square reaches bedrock at 640 mm (see Figure 4.27) and shows the highest percentage of small stone. 14% of the total weight of stone for square 4C level 4 is small stone (<20 mm in length). There is much less in square 4C level 3 up to the surface, and the total of small stone for the whole of square 4C is only 2%. As the square 4C is mostly loose stone and in no sediment matrix, then the downward movement of small stone is very likely. The effect is to limit the spatial integrity of the small stone in the square 4C, and generally in the loose flake mounds at the quarry. I have not included the small stone less than 20 mm in length in the recording and analysis of stone at the quarry.

The effect of the study of the ratio of small stone less than 20 m in length from the excavation of square 4C in the stone mound is to suggest that there is some movement downwards through the stone mound. This movement is to be expected and makes the small stone unreliable in relation to the context of deposition. The prospect of stratigraphic interpretation of the stone mounds is also limited by the possibility of movement. But there is no evidence for the large-scale downhill movement suggested for mounds of loose stone at quarries.

I classified as 'unworked' all stone which had been subject to weathering as a natural process. Weathered stone was recorded as 31% of the bottom level of square 4C. The high incidence of weathered stone at square 4C level 4 suggests some was
worked stone which can no longer be recognised as such. It cannot be accounted for by breaking out of the base of the excavation square in the process of stone extraction for axe making. The bedrock is the wrong shape for such extraction to take place. The existence of weathered and non-weathered stone in the same bottom level of 4C is difficult to explain. Possibly a disturbance pattern after the weathered stone base has been put down; or some stone breaks down and weathers in the ground. The existence of a higher than average percent of weathered stone will affect the amount of worked stone found for the excavated stone at 4C 4. The amount of weathered stone is given for the excavation units in the squares in Table 4.17 of GFM1.

**In summary,** most of the measures (metric and non-metric) sought in the archaeological material could be recorded in the excavation from GFM1 at Gulgong. Although not all features which were potentially useful were visible in the archaeological material, many of the features can be recorded in usable quantities and interesting patterns.

### 4.7 Comparison and contrast in the data at Gulgong and Warren

For a comparative study of extraction and axe making technology, features of past behaviour must be accessible from the archaeological material found at the sites. These features are ideally those which draw out the differences existing in the data sets. This section will discuss three key areas of comparative data, which are then discussed in detail in Chapters 6, 7 and 8.

From the baseline study of the quarries at Gulgong and Warren, an appropriate approach is to compare and contrast the features of the quarries and their products (Torrence 1994). If the material record is accepted as the source of archaeological knowledge about the past (Davidson 1988), then I expect the variations recorded between two quarries to be important in their evaluation. As Edmonds discusses for Great Langdale quarry, the significance of the debris patterning there only became apparent 'when contrasted with other procurement sites' (Edmonds 1989, 130).

A framework is needed where the significance of the differences and similarities between the archaeological material at the quarries can be evaluated. For this framework a set of expectations for behaviour in making axes must be developed. In my study the framework (in Chapter 2) is based on expectations for the making and distribution of axes as an economic transaction.

The aspects of axe making which can be compared and contrasted are:
1. Selection and extraction of raw material. One of the most fertile of areas for research questions directed to identifying and evaluating variation at a quarry is in the selection and extraction of raw material (Torrence 1986; Bradley and Ford 1986; Petrequin and Petrequin 1993). The selection and extraction of stone for axe making will be discussed in Chapter 5 on quarries. In terms of the expectations of an economic model for axe making and distribution there are differences between Gulgong and Warren. The differences and opportunity for comparison occur in evaluating efficient behaviour and the value-adding process at the quarries. This discussion on choice of stone for axes is done through the archaeological and ethnographic record on quarries.

2. Flake debris and preforms produced by axe making. In the main part of the quarry at Gulgong there are numerous mounds of worked stone and flakes. These mounds of stone were mostly small (less than 20 square metres), and if not divided by cattle tracks and small patches of grass, they would form a continuous surface for large parts of this area of the quarry. On the other hand, the quarries at Warren do not have flake mounds with a depth of deposit. Flakes as scatters on the surface of the quarries are few and only found in any density on rock ledges. Both sites have a large number of preforms. The differences and opportunities for comparison are found with the symmetrical shaping of axe preforms; efficient traits in axe making found in flake debris and preforms; and the value-adding decision process in the stages of reduction. The patterns of flake debris and preforms at the quarries are discussed in Chapter 7.

3. Toolkits and the organisation of production. There is a whole kit of tools and equipment associated with making axes at a quarry. Tools and equipment include lever poles for extraction, anvil blocks for reduction and shaping, grinding grooves for finishing, and whetstones for sharpening and rejuvenating. Most frequently found and extensively used are the percussion tools, known as hammerstones. The hammerstones used at Gulgong and at Warren are different. They differ in origin in that exotic stone is used at Gulgong but not at Warren; and in their production trajectory where some are made as hammerstones from local material. The equipment used at Gulgong included anvil blocks, which were not found at Warren. Grinding grooves of the same material type used for axes are found on Little Mount at Warren but not at Gulgong. Toolkits raise questions of specialisation and efficiency in axe making. The differences between toolkits at Gulgong and Warren concern local and exotic stone, and whether tools are special purpose or opportunistic and recycled. The organisation of production and toolkits used at the quarries is discussed in Chapter 8.
In summary, there is scope for the economic model of axe making to be tested on data from the quarries. The testing can be done by comparing the differences in sets of data from Gulgong and Warren. These sets of data are from the selection and extraction of raw material, the knapping of axe preforms, and the toolkits used.

4.8 Conclusion

My review of the quarries suggests the economic transactions model can be tested with the archaeological material found there. The testing must be done with operating concepts. For these I have identified efficiency as registered through control in knapping behaviour, and value-adding as a decision making process based on distribution and the organisation of axe making at the quarries (see Chapter 2). By means of this framework I can address questions related to distribution through the variation found in the production process. This view of the production and distribution of items of material culture needs a cautious approach to what can be known. As McBryde has commented, characterisation and petrological analysis of stone will give 'precise information on source areas and distribution', but this 'cannot answer anthropological questions on the nature of exchange involved' (Binns and McBryde 1972, 2).

The purpose of this chapter has been to build a descriptive and quantitative baseline for two very different quarry complexes, known as the source of geologically identified stone axes which are dispersed across the landscape. The baseline is intended to establish a data base from which analysis of the stone resources can be used to focus on particular aspects of the quarries. These quarry sources offer comparison and the use of contrastive devices between the quarries. I have been developing and implementing a research design, where the expected output is data from the stone assemblage at the quarries. My purpose is to use the output in evaluating hypotheses about the nature of production at the quarries.

With the excavation material reviewed, I have built a baseline of data about the quarries. This data has given me a better understanding of what questions can reasonably be asked when using a mass of stone such as that found at a stone axe quarry. The results suggest there are ways of measuring and evaluating economic transactions in manufacturing. The economic transactions model of axe making is tested with operating concepts. I have identified efficiency as registered through control in knapping behaviour, and value-adding as a decision making process for axe making at the quarries.
Warren is an extensive complex of stone tool material, where the scattered stone is homogeneous and uniformly available across the sites. This scatter of readily available material across the surface of the quarry characterises the sites. Gulgong axe quarry is a restricted area of intensive exploitation. The deposit of suitable raw material at Gulgong has depth unlike at Warren.

The archaeological investigations of the surface guided and suggested the excavations at the quarries. The results of the surface study of the two quarries were valuable in deciding what and how much to measure in the depth of stone debris at the quarry. Based on my expectations the data sought in the excavation material was found to an extent which made it useable for analysis. The implication of the work described in this chapter points to the possible direction of research in subsequent chapters. The relevant chapters are: Chapter 6 on selection and extraction of raw material at the quarries; Chapter 7 on axe making at the quarries; and Chapter 8 on hammerstones and toolkits used in production. The refinements of the data collection are discussed in these Chapters.
CHAPTER 5

Symmetry in axes

5.1 Symmetry and control

In this Chapter I will discuss the reason for symmetry as a means of distinguishing the exchangeability of axes. In Chapter 2, I have discussed symmetry as a concept in axe making, and in relation to the production trajectory of axes at the quarries. In that Chapter I argued that the exchangeability of axes was based on the symmetrical shape of the axe. I proposed a production trajectory for the manufacture of stone axes, in which the shaped stone tends towards symmetry as it is prepared for distribution (see Figure 2.1). The concepts of symmetry discussed by Dickson (1981), Bradley and Edmonds (1993), and Davidson and Noble (1990) deal with symmetry respectively as a technical, performance aspect of axes, in the context of economic anthropology, and as a feature of the reduction process.

Within the general framework of production for distribution, the need to achieve symmetry of shape guided the making of axe preforms at the quarry. Two aspects of symmetry were important in my study: (1) symmetry in plan from the middle face to the margins and, (2) symmetry in mass from the proximal to the distal end along the length of the margin. These are illustrated in Figure 5.1.

My reason for evaluating the symmetry of an axe lies in the relationship between the propensity of people to exchange goods and the type of exchange transaction taking place between the parties. If the distribution of goods can be achieved by several means some of which take the form of an exchange, then there must be some means whereby people can recognise the axe as an exchange good. The recognition of an exchange good is necessary to make the good acceptable within the form of exchange used by the transacting parties. Recognition and acceptability of the good by the transactors as being an axe suitable for the intended purpose is important in the exchange process. The two factors of recognition and acceptability exist to facilitate the exchange process, under circumstances of exchange which may be different from the product identification found in modern economies. But, there must be some means of recognition to enable the other transacting party to accept the good as an axe with a provenance, that is a place of origin, or of reputed origin. With the ability to recognise an axe prepared for exchange, the transactors at ceremonial meetings, barter centres and through trade partnerships, can accept the good offered by the other party.
Recognition features for axes are sometimes distinctive, such as the patterning of minerals in a particular stone used for axes. Distinctive features of colour and patterning are found on axes in Highland New Guinea (Strathern 1969; Chappell 1966; White 1972; White and Thomas 1972). In east Australia there are some axes with distinctive features, such as the discoidal shape of axes from Moondarra quarry in north-west Queensland and the greenstone from the axe quarries at Mount William and Mount Camel in Victoria (McBryde and Watchman 1976). The ability to recognise some axes by these features emphasises the general similarity of stone quarried for axes used in exchange. Most axes circulating in east Australia are not distinctive. They cannot be recognised as coming from one particular quarry rather than another, or as having particular performance properties associated with stone axes.

The ability to recognise shaped stone axes at exchange points some distance from their sources will be altered by incorporation into Aboriginal material culture and possible use of the axes. The axes exchanged are not necessarily in pristine condition, or as they would be on leaving the quarry after manufacture. Many factors will affect their appearance and form. They will be transported from one place to another, edge-ground and possibly reworked at some point, stored and possibly used, before being presented for exchange. Under these conditions a feature like the symmetrical shaping of an axe will be a useful, and possibly crucial, means of recognising goods which are intended for, and are acceptable in, exchange.

The existence of symmetry as a recognition feature in the acceptance of axes for exchange is different from the making of axes as a value-adding economic activity. My point about the exchange of axes is that they will not necessarily have been transacted solely and always on the basis of economic transactions. The recognition of exchangeability through symmetry means that goods were exchanged between interacting groups before any regularity appeared in the system of exchange transactions. It is from exchangeability that the value-adding model of economic transactions could develop as a means of supplying axes into a distribution based on efficient production and material gain. The distribution and exchange of axes between groups is conceptually separate from the exchange of goods based on value-adding economic transactions. Logically (and possibly temporally) symmetry within the system of axe exchange, will precede making axes by value-adding economic transactions. The opportunity for an exchange system based on value-adding economic transactions, will exist where exchangeability has been established by manufacture and distribution of symmetrical axes.
As I have discussed in Chapter 2 efficiency and symmetry in axe making are not the same. Where efficiency is the basis of axe making as an economic transaction, symmetry guides the preform manufacture as an exchangeable good. An axe can be symmetrical in shape, but not made by efficient means. Both symmetry and efficiency require control in manufacture, but for different purposes and with actions which have different traits. The control in symmetry and efficiency will be evaluated through knapping features found on the work. In particular I have approached symmetry and efficiency in the following terms: (1) symmetry is evaluated through the morphology of the preforms in the production process and the reasons for abandonment at the quarries; and (2) efficiency is evaluated through flake features found on the preforms and in the flaked debris at the quarries.

5.2 Symmetry as an ideal in axes

Symmetry as a desirable state has been discussed in stone axe studies. A better understanding of the relevance of symmetry to production and exchange can be gained by reviewing ways in which it has been related to axes.

Firstly, as part of an experimental program of making and testing of stone axes, symmetry in axes around the median plane was investigated by Dickson (1981). In this case the median plane was not primarily a plane of symmetry for shape, but for mass (Dickson 1976). Dickson describes symmetry in the median plane for a sample of axeheads from collections in eastern Australia. For blanks or preforms the median plane is that one about which the mass is in symmetry or can readily be brought into symmetry (see Figure 5.1). This was established by the degrees of departure of the bevels from symmetry about the median plane. The position of the median plane could be seen in them all and only a few showed a departure from mass symmetry about it.

This median plane symmetry of Australian axes can be compared with findings from Papua New Guinea. The axe heads from PNG are more completely shaped than those from Australia, and this makes measurement more certain. For example, Hughes (1977) study of highland Papua New Guinea axeheads with symmetrical bevels, suggests a frequent divergence of the longitudinal plane from the median plane. Yet the median plane is a prominent feature of New Guinea axeheads as in Australia (White and Modjeska 1978).

The median plane can be seen in stone blanks or preforms. Dickson (1981) reports the possibility of locating the median plane on an axe preform and that this can be done with some precision. From this plane it can be seen where the edge will lie in
the making of a ground bevel axe. This can be used as a guide to dressing the edge of the axe. Quarried blanks can be expected to be worked in this way. Quarried blanks require extensive treatment of their surface and in this manner must be compared with pebble axes (Baker 1987). Pebble axes made on cobbles are commonly found in Australia and are the dominant form of ground stone artefact on the east coast (Binns and McBryde 1972). The ground bevels of some Australian pebble stone axes are the only signs of working on them.

Dickson assumes axes have a function which is based on repeated chopping or impact action. My study does not assume axes must have this function, but observe and distinguish that they have a tendency to symmetrical shape (in the mass of the axe in this case). Ground-edge axes performed several functions, but my research question is directed to trade, not to questions of function. The Solutrian/Kimberley spear points are an example of traded stone with functional limitations; the brittle points would shatter as spear points, but even the broken ones were traded. The comparison is difficult but makes the point that while function may be important, it is not the sole criterion.

The importance of the median plane as a plane of mass symmetry rather than of pure shape comes from the working dynamics of the stone tool and the relationship to the ground edge. Experimental archaeology by Dickson (1981) shows that symmetry at the edge is not governed by the shape near the end, but by the whole form of the preform. If the centre line deviates from the median plane by as much as one quarter of the thickness of the butt, the preform should be discarded. Consequently rectification and redressing work on the stone becomes necessary.

If Dickson can be seen to give priority to the technical and functional aspects of a stone tool, then the approach taken by Bradley and Edmonds (1993) is different. In this second approach Bradley and Edmonds (1993) set the concept of symmetry in the context of problems in economic anthropology. Their use of symmetry as a measure in the form of the axe, is intended 'as a lead in to broader issues of the changing significance of axes across the country' (Bradley and Edmonds 1993, 131). They use the example of Great Langdale in the north of England, where there was a significant change in the ways in which stone was being worked at a single site. Bradley and Edmonds (1993) argue that some of the variation through time must have been due to changes in the mode of working. Using symmetry in axe form, they argue that, although the nature of finished products remained largely unchanged through time, the means by which the axes were produced altered during the productive life of the quarry.
In some parts of the Great Langdale site there was a greater emphasis on creating symmetry in the plan shape of the axe than in section and in other parts of the quarry the emphasis later shifted to symmetry in plan and in section (Edmonds 1989; Bradley and Edmonds 1993, 124). Symmetry in section is more difficult to achieve than symmetry in plan (Edmonds 1989, 244), because the former requires flaking that is more invasive and is likely to lead to breaks. Abandoned blocks of shaped material from the later levels differ from those from the earlier stage of working. The later levels of the site contain blocks with alternate patterns of flaking and seem to aim at symmetry in shaping. In addition there was a closer adherence to a pattern of alternating the working face, even during the preliminary stages of manufacture.

Bradley and Edmonds suggest a greater emphasis on symmetry would be indicated by a dorsal ridge pattern originating at a central crest on the platform edge, which implies there has been a high level of accuracy in positioning the point of impact (Bradley and Edmonds 1993, 125). The frequency of blade-like flakes with dorsal scars cutting across their long axis from both directions was suggestive of a greater emphasis on establishing a symmetrical cross-section (Edmonds 1989, 265). They relate the flake pattern to finds in other parts of Great Langdale where some places have a technology like the earlier phases and other locations resemble the later phase. There seems to have been a change towards a better attainment of the intended form of the axe during 'roughing out'. Bradley and Edmonds argue that a change towards defining the form of the axe at an earlier stage suggests a corresponding difference in people's perceptions of the object itself. The shaping effort in the earlier stage reflects a more explicit concern with the form of the axe (Edmonds 1989, 310).

Thirdly, the problem of symmetrical shaping to produce handaxes has been discussed by Davidson and Noble (1990; 1993) in the context of what they call 'the finished artefact fallacy', defined as the situation in which artefacts in an archaeological context are seen as the intended end products. So the finished artefact fallacy is about whether forms found were tools and also about whether there was a sense in which they were finished. Consequently the notion of symmetry in the shaping and form of handaxes, is an important means of comparison with other views of stone working behaviour.

For example, Bradley and Sampson (1986) and Pelegrin (1990) discuss the form of Acheulian bifacial tools of 300-500Kya in terms of symmetry, with symmetry representing the 'evidence of the idealised nature of the pre-existing mental image' (Pelegrin 1988, 4). Because flake removals are interdependent and the intended shape is independent from that of the raw material, then the necessary symmetry is attainable.
CHAPTER 5

by prior intent. Davidson and Noble (1990; 1993) question this approach on the grounds of incompleteness and failure in production. If handaxes are recognised as stone artefacts from which flakes have been removed from both edges (Davidson and Noble 1990, 384), then 'the regularity of handaxes can be seen not as the result of design, but rather as the unintended by-product of a repertoire of flaking habits' (Davidson and Noble 1990, 370). Their argument is supported by the observation that handaxes are diverse from region to region, but seem to be standardised at individual sites. The outcome of their proposal is a questioning of the value of symmetry in understanding the technique of production or the socio-economic context of exchange.

5.3 Symmetry, technology and organisation in axe making

The reduction sequence results in axes produced for exchange being symmetrically shaped, and for other products to be non-symmetrically shaped output from the process. Examples of other outputs from this process include axes with no symmetry and therefore not exchangeable (see Chapter 7), and hammerstones used on site in axe making (see Chapter 8).

The reduction sequence is a varying and flexible process by which the symmetrical shaping of stone results in (amongst other things) an axe which can be distributed and used. This symmetry in mass shape can be attained (and lost) at any time in the reduction, but within this reduction there is flexibility. A rigid stage-based production process with only one series of steps and only one type of output is unlikely for Aboriginal stone-tool production (see Shott 1994). The preform reduction was not highly standardised, but was flexible and not systematic as in the way described by Torrence for Melos (Torrence 1986, 196).

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 extent of symmetry in the making of axes at quarries, such as Gulgong and Warren. We can therefore predict axe preforms were abandoned with certain technological features which have resulted from knapping procedure and flaking features and which indicate the degree of control of force. The technological features I consider relevant to symmetry are found in the reason for abandonment of the preform. For this reason my approach to symmetry in axe making considers control in the reduction sequence at the quarries.

My approach at the quarries is to evaluate the symmetry in axes from the preforms abandoned at the sites. To make this evaluation, I classified the reasons for
abandonment of preforms as: (1) transverse snap; (2) edge damage; (3) mass removal; and (4) raw material flaw (see Chapter 7). Of these features, the first three are most relevant to control in knapping. Edge damage and mass removal are the two features related to the control of symmetrical shaping. The morphology of the preforms is in some part reflected in the reasons for abandonment, but is also found in the exterior dimensions of the preform. The length, width and thickness (LWT) measures give valuable guide to the symmetry of shaping in axe making (see Figure 5.1).

5.4 Symmetry in axes from the areas around Gulgong and Warren

My evaluation of preforms at Gulgong and Warren was preceded by recording symmetry in the shape of axes in the Australian Museum collection. The axes used were in the areas around Gulgong and Warren and were based on available material in the Museum collection. These areas are shown in Figure 3.4, Chapter 3. For Gulgong I used axes from places along the dividing range in the Wiradjuri and Kamilaroi tribal areas. The Wiradjuri and Kamilaroi tribal areas are large, and to maintain a connection with the Gulgong quarry I have recorded axes from places up to 200 kilometres north or south of the quarry on a belt one hundred kilometres wide. This recording area follows the north-south distribution pattern along the plains and ranges, but does not cross the Dividing Range in the east. The recording area around Warren covers the tribal areas of the Wongaibon, Kawambarai, Weilwan, and Ngemba. The Wongaibon area is large and I have confined my recording to places 200 kilometres around the Warren quarries.

There are fewer axes collected in the Warren sample than from around Gulgong (see Table 5.1). The axes recorded in the areas around Gulgong and Warren are not usually from the quarries at those two places. Only 3 of the 134 axes from around Gulgong are from the Gulgong quarry, and 12 of the 81 axes from around Warren are from the quarries at the Mounts.

5.4.1 Methods

I have evaluated and classified the axes on the basis of their symmetry, that is in the shape of the mass from the bevel end across the face to the distal end. My criterion for classifying the degree of symmetry is not based on a measured standard (see Giopoulos 1986). My classification is based on the trend observed in shaping of the sample from the Australian Museum. I evaluated symmetry by placing a straight edge along the line from the bevel edge to the mid-point of the butt, and with calipers
measured the divergence from equal mass on either side of the line. I measured the divergence at the mid-point along the face of the axe, at the quarter points where necessary, and on this basis I identified symmetry in the axes.

My observation of the collection at the Australian Museum was the basis on which I devised a means of classifying axes into one of three categories. In distinguishing between the axes with symmetry 'attained' and the other two categories, I did not devise a measure of the degrees of symmetry over a range of deviation. Instead I took the state of symmetry as I had defined it for the purpose of the study and then recorded those axes which conformed to this reading of symmetry. My impression at the Museum was that my judgement of symmetry did not leave many ambiguities; there were not many in doubt.

Symmetry in mass and in shape are different. Symmetry in mass requires an equal amount of stone material on either side of a line, such as the median plane. Symmetry in shape is where the axe is identically shaped on either side of the median plane. To compare axes in circulation with preforms in manufacture at the quarry I needed a form of symmetry which was distinguishable in both sets of data. I use the mass on either side of the median plane from the bevel end to the butt as the basis of distinguishing symmetry for axes in collections and the preforms at the quarry. The mass on either side can be symmetrical in shape, but the shape is not easy to recognise in the stages of reduction. Symmetry can be attained in any stage of reduction but there will be a tendency for it to develop through the stages of reduction and be more frequent in the later stages.

The axes I have classified as 'symmetry attained' are in a range and do not form a unique point as an axe shape. In his study of axes Dickson (1981) takes a similar approach, expressing bias in the axes as degrees from symmetry. There are considerable visible differences between the three categories of symmetry. The states where symmetry is 'approached' but not attained and where symmetry 'cannot be attained' are divergences from where symmetry is 'attained'. There will be a mass of unremoved stone visible on axes where symmetry is approached but not attained. The potential for developing the axe to symmetry was not followed for some reason, but the axe still passed into circulation. The other case is where symmetry cannot be attained because of the shape of the axe. The feature which places the axe in this category can be seen, and is typically where part of the mass of the axe needed for symmetry is missing. The mass may have been removed in knapping; or it may never have been present, such that the stone was always asymmetric; or the axe may be asymmetric
because of damage in use. The statistical significance of the difference between these categories is given by chi-square calculations.

I have classified axes at the Australian Museum as having one of three kinds of symmetry:

1. Symmetry has been attained in the axe shape of the mass of the axe (see Figure 5.1); or

2. Symmetry was approached in shape and can be attained if the axe were further shaped before being edge ground and passed into use-life (Figure 5.2); or

3. Axes have not attained symmetry, and will not be possible to shape to symmetry (Figure 5.3).

In one way the data is limited by the circumstances associated with collection of the axes, in that by the time the axes enter the Museum collection they would have been in circulation and have had a use life after their point of manufacture. The effect of this would be to alter some of the axes away from symmetry, such that symmetry would not be attained on the axe as it appears in the Museum collection. The reason for the lack of symmetry could then be not only that the axe was shaped without symmetry in mind, but that the axe was damaged in use and symmetry was not regained by shaping. It was not possible to distinguish these two sets of circumstance from each other. But some use could be made of the sample, in that some axes are symmetrically shaped and some are approaching symmetry, and these classes can be compared between Gulgong and Warren.

5.4.2 Results

Table 5.1 presents information about the axes from Gulgong and from Warren areas in the Australian Museum collection. At Gulgong and Warren most (65%) of the axes are not in symmetry, with 9 out of 10 (93%) at Warren in this condition, and half (49%) of the axes at Gulgong in this state. There are very few (5%) axes classified at Warren as approaching symmetry, but this class had 14% recorded for Gulgong. The class of axes recorded as approaching symmetry represent a group which could be worked by further grinding to produce axes with a symmetrical shape. The recording of axes in this class suggests there are axes in circulation for which there is no emphasis on symmetry during either manufacture or use. At Warren there are very few (2%) symmetrical axes recorded, compared with Gulgong where more than one in three
(37%) of the axes are symmetrical. The results of classification on the basis of symmetry suggest a regime of symmetry in the axes from the Gulgong area and much less emphasis on symmetry in the axes circulating in the Warren area.

I tested the difference between symmetry in axes in the collection from Gulgong and Warren at the Australian Museum by the use of Chi-square (Table 5.1). The results of the test give a highly significant difference between the data from Gulgong and from Warren, and suggest this difference is more than chance.

One exception to the low incidence of symmetry in quarry axes from the Warren Mounts is a group of three axes from the Dubbo area (see Figure 5.4). Dubbo is not in the area of classification I have used for Warren, but is in the Wiradjuri tribal area and so associated with Gulgong. The three axes are ground on the bevel edge and show a high degree of symmetry.

5.5 Symmetry in preforms at Gulgong and Warren quarries

5.5.1 Predictions for symmetry in preforms

I have predicted that symmetry guides the exchangeability of an axe which passes into distribution. 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 for Warren because the dispersal of axes from these two quarries across the landscape of east Australia suggest different forms of exchange and distribution 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. In these circumstances my expectations for the making of axes at Gulgong and Warren will be different for the two quarries.

In Chapter 2, I have predicted that axes at Gulgong will be made as part of a value-adding economic transaction, where manufacturing preforms was based on efficiency, and the product is exported from the quarry. The summary of predictions presented in Chapter 2 identifies symmetry as the feature by which to recognise and accept an axe for exchange. From expectations about distribution, the exchangeability of axes predicts there will be symmetry in the preforms made at Gulgong. In the reduction sequence for making axes, I predicted that symmetry would be recorded as...
attained in the advanced stages of reduction more frequently than any other stage. The reason for this lies in subtractive stone technology, where progressive reduction by flaking would tend towards an intended symmetrical shape.

My prediction at Warren is that the dispersal of axes is not part of an economic transaction. My prediction for exchangeability based on symmetry at Warren is that symmetry will not be found in the preforms. I predict that, at Gulgong symmetry will be more frequently found in the axe preforms than on those from Warren, because Gulgong is a place of axe making as part of a wider distribution system, whereas Warren axes are part of a restricted distribution as an interaction among local groups.

In summary, from the predictions for distribution and control in Chapter 2 only exchangeability, as registered by symmetry, is relevant in this present Chapter. The relevant stage in the reduction sequence where symmetry can be evaluated is after the selection and extraction stages, that is from stage 3 when preforms are made. Symmetry is predicted for preforms at Gulgong, but not for Warren.

For the preforms, I have measured symmetry (in plan) along the middle line of the face at three points. The width at mid-point along the length and at the quarter points on either side were measured. The plan face of the axe and the quarter points are shown in Figure 5.1. My expectations were that the symmetrical shape would develop around the mid-point width through the stages of the reduction sequence. I also predicted that there would be fewer deviations from this in the later stages of reduction and more in the earlier stages of reduction, because symmetry in plan would develop through the stages of reduction. My expectation for shaping symmetry in mass was that the asymmetrical mass found on either side of the marginal length would be removed through the stages of the reduction sequence.

5.5.2 Methods of data collection

My methods of data collection and means of evaluation are the same for both quarries. I have evaluated both quarries in terms of symmetry in axe shape and axe making. The trend of symmetry in the preform was recorded as either, (1) attained, (2) lost, or (3) not attained. My approach to the evaluation of these was through the axe making and reduction sequences for Gulgong and Warren.

Symmetry in the reduction stages of axe making was evaluated from abandoned preforms at the quarries. Establishing the symmetry state of the preforms can be difficult without the use of purpose-built and designed measuring instruments (see
Dickson 1981; Giopoulos 1986). But in my study this measurement was less important than for the ground-edge axes used by Dickson (1981) and by Giopoulos (1986). The axe preforms at the quarries were not completed and so what I required was a means of evaluating the direction the knappers' shaping of these pieces were heading in.

The raw material at Gulgong and Warren was not extracted in a form which suggested a symmetrical shape for the axe preform. Examples of these shapes, such as lenticular and lozenge, are sometimes described for axe quarries (Burton 1984; Chappell 1987; Edmonds 1989). The material from Warren and (especially) Gulgong was irregular in shape at the point of extraction and blocking out.

5.6 Results from preforms at Gulgong and Warren on symmetry

My expectations for the shaping of preforms at Gulgong and Warren are that symmetry in plan can develop from the early stages of reduction through the reduction sequence. The results are given in Table 5.2. I have also recorded the width of the preform at the quarter points. These points are used to record any divergence of my expectations from the mid-point as the widest point. Where the widest point is closer to one of the quarter points than the mid-point, then I have recorded this as the maximum width of the preform from margin to margin.

In Table 5.2, the result of recording the width of preforms at the two quarters and mid-point at Gulgong and Warren is that many axes diverged from the symmetrical shape expected where the axial mid-point is also the maximal mid-point. At Gulgong 25% of the preforms have their maximum width closer to a quarter point than to the mid-point. At Warren 6% of these preforms have maximum measures which are closer to the quarter points. The reason for this difference between the two sites is that the plan shaping of preforms at Warren is more easily achieved from the loose available blocks than from the solid rock outcrops at Gulgong (see Chapter 6).

The general proposition that the trend in symmetry in plan can be registered from the width measures, and that this symmetry is more readily achieved than in mass or cross-section, can be seen from measures of preform thickness. At Gulgong the maximum thickness measure is found away from the mid-point in 32% of the preforms, and at Warren this is recorded for 10% of preforms. As with the width measures, Warren has fewer preforms than Gulgong which diverge from the maximum thickness at the mid-point. But in both sets of preforms, the divergence of thickness measures from a maximum at the axial mid-point is more frequent than for width measures. The greater divergence is to be expected where symmetry in mass and cross-section is more
difficult to attain than symmetry in plan. The removal of mass in shaping the preform illustrates the problem of attaining symmetry in mass and cross section (Edmonds 1989). The invasive flaking needed to produce symmetry in cross-section causes errors in shaping and abandonment of preforms. This mass is a factor in the divergence recorded in the maximum thickness from the axial thickness for the preforms.

In the classification of symmetry in three states as (1) 'attained', (2) 'lost', or (3) 'not attained', I predicted that symmetry would be recorded as attained in the advanced stages of reduction more frequently than any other stage. The difference between (2) where symmetry is lost and (3) where symmetry is not attained is, that in (2) symmetry is attained in shaping the preform, but further knapping for reduction results in symmetry being lost, and the preform being abandoned as an exchange axe. In (3) the shaping process in the reduction sequence results in the preform not reaching symmetry before it is abandoned. In my production trajectory for axe making (see Table 2.1 in Chapter 2) it is possible for symmetry to be attained (and lost) at any stage in the trajectory. With a subtractive technology like stone axe making where symmetry is an objective of the output, then symmetry is likely to be attained as an increasing percentage passing from one stage in the reduction sequence to the next stage.

5.6.1 Symmetry in the stages of reduction

I classified all preforms in the stage of reduction as initial blocking out, shaping, and advanced thinning, and then compared these with the state of symmetry. Tables 5.3 to 5.6 present the results of the classification of preforms by the stages of reduction and the state of symmetry. The data in these Tables is presented on two bases for Gulgong and Warren. Tables 5.3 and 5.4 give the results from Gulgong and Warren for preforms recorded along transects, whereas Tables 5.5 and 5.6 have been collected on the basis of all preforms recorded from the quarries. The use of all preforms recorded at the quarries gives a bigger sample than data based on only the transects, but the transects have more validity as a sample. At Warren the percentage of preforms with symmetry attained at 11% is lower than for Gulgong with 28%. Two-thirds (65%) of the preforms on the transects at Warren did not attain symmetry and I recorded one-quarter (24%) with symmetry lost. The blocking out stage shows the most frequent incidence of symmetry not attained. The chi-square tests for Tables 5.3 and 5.4 combined shows a highly significant difference between the two quarries, with less symmetry at Warren.

At Gulgong symmetry is recorded from all preforms in the study as a larger percentage of each successive stage of reduction. In Table 5.5, 25% of all preforms
attained symmetry. The increase in the frequency of symmetry attained occurs from the blocking out stage, where 15% of all blocking out is classified as having attained symmetry, to 25% of all shaping being in symmetry. The advanced thinning of preforms has the most number of preforms where symmetry is attained, with 49% of all advanced preforms in symmetry.

The case where symmetry is not attained (3) follows the same pattern as for attained symmetry (1) only in reverse order. The chi-square test result from combining Tables 5.5 and 5.6 shows Warren with significantly less symmetry than found in the Gulgong stages of reduction. In Table 5.5 for Gulgong, no symmetry is recorded for 64% of all preforms in the blocking out stage, for 31% in the shaping stage, and 20% in the advanced thinning stage of reduction. The recording in the stages of reduction where symmetry is classified as 'lost' (2), suggests this takes place most in the shaping stage of reduction after blocking out and before advanced thinning, although this is not a strong trend. 44% of all lost symmetrical preforms are recorded in the shaping stage at Gulgong.

At Warren the features and trends of symmetry found at Gulgong are also recorded. The sample is smaller, but the subtractive process of reduction gives stages of reduction with three states of symmetry. In Table 5.6, 43% of all advanced thinning is where symmetry is classified as attained in the advanced stage. In the shaping and blocking out stage there are few preforms with symmetry (2% and 1% respectively). Where I have recorded no symmetry attained at the blocking out stage, then 94% of all blocks are in this state of symmetry. As for Gulgong this figure reduces for Warren through the shaping stage (39%) to the advanced stage (21%). Three out of five (59%) of all lost symmetrical preforms are (like Gulgong) recorded in the shaping stage at Warren.

In summary, the results from the transects and for all preforms at Warren and at Gulgong suggest no substantial difference between the two sample bases. At Warren two-thirds of the preforms have not attained symmetry, about one-quarter have lost symmetry, and a small percentage have attained symmetry. At Gulgong two-fifths of the preforms have not attained symmetry, about one third have lost symmetry, and one-quarter have attained symmetry.

5.6.2 Symmetry and abandonment of the preforms

The removal of mass and damage to the edge of preforms is important in evaluating the symmetrical shaping of axes. Table 5.7 and Table 5.8 gives my
classification of the preforms at Gulgong and Warren. This data is given by their state of symmetry and in the stage of reduction, with the reasons for abandonment recorded as edge damage and mass removal on the preforms.

Of the preforms where edge damage is recorded as the reason for abandonment in the stages of reduction, symmetry is either lost or not attained in 77% of cases at Gulgong and 89% at Warren (Tables 5.7 and 5.8). The preforms with edge damage classified as in a state of symmetry are 23% of those measured at Gulgong, and at Warren are 11% of the total. The difference between the recordings of edge damage at Gulgong and Warren in relation to the three classifications of symmetry can be expected from the reduction of stone.

At Gulgong the extracted blocks available for making preforms are more irregular in shape than the raw material used at Warren. Throughout the reduction sequence at Gulgong, there is always the problem of edge damage from the battering and striking of the material. Control over knapping to reduce the preform is hampered by lack of homogeneity in the properties of the raw material. In contrast, the material at Warren is more regular in shape and homogeneous in raw material. As knapping proceeds through the reduction sequence, there is less need for heavy battering.

Edge damage in relation to symmetry in the shape of preforms is most important where symmetry is 'lost' through the process of reduction. Where the reason for abandonment is edge damage, symmetry is lost in 47% of the cases at Gulgong, and at Warren in 41% of the cases (Tables 5.7 and 5.8). Where edge damage is substantial the mass of the preform becomes asymmetrical in shape. This asymmetry did not exist on the preform before the (heavy) knapping action which produced the edge damage.

I have classified one state of symmetry in shape as being 'not attained'. An expectation of why symmetry would not be attained in shaping a preform is that the removal of mass would be difficult and deter the knapper in the axe making process. This difficulty requires novel techniques of removal and attempts would often result in abandonment (Hayden 1987). At Gulgong and at Warren, 56% and 64% respectively of the mass removal reasons for abandonment occurred in the classification of symmetry as not attained (Tables 5.7 and 5.8). Where symmetry is not attained, most of these problems in mass removal at Gulgong and Warren are found in the early blocking out stage of reduction. At Gulgong, of the 29 preforms where symmetry is not attained 69% are found in the early blocking out stage of reduction. The predominance of mass removal in the early blocking out stages of reduction at Warren is found in 85% of the preforms where symmetry is not attained.
In summary, as is predicted from the exchangeability of axes in transactions between groups, symmetry is more likely in the advanced stage of reduction than in early stages. What emerges from the study of abandoned preforms at Gulgong and Warren is that the strong trend to symmetrical shaping expected for preforms at Gulgong is not supported by the comparison with results from Warren. The results from Gulgong and Warren suggest that symmetry is more frequently attained in preforms from Gulgong (28% on transects) than from Warren (11% on transects). But, the attainment of symmetry (especially in plan) at Warren should be more frequent than at Gulgong because of the easier reduction process for raw material, when compared to the difficult and irregular shaped material at Gulgong.

Loss of symmetry is associated with the reasons for abandonment I classified as mass removal and edge damage. This was found for both Gulgong and Warren.

5.7 Conclusion on symmetry

In Chapter 2, I predicted that axe making for distribution in exchange systems would be aimed at achieving symmetry in shaping of stone. In this Chapter I have discussed symmetry as a concept of control in axe making.

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, which is discussed in Chapter 7, and (2) symmetry in the shaping of the axes as products for exchange, which is discussed in this Chapter.

The purpose of symmetrical shaping of the mass in axe making is not only in terms of its performance and functional properties as Dickson (1981) describes. While this may be achieved by the shaping of the stone (see Chapter 2), the purpose of the symmetrical formation of an axe is to enhance its exchangeability as an item in the material culture of Aboriginal society. Symmetry acts as a guiding factor in the exchangeability of axes, and the purpose of symmetry is recognition and acceptability.

My initial review of symmetry in axe shapes suggested symmetry is found in plan, in mass, and in section. From my measures of width and thickness at Gulgong and Warren, I find that symmetry in plan is easier to attain than in section. The difference is more likely to be due to the action of knappers, rather than the working properties of the raw material.
The incidence and frequency of symmetry in axes evaluated from a sample of axes in the Australian Museum was useful in establishing symmetry in axes which have been circulating and in use before collection. The results suggest the axes from around Gulgong, not many of which come from the Gulgong quarry, are more often symmetrical than those from Warren.

Symmetry is attainable at any stage of reduction, given that the inputs of raw material into the reduction sequence are likely to have varying shapes.

My predictions for symmetry in axe making at Gulgong and Warren were for symmetry to be frequently found in preforms from Gulgong, and for symmetry to be less frequently found from Warren. At Warren there was a more restricted distribution of axes from the quarries, and the colour and patterning on the stone gives other recognition features associated with axes from Warren. Under these circumstances, symmetrical shaping of the axe will be less important at Warren than for Gulgong.

The hypothesis that axe making was a value-adding economic transaction, suggests that symmetrical shaping was found more strongly at Gulgong than at Warren, because axe making at Gulgong was more directed to material gain in the transaction of goods. At Gulgong and at Warren symmetry is recorded from all preforms as a larger percentage of each successive stage in reduction, with most symmetry recorded in the advanced thinning stage. In contrast the early blocking out stage of reduction more often has symmetry not attained. The main reasons for the loss of symmetry on preforms in axe making are abandonment from mass removal and edge damage. Edge damage especially gives a loss of symmetry, which was more likely with Gulgong preforms than for Warren.

The results from Gulgong and Warren suggest that: symmetry in plan is more easily attained in preforms from Warren than at Gulgong. However, symmetry in mass is more frequently attained in preforms from Gulgong than from Warren. The reason for this attainment at Warren is related to the easier reduction process for raw material from Warren compared to the difficult and irregular shaped material at Gulgong. Some raw material will give more errors in shaping than other materials, in spite of the variety of reduction approaches available and flexibility in knapping trajectories. Recognition and acceptability is needed for a good distributed in an exchange system; symmetry in axe shape gives the good exchangeability.
CHAPTER 6

Raw Material Selection and Extraction at the Quarries

6.1 Value-adding and efficiency in selection and extraction of axe stone

In this Chapter I will investigate the degree to which the selection and extraction of stone at the quarry source, which is done in stages 1 and 2 of the reduction sequence, were efficient, and will determine the role of value-adding in the axe making process at these stages. Specifically, the hypothesis to be tested in this chapter is as follows. If value-adding economic transactions formed the operating basis for the distribution of goods across the landscape from quarries in eastern Australia, then selection and extraction of axe stone would have been carried out in an organised and efficient manner.

Studies of quarries from Holmes in the late nineteenth century (1894; 1919) to those of Sheets (1972; 1975); Torrence (1982; 1984; 1986); Burton (1984a; 1984b); Bamforth (1990) and Bradley and Edmonds (1993) have developed from the observation of artefacts to focussing on the quarry resource as a means of explaining human behaviour and social interaction. This Chapter will demonstrate how sources of axe stone can contribute to understanding stone axe distribution in eastern Australia, by examining whether raw material was treated in an economic fashion.

Value-adding considers the decision process and other courses of action in relation to the choice within the identified stone quarries. Aboriginal knowledge of stone sources in a region provided the basis for a process of selection, a process whereby people return to the same sources. The knowledge of available stone and location puts those who control access to the source in a decision-making situation. At this point they can proceed to extract the raw material suitable for axe making. An other course of action is to invite others to get stone from the quarry, based on the knowledge of those who control access. At this point an economic transaction between quarry owners and quarry users can be established. The value-adding process stops at this point in the transaction between producers who identified the raw material for selection, and the consumers. The consumers can take stone away from the quarry and work the raw material into axes.

The predictions for selection and extraction presented in Chapter 2 and evaluated in this Chapter, can be given in summary:
The value-adding process will require decisions about production for exchange. If the control of axe making is aimed at efficient actions, then:

(1) **Selection** is predicted to be one particular type of raw material, with properties and features favouring use in axe making;

(2) **Extraction** will maximise the amount of raw material available for making axes.

At **Gulgong**, where axes enter the distribution system as value-added economic transactions, my expectations are that:

(1) Only one type of raw material is **selected** for axe making;

(2) Techniques of **extraction** will maximise the amount of raw material available for making axes, and have the potential for sustained economic exploitation.

Expectations for **Warren**, where axes are not exchanged on the basis of value-adding transactions:

(1) **Selection** criteria for raw material will not be based on a single raw material type;

(2) **Extraction** will be casual and opportunistic, and will not maximise the units of output of axe stone.

To make an evaluation of value-adding and efficiency in selection and extraction of axe stone, I need to know about quarries as sources for raw material and what constitutes suitable stone for axes.

### 6.2 Quarries as rock resources

Quarries contain rock, the raw material for stone tools. Rock is 'the material about which we know least' (Baurat, quoted from the foreword to Lama and Vutukuri 1974), yet for most of human existence it has been the primary material for implements. Above all, stone has been the main provider of sharp edges for repeated cutting as well as impact and cutting in stone heads for axes. The range of the Earth's rocks on the surface of the land provide a choice of materials with varying technical and mechanical properties. These rocks have been used by people as sources of stone for particular
purposes including marble statues, storage vessels, road gravel, building blocks, stone axes and glass-sharp cutting edges. The important properties for studying stone tool technology are workability, edge holding, impact strength, and durability.

At different places at different times in the past, the procurement of stone as an activity in the economy of human groups led to the concentrated and intense exploitation of a particular rock resource for its stone properties, although it had not been previously used. The exploitation was intense in that a high percentage of the available resource was used over a short time period.

Concentrated exploitation took place at quarries. It can be seen most strongly at quarries that contain masses of a single type rock. Typically such quarries are used for road gravel, marble, clay for pottery, or stone for tools. Yet within this uniformity there may be variation in the nature of selection of raw material. To operate this choice, people had to exercise judgement on the basis of some relevant criteria. This situation may have been preceded for a long time by periods of occasional and casual use of the material by humans.

To exercise choice the properties of rock need to be evaluated on the basis of suitability for a particular purpose, such as axe making. Before the making and distribution of axes can be tested and evaluated as an economic transaction based on value-adding and efficiency, a means for evaluating stone as raw material for axes is needed. The means should be an objective measure of the properties of stone, and one which considers the relative importance of specific properties. The evaluation of the suitability of stone for axes can be considered by employing results from tests of rock mechanics, as discussed in the following section. Suitability of stone derives from a combination of factors, including quality as a threshold property which the stone must possess before it can be used as raw material in making axes for distribution and exchange.

The use of tests provides a means for understanding why some raw material was selected for axes and not others. Linking the process of selection of raw materials with measurements of tests in rock mechanics can serve to clarify Aboriginal selection of stone material for axe making. Both Dickson (1981) and Bradley et al. (1992) argue that some tests are relevant to understanding the criteria for selection of raw materials to enable ranking of the material in relation to others. Dickson (1981), Bradley et al. (1993), and Semenov (1964) focussed on the property of 'toughness' in the use of material for stone axes.
Toughness is a complex property in which elasticity and tensile strength are important features. Toughness in stone is indicated by the rock returning to shape from a deformity under impact. The stone will be hard enough to cut and impact other materials without the stone chipping. Resistance to flaking will be functionally necessary. Tough stone is not brittle and will give an edge that does not chip. In general, rock with high degrees of toughness will have a fine interlocking crystals with a random orientation (Dickson 1981, 27). The properties possessed by tough stone suitable for axes can be classified by the tests used. Properties used to measure toughness include the following: (1) hardness; (2) tensile strength; (3) elasticity; and (4) flakeability.

Table 6.1 gives the relevant tests used in rock mechanics research for evaluating the selection of stone for axes. Different tests get results which are similar to those given by other tests. The tests are designed to measure the performance of the rock in relation to a specific property considered relevant to the raw material as axe material. These measures are related mostly to its performance property as an impact tool. But the use-function properties must be viewed in association with the working properties of the raw material, as they influence the extraction and knapping of stone in the axe making process. The evaluation of axe making in the economic model of transactions will require that the different working properties of stone axe making are recognised. The properties used as measures are discussed below.

(1) For the measurement of toughness in rock mechanics, Dickson adopted the Los Angeles Test. This test is used to measure the attrition level of road stones by a combination of impact and abrasion. It is described by the International Society for Rock Mechanics (1977) in the survey of suggested methods for determining the hardness and abrasiveness of rocks. The test evaluates the hardness of rock, particularly during crushing and compaction (Lay 1990). Tests done on a variety of materials showed coarse grained rocks tended to be less tough (as determined by the Los Angeles Test) when compared with rocks having smaller crystals (Minty 1961).

Hardness, as measured by indentation or abrasion, is not the major property sought in the rock used for axes. For example, the results of the Los Angeles Abrasion test shows hardness increasing from andesitic basalt to obsidian (Minty 1961). Andesitic basalt is a tough material which would be selected for axes where impact performance is important. The outcome of this test is that basalt, dolerite and hornfels have greater toughness than granite and that the toughness of the same type of raw material will vary from source to source. An example of this may be found in the Los Angeles Test where on a scale of soft material at 40, then less than 25 is hard stone.
Dense basalts registered 12 to 15, and vesicular basalts are between 20 and 30 (Lay 1990). Variation could be expected within a single quarry.

(2) Tensile strength as the tenacity of stone to resist breakage or tearing, was suggested by Bradley et al. (1992) as an important feature of the raw material suitable for stone axes. The measure of toughness used was the Brazil disc method of tensile strength as described by the International Society for Rock Mechanics (1978a; 1978b). In this indirect compression method, a circular solid disc is compressed to failure across a diameter. There are limitations with every method of measurement. Lama and Vutukuri (1974) and Vutukuri et al (1978) conclude their survey of tests for the tensile strength of rock by saying the Brazil test on solid diametrical compression of discs is practical and simple. The use of such tests must be done with care as the testing methods have not been perfected. The assumption with the Brazil disc test is that the rock being tested is homogeneous, isotropic and linearly elastic (Lama and Vutukuri 1974).

Problems of raw material selection would be clarified by a reliable and appropriate measure of toughness (Torrence 1979b; 1984; Bradley et al. 1992; Edmonds 1989). Dickson (1981, 27) argues for the ground stone axe enabling the more ready use of a tough kind of stone and not just flaked flint (ie, microsilaceous materials). The appropriateness of what is measured to the research problem is important in the study of axe manufacture and use. The raw material is under tensile stress in making the axe and high impact values occur in use.

(3) Apart from the important measures of toughness and hardness, the features isolated as relevant properties for evaluating the raw material of stone tools are density, resiliency and flakeability (Goodman 1944; Dickson 1981). When Goodman considered toughness in raw materials used for stone tools an impact test (Paige Impact Test) was taken as the most appropriate means of comparison. The relevance of the particular test method was established by the measurement of properties significant in percussion flaking and the use of impact tools, like axes.

Goodman (1944, 425) identified resiliency as a property that describes the differences in workability of a raw material used in stone tools. The test used measured the height of rebound of a hammer on particular rocks, as an approximation of the elastic constants of rocks. The property of elasticity is important in the behaviour of raw material under percussion and pressure flaking and for the behaviour of tools in use. A rock is elastic when it recovers its original state after being loaded to deformation (Lama and Vutukuri 1974). The static elastic constants of rocks use
deformation to determine the strength of rock. Results suggest materials increase in resiliency in the same general order for hardness.

(4) **Flakeability** has been identified by Dickson (1972, 206; 1981) as an important property of raw material in stone tools. Dickson defines flakeability as 'in inverse proportion to toughness' and measures this by the Los Angeles Test (Dickson 1981, 33). The tough axe stone will be sufficiently brittle to give a smooth break in flaking and shaping by the knapper. Tests by Minty (1961) show flakeability being in inverse proportion to the toughness registered by the Los Angeles Test. In the production of stone axes, the relationship between flakeability and toughness or hardness appears to be important. For stone axes an isotropic raw material with random orientation to the crystals is an advantage in use wear (Dickson 1981). There are no directions for easy fracture and breakage of the axe material under impact. So the tougher fine-grained materials used for axes, such as basalts and metabasalts, have reduced flakeability. At the other end of the scale, coarse-grained stone flakes poorly and detaches with a rough fracture surface and ragged edges (Dickson 1981, 32). The effect of this situation is that there are differences between the properties of raw material used for axes made of low silica hard rock (such as basalt) and those from siliceous materials. The axe stone from Gulgong and Warren reflects this difference, even though they are not as different as igneous rock and flint.

The test results of the different properties suggest a conflict in that the desirable property of toughness in a finished axe also creates a problem in production. To flake tough stone, increased force must be applied to detach the flakes and in some cases the working process becomes one of chipping. Flaking is an important technique of stone reduction and where the material is too tough to allow flaking unless great force is applied, then other impact methods may become important. For example, some of the axes from the sources described by McBryde (Binns and McBryde 1972) as group 2B and group 10 are hammer dressed or pecked on the surface. It is possible that the axes treated in this way are made of particularly tough material, and that the toughness may vary across the range of the raw material available at the quarry. With a particularly tough material battering and chipping might be appropriate, particularly for the late stages of reduction.

I have discussed hardness, tensile strength, elasticity, and flakeability as properties used to measure toughness in rock. Recorded measures of these properties are available, but should be used with caution. The physical properties of axe stone have been evaluated by reference to tests developed in rock mechanics (Dickson 1981). Goodman (1944) was one of the first to recognise the need to know the physical
properties of stone selected and rejected in the production of stone tools. She describes
the characteristics of rock important for axe and tool stone in terms of hardness,
toughness, resiliency and density. Goodman points out that although hardness,
toughness and resiliency are concepts related to the physical properties of rock, they are
also names given to results from specific tests. It is largely an assumption that the test
will reflect the concept. For example, hardness in rock may be measured as resistance
to either scratching, abrasive wear, or penetration by a particular instrument. For each
of these traits, there are different scales of value, such as the Moh scale from the scratch
test, and the Rockwell penetration test. The assumption is that the scratch or penetration
results will evaluate the degree of 'hardness' of the rock in a manner that is useful in
understanding the properties of the rock and how it compares to other rocks.

The available tests must therefore be used with caution because they were
developed to test rock properties associated with particular problems. Table 6.2 gives a
sample of rock types from various parts of the earth and the results of performance
tests done on these rocks used in axe making. The measures available record density,
elasticity and tensile strength. All three measures are relevant to raw material for axe
making, but only the tensile strength results from Bradley et al. 1992 can be related to
the raw material from axe quarries. The results of tests of tensile strength done by
Bradley et al. (1992) on the raw material from axe quarries in the United Kingdom can
be compared with those from various rock tests from Lama and Vutukuri (1974). The
rock types selected for the Table are hard rock materials which fit the description of
rock used for axes in eastern Australia. Table 6.2 can be used in evaluating the
criterion for selection of stone as raw material for axes. Readings for rock types for the
properties tested and recorded show that stone for axes is selected among rock with
specific ranges of values. The raw material types given for the quarries are the most
likely choice of (hard rock) raw materials on the landscape. This does not mean all
material of the same general petrological type will be used for axe stone. Nor does it
mean the types given are the only raw materials to be used in making axes.

In summary, mechanical tests of rock are used for evaluations, such as the
suitability and expected performance of a rock as road base, building aggregate, or in
civil engineering projects (Lay 1990). Some of these tests may be appropriate for
evaluating the raw material properties of stone tools, but they were not designed for the
purpose.

The performance properties of rock are important criteria for selection of stone
for making axes. Performance properties are hardness, tensile strength, flakeability
and elasticity. The tensile strength test ratings given by Bradley et al. (1992) and the
impact and abrasion tests by McBryde (1978) are a good indication of the properties of axes made from hard rock. These performance properties are related to toughness and workability in raw material selected for axe stone. They are measured by standard tests in rock mechanics, and the use of these tests improve the evaluation of axe stone found in Australia.

6.3 Stone suitable for axes in eastern Australia

Stone for axes is expected to be a tough, high impact material capable of being shaped by flaking. My method for evaluating the stone considered suitable for axes in eastern Australia was to connect the properties of rock with those used as raw material in the making of axes. To do this, studies of the mechanics of rock were evaluated. The results of this study gave guidelines for the properties of hard rocks on a comparative scale of measurement. These scales of measures are used by structural and civil engineers. The variability of rock is important, both within rock types (such as basalt) and between the types. The variability is based on the different properties of rock types, such as hardness, elasticity and tensile strength.

With some expectation of the properties of hard rock for Aboriginal stone axes, the suitability of rock for use as axe stone can then be indexed. This index can be used to compare raw material from different sources. The criteria for selection are the result of expectations of the economic model of production and distribution. My approach to the development of an indicator of suitability for axe material was to survey the rock types found at axe quarries and identified in collected axes. From the results presented in Lama and Vutukuri (1974), I have selected descriptions of rock types which were likely to coincide with the descriptions of raw material for the east Australian axe quarries. The rock types for quarries known as sources of axe stone in east Australia are given in Table 6.3.

I expect the hard rock axe stone selected in eastern Australia will have certain properties. The measurement of these by standardised tests gives the opportunity of an objective mechanism which can be used on different data sets.

If toughness, tensile strength and hardness are viable descriptions of the properties found in hard rock types used for axes, then the measures of density, elasticity and tensile strength recorded by Lama and Vutukuri (1974) are relevant. Linking the process of selection of raw materials with measurements from tests in rock
mechanics means the relevant properties of the stone used for axes must be considered and clarified.

The simplified scale of 'suitability' of raw materials presented here has two objectives. These are to evaluate: (1) the rock type and properties of stone used for axes from the quarries in eastern Australia, and (2) the place of Gulgong and Warren as stone sources in the dispersal of axes. If the influence of raw material in the selection of stone and production processes can be isolated, then more valid comparisons between raw material sources can be made and other factors, such as the logistics of procurement and cultural preferences can be considered.

Stone was used extensively in prehistoric Australia (McCarthy 1939; Hayden 1977a; Wright 1977; Jones and Johnson 1985; Davidson and Noble 1990). Some of the stone sources in Australian Aboriginal material culture are of a specific material and are located at a point of concentrated activity and used intensively. The distribution of Aboriginal exploitation of a valued raw material, such as the hard rock suitable as axeheads on impact tools, appears concentrated and intensive from the quarries of eastern Australia.

I have investigated why the exploitation of hard rock material for stone axe making was specific to certain outcrops. Table 6.3 gives the type of rock at axe quarries in east Australia. The axe quarries listed are from the study by McBryde (Binns and McBryde 1972; McBryde 1973; 1978; 1984). Most of the rock types at the quarries listed are igneous or metamorphosed rocks with a low silica content. The quartzite at Brewarrina and possibly the siltstone sources are exceptions.

If the greenstone (andesitic hornsfels) material of Mount William in south-east Victoria is considered to be material high on the scale of 'suitability' for axe making and use, then where are other sources of quarried axe stone positioned on the scale? The quartz feldspar porphyry at Warren is hard, brittle material, considered intractable in its working properties, and can be seen as low on the scale of 'suitability' of raw material. Tests of toughness undertaken by the NSW Department of Main Roads (Dickson 1981, 28) suggest that the fine-grained rocks are more resistant to crushing than coarse-grained material. This toughness is important in axe material and would suggest the basalts are high on the scale of 'suitability'. Examples of this material are the amphibolitised metabasalt at Lowes Mount (Baker 1987) and the laminated amphibolite at Tia (Binns and McBryde 1972). The axe stone from Lowes Mount is described as typical of the tough stone from which axes are made. In particular, the Lowes Mount
stone does not flake under impact. The actinolitic schist from Gulgong can be
described as having working properties similar to that of Lowes Mount and Tia.

From these examples it is suggested stone from Warren would be low on the
scale of 'suitability'. There will be a progression from Tia, Lowes Mount and Gulgong
through to the andesitic greywacke at Moore Creek. The fine-grain basalts and
hornsfsels represent the high end of the scale of 'suitability'. In some ways this result is
to be expected as tests suggest low silica material, such as basalt, is favoured for
chopping tools and can be ground (Kamminga and Hudson 1982).

What is noticeable with the test data from Bradley et al. (1992) are the high
values for the quarry stone used in axes when compared to the results from Lama and
Vutukuri (1974). The tensile strength tests of Bradley et al. show considerable
variation in the results recorded (see Table 6.2). Many of the test results are well below
the expectation for raw material considered suitable for axes. Of those listed from
Lama and Vutukuri (1974), only the greenstone from the USA and amphibole from
India gives results in the range selected for stone axes.

I expect tensile strength in axes to be above 20 on the Brazil disc test scale,
which is where the results from Tievebulliagh quarry and the greenstone and amphibole
tests in Table 6.2 are found. There is the possibility of a rock type being too tough for
effective working, a situation which exists with some greenstones and metabasalts
(Leach 1984). McBryde (1984, 273) comments on the andesitic hornsfsels at Mount
William in south-east Australia: 'the extreme hardness of the greenstone of this site
would make the removal of large blocks by percussion a severe technical problem.'

There have been no tests done on material from axe quarries in Australia to
compare with the tensile strength tests from the north European quarries. Results have
been reported by McBryde (1978, 358 and 366) from impact and abrasion tests. The
aggregate impact value of the Mount William stone is 10%, its aggregate abrasion value
is 1.4%. While these results do not have any comparative values, readings given from
the test run seem low enough to suggest resistance to impact and abrasion in the Mount
William stone. Goodman (1944) uses and describes a similar test (the Paige Impact
test). Hayden (1987) discusses the use of impact tests in measuring the properties of
basalt used as grinding dishes (metates) and hammerstones (pies) in modern
Guatamala. He questions whether the impact tests are appropriate measures when tests
of compressive strength are available. The unconfined compressive strength was
measured by Hayden (see Table 6.1) and claimed to give a more accurate test of the
rock used in metates and pies. The raw material of metates is a porous vesicular basalt
and that of the Pics a dense basalt. The tests returned a result of 24 mega pascals for the metates and 110 mega pascals for the Pics (where 1 mPa = 145 lbs psi). The two sets of samples used gave results with sufficient difference between them to suggest that raw material properties associated with compressive strength are important in the selection of stone by Guatemalan metataros.

In summary, the survey and discussion of stone used for axes shows it is clearly not the type of rock (such as greywacke or diorite), which makes it a suitable raw material for axes. This situation can be seen in Table 6.2 from comparison of data from Lama and Vutukuri (1974) and Vutukuri and Lama (1978) with the description of raw material types at axe quarries in NSW in Table 6.3. What makes a stone suitable as raw material for axes is the particular properties of the rock in terms of structure and minerals.

My evaluation of the raw material properties at Gulgong and Warren suggests that the rock at Warren is low on the scale of suitability and that Gulgong rock is higher. The differences in the properties of the stone used in axes at Gulgong and Warren is reflected in the distribution of axes from their source. Axes from Gulgong are dispersed over long distances, whereas axes from Warren are restricted in distribution (see Chapter 3).

If this observed difference in the distribution from the quarries at Gulgong and Warren was based on economic transactions, then selection and extraction of axe stone was done in an organised and efficient manner, and there was decision-making behaviour based on value-adding concepts. In these circumstances, I have predicted the result to be selection of a single geological rock type for use in axe making. In the next section I will look at the selection criteria and extraction technology at the quarries.

6.4 Raw material selection

The selection of a stone material source is not always a simple reflection of what is available, but more a question of choosing between a range of possible alternatives. Choice is required both between potential raw material sources and within various outcrops at a particular quarry. What determines the choice of raw material between sources is partly a question of the properties required for axes.

The required properties for axe making material are toughness and good flaking properties together with the capacity to withstand chipping at high impact. The material
must be isotropic, in that the random orientation of the crystals gives no direction for easy fracture; this is important if the head is not to break under impact. With elongated crystals of small size and a fine grain to the structure the material will be suitably tough for chopping. In fact, all these criteria cannot always be satisfied by the material available. For example, the material at Warren is relatively coarse-grained brittle and intractable, although it will serve as an axehead for impact work.

The criteria for the selection of particular raw material from a number of places both within a quarry and between sources may not resolve themselves solely into questions of raw material properties. Cultural factors will influence the perceptions of individuals and groups about what is suitable and available as stone for a particular purpose (Torrence et al 1992; Cook 1982; Bradley and Edmonds 1993). For example, Bradley and Edmonds (1993) recorded procurement places at Great Langdale where access was difficult compared to nearby points, at which the material was suitable and had higher impact values. The cultural construction of the choice of stone sources is strongly suggested in the exploitation of quarries in Highland PNG. Burton (1984a; 1984b) described the movement of stone axes into areas where there were quarry sources of material which had been used, but were not operated in living memory. Yet the suggestion from the available knowledge of hard rock quarries is one of a technical criterion being applied to selection. Axe stone is hard rock with certain impact properties and the exceptions to this are noticeable.

How have researchers approached the question of raw material selection by stone workers in prehistory? Holmes (1894a; 1894b) researched quarries in North America and observed their extensive and intensive exploitation. From observations of discard material (waste) at the quarries, the choice of materials made by prehistoric axemakers has been supposed by Crabtree (1975) to be highly discriminating. At Melos, Torrence (1982; 1986) established criteria for the selection of suitable raw material from the available rock outcrops. Density of material, ease of extraction, the potential for regular supply were used to evaluate the raw material at different places in the quarries. In her survey of raw material Torrence asked if the methods used to extract obsidian from outcrops were efficient with regard to inputs of time, labour and technology. The criteria applied in the Torrence survey were physical and operational, including evaluation of the source potential in efficiency terms. The potential for sustained economic exploitation of outcrops was judged using size, hardness, and content of deposits to assess the overall quality of each source and was ranked poor to excellent.
Using Torrence's (1986) research design for the Melos quarries, Bradley and Ford (1986) asked how efficiently quarry locations had been selected at Great Langdale. The quality of rock was assessed on a four-point scale at each of the sample locations. The flaking quality, accessibility, and the extent of exposures were recorded in the field. In each analysis separate scores were compared with the density of flaking debris at the sampling site. The researchers concluded that there was only a limited relationship between the most suitable locations and those sites where stone working actually took place. They argued the larger outcrops were preferred even when more accessible sites had equally suitable raw material.

At Talasea, Torrence et al. (1992) hypothesised that the choice of material would be that with least investment of energy: that is, a least-cost model. The relevant variables were identified to evaluate 'whether energy minimisation played a role in source selection' (Torrence et al. 1992, 94). They argued that the hypothesis offered concrete predictions which could be evaluated with archaeological data. Once least-cost considerations are accounted for, then one can look at other possible factors. The elimination of behavioural possibilities, is followed in the study of distribution from the Gulgong and Warren axe quarries.

The criterion of selection at the Gulgong and Warren quarries must be tested. From this quantitative and qualitative evaluation, an assessment can be made whether raw material properties characterise the selection of raw material at the quarries. The selection of raw material for the production of stone axes was probably not done on the basis of a single feature of the material. It is more likely that the selection criteria covered a range of features important in the successful production and operation of an axe. Some of these features are known in the study of rock mechanics and tests have been developed for them. Selected materials from rock sources can be described in three forms: either (1) loose weathered blocks and boulders on the surface; (2) in situ blocks with fissures; or (3) sheer faces and ledges emerging from bedrock. Raw material sources in these three categories must be exploited by stone procurers using different methods of extraction.

The study and analysis of raw material selection at the quarries required a survey of the potential sources of raw material. The survey of the potential sources of raw material at the sites was designed to distinguish those features of outcrops utilised for axe material and those not used. In addition, the data was structured in such a way as to allow comparison between the material used for axe making at Gulgong and at Warren.
6.5 Torrence's method in raw material selection

The survey of rock outcrops and raw material potential of the quarries at Gulgong and Warren follows the method and format established by Torrence (1982; 1984; 1986) for evaluating the potential for sustained exploitation on Melos. Because Torrence's method used specific features of the Melos site, such as cortex types, to identify the principles of exploitation, there are differences in the physical features used in my survey and recognised as important in the evaluation of Gulgong and of Warren. Torrence (1982, 204) ranked four features at the outcrops and identified each source by the type of matrix in which the obsidian was outcropping. Most outcrops are either fine-grain or coarse-grain and some are mixed. Torrence ranked the ease of extraction of obsidian from the matrix as one of the features surveyed at Melos.

Torrence's final feature in the study of Melos obsidian sources 'in terms of properties which would have been important for their use by prehistoric knappers' (1982, 198) is the evaluation of the source potential for providing a regular supply of stone, that is for sustained economic exploitation. Torrence uses this evaluation to assess source potential in relation to the extent of prehistoric use of stone from the outcrops, as a method of distinguishing efficient and specialised extraction. Using these criteria of evaluation, Torrence found that the highest ranking sources were intensively used on Melos. Other sources were used, but with less intensity, judging by the amount of debris to be found in proximity to the outcrops. Overall, the exploitation of the outcrops conforms to Torrence's prediction that the high quality sources will be used more extensively than others.

6.6 Predictions for selection of raw material at Gulgong and Warren

In the value-adding economic model used here, the stone selected by axe-makers is expected to be from a single well-defined source, which is geologically distinct. By identifying stone which is suitable for axe making, the selection of one particular type of raw material gives control over performance and quality in the output of stone to be used.

(a) Predictions for raw material at Gulgong. Predictions for raw material selection were evaluated from the rock outcrops across the site. The exploited quarry material at Gulgong was predicted to have been selected for stone axes on the
basis of (1) being fine-grained, (2) having few flaws and (3) derived from outcrops of solid blocks.

For Gulgong my prediction for stone properties suitable for the production of axes was that the actinolitic schist as a fine-grained material would have been selected in locations where there were no visible flaws or fractures, and where it occurred in sufficient quantity. All the exploited area of the quarry would contain fine grained material; coarse-grain would not have been quarried. Not all of the rock outcropping is in solid block form. At Gulgong the material is flawed and fissured in a way that is predicted to limit the viability of fine-grain material as axe stone.

(b) Predictions for raw material at Warren. My predictions were that a single geological rock type would have been selected at Warren, and that this raw material in the selected outcrops would have had few flaws. My expectation was that stone as axe material was evenly available across the site and that it was uniform in type and standard. From this outcrop of igneous material, selection was certain to give material suitable for axe making.

Compared with the quarry exploitation face, many rock outcrops at Gulgong appeared not to be used for axe stone. At Warren the extensive outcropping of raw material for axes seemed to be mostly unused. What characteristics distinguish the exploited from the unused? Can these be identified in the field? An argument based on efficiency in raw material selection would predict that the most suitable raw material outcrops would be most exploited. It was expected that there would be a threshold in the parameters for exploitation of raw material, and that the stone procurers of prehistory recognised this limitation. Outside this range of suitability, material would not have been chosen for making axes.

My approach to testing the proposition that a single geological rock type represents efficient procurement at Gulgong and Warren was to survey the rock outcrops across the sites. The first task was to identify the individual outcrops of raw material. In the case of Gulgong there are numerous source points within what is generally recognised as the quarry as well as some outlying rock outcrops within half a kilometre of the quarry (see Figure 6.1). Since the outcrops at Warren stretched for a total of more than three kilometres along the Mounts at Harris and Foster as well as at Little Mount (see Figure 6.7), a different sampling procedure was adopted. Since it was not feasible to record and sample every outcrop on the three Mounts, a systematic sampling strategy was followed.
Secondly, I evaluated the raw material in terms of suitability for axe material. Generally, a tough rock that resists flaking and compressive bending fracture is selected for axes as opposed to hard brittle rock. But within a particular quarry or series of outcrops there are likely to be differences in the composition and structure of the raw material (Bradley et al. 1992).

In summary, I predicted a single raw material type would have been used at each of the two quarries. At Warren the raw material source suitability is obviously easily verified. The landscape is flat and the mounts of uniform and appropriate raw material are seen from some distance. The source of the sought raw material is obvious. In this flat landscape sources of raw material are rare and Warren's three mounts represent an abundant resource at single locations. At Gulgong I predicted the rock outcrops to have been exploited where the fine-grain material is concentrated.

6.7 Gulgong: Field methods

My field method at Gulgong was to conduct two surveys, one of the rock outcrops across the site (see Figure 6.1) and the other in the main extraction area where there are mounds of flake debris (see Figure 6.2). The site was defined on the topographical map and the rock outcrops in the site area were enumerated.

(i) Survey SGW4. In the survey across the site, 49 outcrops have been defined as bedrock above the present ground surface. These are separated by areas with no rock (see Figure 6.3). Three features were scored:

(1) Grain-size. Overall the actinolite schist used in the quarry is fine-grained, but there are two varieties. One is distinguished from the fine-grained as being coarse-grained. Any outcrop of fine-grain material scored high.

(2) Fracture patterns. The fractures and jointing found in rock influence the procurement strategy and suitability of raw material as stone for axemaking. These fractures are flaws that may come from jointing in the rock and may allow fissures to weather deeply into the rock. Any outcrop without fractures scored high.

(3) Outcrop is a solid block or loose stone. The raw material for axes seems to come from material broken out of solid bedrock or from large boulders. The rock outcrops contain material in solid block and loose stones. In some cases the loose material has been detached by natural processes, such as frost fracturing and
weathering where the bedding planes of the raw material become slaty. Outcrops of solid rock scored high.

The scores for these features are summarized in Table 6.4, and Table 6.5 provides full details for each rock outcrop scored. The scoring of rock outcrops where there are extraction signs and archaeological material is shown in Table 6.6, and I have matched these features with the rock outcrop ranking from my survey.

(ii) Survey SG5. In my second method of approach, rock outcrops in the main flake mound area were studied using the existing survey stations from the topographical survey (see Chapter 4). From field observation, it appeared that the two flake mound areas were the main areas of exploitation for axe stone (see Figure 6.4). The ridge of outcropping rock runs for more than eight hundred metres, with the exploited source of raw material found in less than one hundred metres of this outcrop. From this situation it appears the selection of raw material suitable for axe stone was extracted from a particular raw material found in one part of the quarry. My expectations were that material in this flake mound area would be fine-grained material and that the rock outcrops would also be fine-grained and show signs of extraction.

My method of survey was to take the main area of the flake mounds in Area B.X and study the rock outcrops in that area (see Figure 6.2). I located all the rock outcrops and large boulders in the main flake mound area. These rock outcrops were then identified by the degrees from the named survey station (e.g. station Ga). The second part of the identification was the distance along the tape from the survey station (e.g. station Ga at metre 27). The rock outcrops were identified as coarse-grain or fine-grain and then scored for the presence or absence of signs of extraction. Some of the rock outcrops are also likely to be anvil blocks and used in the reduction of preforms at the quarry. The role of anvil stones will be discussed in Chapter 8. The results of surveys of rock outcrops in Area BX are presented in Tables 5.7 and 5.8.

In summary, the survey methods used at Gulgong and Warren were designed to test the selection of raw material at the quarries. For this purpose surface recording took place across the quarry sites.

6.8 Results of raw material selection at Gulgong
Predictions for the selection of axe stone under the economic model have been specified for Gulgong and the data gathering methods described. I will now discuss the results for the two surveys conducted.

(i) Survey SGW 4. The results of the first survey across the whole site is given in Table 6.5, and is summarised in Tables 6.4 and 6.6. Table 6.4 is a summary of Table 6.5 with a grouping of raw material selection characteristics. I will discuss Table 6.5 and the summary in Table 6.4 in terms of the presence of fine or coarse grain material, fractures in the rock, solid rock or loose stone at the rock outcrops, and the score this will give. I will also discuss the recording of archaeological material and extraction signs at these rock outcrops, and the significance of this material in relation to rock outcrops. The result as a ranking of outcrops matched against scoring for extraction and archaeological material, is given in Table 6.6.

Table 6.5 shows the results of the total of 49 rock outcrops identified across the site at Gulgong. The table gives the surface area of each rock outcrop surveyed; the scoring of rock outcrop characteristics on selection criteria; the scores and ranking for these characteristics; and the recording of proximate archaeological material and signs of extraction on the rock.

The surface area of the rock outcrops is given in column 1 of Table 6.5. The rock outcrops varied in size from 10 square metres to 1300 square metre, with an average size of 487 square metres. The size of the outcrops may be significant in the choice of rock as sources of raw material for axe making. Bradley and Ford (1986) commented on the choice of stone for axe making at Great Langdale being from the larger outcrops available. The five outcrops ranked as high are not all large. They include the largest outcrop (1300 sqm.), with two out of five less than the average size.

The results of characteristics to be evaluated at the rock outcrops are given in columns 3, 4, and 5. Of the 49 rock outcrops, 25 were identified as fine grain raw material and 24 are coarse grain. Because of the influence of the other selection criteria, not all the fine grain raw material was used as axe stone. This fine grain material was often passed over at Gulgong if the rock had fractures. These fractures would either become flaws in the axe preform or limit the size of the block available for producing a preform. In some cases there were fine-grained outcrops with fractures creating a slatey structure to the rock. Most of the outcrops had fracturing in the rock, with only five of forty-nine recorded having no fractures. The fractures are not formed in a way useful for removing stone for axe making, as seems to be the case at Moore Creek and Lowes Mount. The rock fractured in a crazed pattern and is close together along the
bedding planes. The outcrops across the site were either loose rock or solid, and in most cases the rocks were loose and had a substantial covering of cortex. There are seven cases where the outcrops are solid rock, which means the rock could not be used for axe making without extraction. Of the seven solid rock outcrops five have no fractures, but not all are fine grain raw material.

The scores from the survey of rock outcrop characteristics were added for each outcrop to give the score for that outcrop as a source of raw material for axe making. The basis of scoring for suitability as raw material was presence or absence of a trait, or the condition of the identified rock outcrop. For example, a score of '6' (in column 6 of Table 6.5) means the outcrop is fine-grained, without flaws and in solid block form. On the other hand, where there is coarse-grain material with flaws and in loose block form, then the score will be '3'. Where any one or two of the three features are scored '1', then the score will be '4' or '5'. With this scoring system, the rock outcrops can be ranked as either, 'high', 'medium' or 'low' (as shown in Tables 6.4 and 6.5). Columns 8 and 9 in Table 6.5 score either the presence/absence of extraction signs on the rock outcrop, or archaeological material.

The result was that five of the rock outcrops were ranked 'high' on the scale with a score of 6 (column 6 in Table 6.5). This result has been summarised in Table 6.4, where the scores obtained are grouped as three rankings. The five outcrops ranked as 'high' are 10% of the total of 49. Their features were a fine grain raw material, in a solid block with no fracture in the stone. In Table 6.4, 31% of the outcrops have a 'medium' ranking, where the rock is scored as fine grain but is available as loose blocks. Most of the outcrops rank 'low' because the material is either coarse grained, or fine grained but fractured and weathered.

Table 6.6 summarises data in Table 6.5 and concerns the rock outcrops which have associated extraction signs and/or archaeological material. Extraction marks are fissure lines on the surface which radiate from the point of impact on the edge of a rock face, and have waves and undulations in the lines. Sometimes a face will show several extraction points at different angles, although many are struck vertically from a point at the top of the rock, where the impact is greatest and best controlled. For the 49 rock outcrops, only four have signs of extraction (Table 6.5, column 9). These extraction scores were on four of the five rock outcrops which rank as 'high' on the criteria for selection. This situation shows a high incidence in comparison with the other outcrops, where no other signs of extraction appear. Extraction signs on rock in these circumstances do not mean that any form of intense or sustainable exploitation took place at the extraction point. The amount of debris recorded away from the main flake
mound is small and in few scatters only. The evidence for intensive and sustainable exploitation is all found in the worked part of the quarry. The extraction marks on the rock outcrops could be explained by actions such as the testing of material and casual procurement of raw material.

Archaeological material was recorded in relation to outcrops in the survey. For this recording the archaeological material could not be considered as part of the rock outcrop in the way of extraction marks on the outcrop. The archaeological material can only be proximate, and so to fulfil the requirement of a rock outcrop having associated stone debris the raw material must be found within a two metre radius of the outcrop. Of the four outcrops scored with extraction marks, two (#1 and #49) also have associated archaeological material. Archaeological material appeared in the proximity of a rock outcrop in 12 cases out of the total 49 (Table 6.5, column 8). Not too much reliance can be placed on the relationship of archaeological material recorded as proximate to a surveyed rock outcrop, because most of the archaeological material recorded near rock outcrops was within 50 metres of the main quarry exploitation area. Only three instances of archaeological material near a rock outcrop were recorded away from this area (rock outcrop #45, #47 and #49 in Figure 6.1), at the north end of the rock outcrop line where the ridge flattens.

Two recordings of archaeological material which rank 'high' but do not occur in the main flake mound area (Area B.X), also have extraction signs in the rock outcrop. These are at rock outcrops #1 and #49. Both represent distant points from the main flake mound area in Area B. Rock outcrop #1 is at the southern end and #49 is the northern end. At these distant points from the main flake mound, archaeological material and signs of extraction is in association with high ranking raw material. The combination of features is the same as in the main flake mound area. The high ranking raw material is fine-grained, without fractures, and in a solid rock outcrop. Rock outcrops #1 and #49 are also larger than the average size recorded for rock outcrops at the quarry. Rock outcrop #1 is 1300 square metres and #49 is 800 square metres.

In summary, of the five rock outcrops that rank 'high' for selection of axe making material, three are close to archaeological material and four have evidence of extraction on the outcrop (Table 6.6). There are only two 'high' ranking outcrops (#1 and #49) with both extraction marks and archaeological material.

(ii) Survey SG5. The next step was to test the raw material selection criteria suggested for suitable axe material on the main flake mound Area B.X. I will discuss Table 6.8 and the summary in Table 6.7 in terms of the characteristics surveyed for.
including my discussion of extraction. I began by identifying all the rock outcrops, then recorded and scored them according to the size of outcrops; loose stone and solid rock outcrops; whether the stone was fine grain or coarse; signs of extraction; any flaws in the raw material. The result can be compared with the results of the rock outcrop survey for the remainder of Gulgong. There were differences from the survey of rock outcrops across the whole site in Table 6.5 because of the abundance of archaeological material. All the thirty rock outcrops in the main flake mound are fine grained. But unlike rock outcrops recorded across the whole site, there are loose blocks of suitable stone.

The size of the rock outcrops were of a different order from the survey of the site. The rock outcrops in the main flake mound consisted of isolated and partly buried, boulders in size and shape. The dimensions of the rock outcrops from Area B.X are given in columns 3, 4, 5 of Table 6.8. They have an average height of 80 centimetres, with a maximum of 145 centimetres, and an average length of 940 centimetres at the base.

In all other respects, the material in this flake mound Area B.X was the same type and condition as the axe preforms, and would therefore have been highly desirable. The material from excavation in the flake mounds and from across the flake mounds in transects showed fine grained waste stone and flakes. There were few pieces of flawed stone in the debris of the flake mound Area B.X, and the rock outcrops in the flake mound showed few flaws (see Table 6.8, column 10). There was only one recording of flawed material on the rock outcrops. This freedom from flaws in the material is confirmed by the results of excavation in the flake mounds. The four excavation squares at GFM1 in the main part of the quarry contained sixteen thousand pieces of stone, but only 1.5 percent had raw material flaws.

In the main flake mound area and extraction area of the quarry Area B.X, I can only evaluate raw material selection on the basis of the outcroppings of rock that remain. These rocks had not been reduced for axe stone, but two out of every three (20 out of 30) carried signs of flaking and the extraction of stone (see Figure 6.5). Summary Table 6.7 gives the number of rock outcrops recorded and the number with extraction and flaking. The interest in the rock outcropping in the main quarry area was in the information they provided about raw material selection. These outcrops were all fine-grained material, with the same properties as the flaked debris and blanks produced on site.
Observation from the heavily exploited areas on the quarry face was that exploitation stopped at the boundary between the fine-grained metamorphosed material and the coarse-grain or slaty material (see Figure 6.6). There seemed to be no exploitation of the less suitable material, but a consistent and extensive use of the suitable material. My expectation was that the suitable material would be chosen from solid outcrops of stone rather than loose blocks, and that the larger concentrations of suitable stone would be the most heavily exploited areas.

In many cases the rocks carried flake and chip marks on their surface which suggested they could have been used as anvil blocks (see Chapter 8). Where signs of flaking extraction appeared on the rocks in situ, these flaking marks sometimes appeared on the sides of the rock and would not be caused by rock outcrops being used as anvil stones (Figure 6.5).

In summary, my field observation at Gulgong showed the flake mound Area B.X was the main area of exploitation. The ridge of outcropping rock runs for more than eight hundred metres, with the exploited source of raw material concentrated in less than one hundred metres. It appears the selection of raw material suitable for axe stone was extracted from a particular raw material found in one part of the quarry.

Raw material selection by Aboriginal stoneworkers at Gulgong concentrated on a single geological rock type. This rock type is a fine-grained material without flaws and contrasts with the coarse-grain material also found in the site. The results from Gulgong indicate that the concentration of high quality material found in the area of the main quarry debris is significantly different from that of the rest of the rock outcropping along the ridge. This concentration is the area where the potential for sustained economic exploitation is highest. The other rock outcrops surveyed have potential in terms of 'sustained economic exploitation', but are either coarse-grain or flawed fine-grain material and as such do not pass the threshold of technical acceptance necessary to be considered as axe stone.

This result follows the expectations for the economic transactions model. Selection of raw material for axe manufacture focused on a closely specified rock source. From this point in the procurement of raw material, the stone used was a single geological type, for which the working properties could be expected to be both consistent and known. In terms of the economic transactions, this behaviour was efficient, because the performance characteristics of the selected raw material was known and did not have to be reevaluated by the axe makers each time they produced an output.
6.9 Warren: Field methods

The first task at Warren was to identify the individual outcrops of raw material. Outcrops occur for more than three kilometres along the Mounts at Harris and Foster as well as at Little Mount (see Figure 6.7). The survey method and sampling procedure at Warren was constructed differently from Gulgong because the material is a homogeneous geological type across the site outcropping more or less continuously. Since it was not feasible to record and sample every outcrop on the three Mounts, a sampling strategy involving two surveys was followed at Little Mount. These surveys were based on: (i) a series of transects designed to record raw material and stone across the site, and (ii) a survey of density by metre squares across the site.

(i) Survey SGW4. To begin with, I surveyed the surface for (amongst other things) exposures of rock outcropping along 15 random five-metre wide transects across the Little Mount. Table 6.9 gives the rock outcrops recorded from the transect survey and Figure 6.7 shows the location of rock outcrops on Little Mount. To evaluate the extraction of raw material on the Mount, the rock outcrops were compared with the flake scatters along the transects (see Table 6.10). A scatter is defined as more than two flakes in a square metre. Table 6.11 gives the count of flakes in scatters, and the number of flake scatters for the surface area of four transects.

(ii) Survey SGW2. Secondly, a set of 216 counts of flake density were taken with a metre square frame (see Chapter 4). These counts were located using random degrees radius from a cairn stone used as the centre point for the compass reading. The random set of metres distance along the survey tape gave the points where the metre square frame was to record the surface. The data are listed in Table 6.12 and Table 6.13. In this survey I recorded the following traits: (1) the incidence of bedrock exposed on the surface; (2) the length and classification of stone as, loose stone greater than 250mm in length, the stone less than 250mm in length, and less than 40mm, worked stone as preforms, blocks, hammerstones, and flakes.

6.10 Results of raw material selection at Warren

Where Gulgong is a quarry located amongst rock outcrops along a ridge, Warren is a series of three mounts containing loose blocks. The selection of raw material at Warren is from an open blockfield where the material is the same composition at all points across the exposure. At Warren the rock is a volcanic block of granite porphyries (or porphyritic granophyre) known as quartz feldspar porphyry.
The raw material is petrologically the same across the site. It varies only in the colour of the matrix, from a gunmetal/black to pink/brown (see Towle 1939; Adamson 1964; Pogson 1994). Variation in colour is probably due to differences in the predominance of particular minerals in the rock and do not seem to influence the selection of raw material for axe stone.

The loose blocks of stone used in axe making were detached from the underlying bedrock along jointing planes and fissures in the rock that fracture and allow the action of weathering. The mounts do not change from zones of selected material into areas of rock different from the quartz feldspar porphyry used for axes.

(i) Survey SGW4. The results of recording rock outcrops on the transects across the site are presented in Table 6.9. Every transect recorded at least one rock outcrop or exposure of raw material. There are 161 recordings of rock outcrops along the five-metre wide transects. Most of the exposures occurred in the middle section of the Mount, that is between transects #5 and #14, and between the 100 metre and 250 metre point along the transect (Figure 6.7). Most of these outcrops are flat exposures of the bedrock and do not rise more than one metre above ground level. Stone could be extracted by leverage and percussion, and in a few cases it could be extracted by percussion alone. In the site at Little Mount there were very few rock outcrops with raised exposures where blocks of stone could be detached. Figure 6.7 shows the four rock outcrops with ledges and sheer faces, in which only one showed extraction. Heavy block detachment was found along an edge on the north-east side of the Mount. Generally there are few signs of extraction across the site, and with flake and axe preforms spread across the Mount, the selection of raw material could result in extraction from any part of the site.

To test the ubiquity of raw material at the site I gathered data from a series of random transects. The widespread availability of raw material in the form of rock outcrops was related to the incidence of flake scatters. Flake scatters recorded from the five-metre wide transects are given in Table 6.10. Most flake scatters were associated with rock outcrops, either adjacent to or on the rock outcrops. Of the 70 scatters recorded, only 6 flake scatters were not associated with rock outcrops. In these later cases the flakes in the scatters were few in number, considering the amount of debris generated in axe making at quarries. The situation is considered in more detail in Table 6.11 for four transects, where the number of flakes in the scatters was recorded. The 62 flake scatters in these four transects resulted in an average number of 15.9 flakes in each scatter. The paucity of flakes in the scatters is emphasised by a total number of 0.164 flakes per square metre across the transects. From the available results it seemed
the scatters were associated with rock outcrops, but there were few flakes in the scatters. The flake numbers were more like small, limited knapping events than the results of extraction and manufacturing.

(ii) Survey SGW2. The random survey of metre squares across the site was designed to test the prediction that the availability of suitable loose blocks and fissured bedrock was equal across the site. Table 6.12 shows a summary of the results of 216 squares surveyed, and Table 6.13 gives the results in full. The survey of the rock available on the surface of Little Mount shows the stone resource as plentiful and uniformly spread across the site. I defined the amount of stone as the quantity of bedrock material found in metre squares, as this was always quartz feldspar porphyry used in axe making.

In Table 6.12, suitable raw material was found in 80% of the surveyed squares where there is loose stone greater than 250mm in length (which I considered to be the minimum length for making an axe preform). This demonstrates the ubiquitous nature of raw material suitable for making axes. The stone greater than 250 mm in length was frequent in the squares recorded: on average 2.4 pieces per square metre. Some of this loose stone comes from the fissured bedrock in the squares, where the survey showed bedrock in 76% of the squares. I recorded any rock outcrop or ledge for five metres around the metre squares and found 83% of the squares had bedrock associated with them. A dispersed pattern of stone working across the site is suggested by nearly one-third (32%) of the squares having worked stone and flakes.

Flaked stone is recorded in Table 6.13 column 9, as the number of flakes recorded in each metre square. But in this test as in the five-metre wide transects, there were very few flake scatters. In the 216 squares recorded only five had more than two flakes per square metre and these contained an average of 4.9 flakes. In addition to flakes, the worked stone in the metre squares was recorded as preforms, blocks and hammerstones. When these worked stone classes were added to the number of flakes, then there was an average of 0.6 pieces of worked stone per square metre.

In summary, at Warren, as predicted, the survey found that raw material was equally available across the site in the form of loose blocks. In this case selection was a matter of indifference, because suitable stone was ubiquitous. Consequently, stone could be procured in many small units. In this way emphasis on quarry organisation and the balance of skill and decision-making shifts from raw material selection in terms of the rock properties to extraction and initial preparation of the axe preforms. These aspects will be considered later in this chapter and reconsidered in Chapter 7.
6.11 Evaluation of raw material selection at the quarries

Crabtree (1975:108 in Swanson) commented from his experience in North America that he had 'yet to visit a quarry without evidence of previous aboriginal use giving mute testimony to the workers' discrimination in the choice of materials'. This comment is also true of the stone axe quarries at Gulgong and Warren. My survey of raw material selection criteria confirms this, both as material chosen and that which is not selected at the quarries used for stone axe making. Crabtree (1975) cites discarded materials which may have imperfections, cleavage planes, lack of elasticity, wrong size, poor texture, and lack of homogeneity. The same is true for selection of material for stone axes in eastern Australia.

The imperfections at Gulgong were recognised by past stone procurers. The few abandoned preforms with raw material flaws found on the site are not knapped further than the discovery of the flaw; at that point they stop work. The knappers avoided flaws in the raw material, and cleavage planes were worked into the selection, extraction and production of axes from the raw material. Between rock sources, the elastic properties and homogeneity registered in the tests of rocks (Lama and Vutukuri 1974; Vutukuri and Lama 1978) are distinguished in the selection of stone. The quarry at Gulgong clearly represents the discrimination of the Aboriginal stone procurers. Raw material at Gulgong was extracted from outcrops which can be distinguished as geological units. When there was a change in the rock unit to a coarser or slaty material, extraction ceased. This situation can be compared with Warren, where the rock was the same across the site and equally available. In this case exploitation could occur at any point.

So why would the Aboriginal choice of raw material be so strongly associated with the selection of one geological unit? In an economic model of exchange, Torrence used the single raw material type as an expectation. Here the raw material is 'specialised in terms of the geological type of deposit' (1986, 171). I see this specific selection as a prerequisite to economic transactions. With the careful choice of one type of raw material, the basis for the production of the stone tool was set. The extraction, blocking out, and reduction stages of the axe were all now completed with a material whose working properties were homogeneous.

In the value-adding economic model standardisation of raw material type was a prerequisite for the exploitation of the stone source. The archaeological correlate offered by Torrence (1986) for the identification of specialisation was found in the
range of outcrop exploited and the kind of stone quarried. The standardisation of raw
material through selection of specific raw material at the outcrops increased the
efficiency of axe making through control of the input of raw material to the process and
output. The benefits of value-adding decisions came from ownership and control of the
quarry. The owners or controllers would have regulated material gains more effectively
where the specific nature of the resource was known. In an economic transaction
model of axe production and distribution this knowledge would have made the stone
resource more closely controlled and highly valued.

6.12 Raw material extraction

Turning from raw material selection, I will now consider extraction or
quarrying of the raw material. At quarries such as Gulgong and Warren besides
selection and extraction of raw material, further stages in the continuum of production
were undertaken. The stages in production found at a quarry site depend on the
organisation of production and distribution in the society and can be recognised by the
nature of the archaeological debitage combined with experimental production of flakes
in a reduction sequence. In some cases, most of the production stages will take place
on the site of the quarried material. In other cases, shaped blocks will be transported
for final working elsewhere. The point is that, in all cases, the quarry is a place of
selection and extraction of raw material (Hiscock and Mitchell 1990).

Quarrying is the extraction of selected stone. An analytical problem is that tools
and implements for extraction, like fire and lever poles, are unlikely to survive at the
stone quarries in Australia. A more fruitful line of investigation may be to study the
type of debris and the rock outcrop features on archaeological sites.

This approach was used to study the extraction techniques at the two quarries.
The classification of the quarry types by their physical features could have been recast
in terms of the solutions available to the stone knappers where there are several tools of
extraction from which to choose. The techniques of leverage, percussion and firing all
potentially have material correlates in the archaeological record (Cook 1973). But some
techniques of extraction are more difficult to establish in the record than say, the
questions of percussion made workable by access to hammerstones in archaeological
contexts. The material remains of levering tools would be organic and of low
archaeological visibility. Smyth (1878 1: quoted in McBryde 1984, 378) reported the
use of wooden poles to lever up the quarried stone. This process has also been
described by Binford and O'Connell (1984). Similarly, with firing which would have
been a small scale and short period event at the quarries. Although thermoluminescence
dating is always a possibility on rock, reliance on charcoal where it is not abundant and the reason for it on the site not clear, presents problems in identifying techniques of extraction. So the problem here was that tools and implements for extraction, like fire and lever poles, were unlikely to survive at the stone quarries in Australia.

Leverage, percussion and firing were behaviours in response to a situation where reduction of the mass or size is required. These techniques have effects on the pattern and form of material found at archaeological sites. For example, evidence of preform making at a quarry site where there were loose blocks and no signs of extraction from the bedrock, would suggest the leverage of loose blocks to extract the selected raw material.

Extraction was part of the selection process in that within the raw material body of the quarry there may be differences in the amenability of particular stone to extraction. The extraction of raw material from a face was a particularly important part of the production process, involving organisation, skill, technology and equipment. Torrence’s (1982, 204) five point scale of the ease of extraction of particular types of deposit was directed to the question of the efficiency of operation of the quarry. She hypothesised that the industry at the quarries was organised and efficient (1982; 1984; 1986). These conditions have archaeological expectations in the use of specialised and sophisticated extraction tools.

My expectation at the Gulgong and Warren quarries was that the means of extraction were adopted from a range of techniques available to the prehistoric stone procurers. Under these conditions extraction techniques which were technologically appropriate were adopted. In an appropriate technology, extraction is not based on a hierarchy of techniques. Instead appropriate solutions to the problem are chosen. Extraction techniques were adopted by Aboriginal stone procurers depending on the form of the selected stone resource.

Appropriate means of technology for a task are effective in achieving ends, which can be expected with efficient behaviour. In appropriate technology this effectiveness does not depend on the rigid use of a hierarchy of technology, but complicated solutions in terms of organisation and technology can be proposed as appropriate to a task. For example, Petrequin and Petrequin (1993) record the stone procurers of Irian Jaya building scaffolds to extract stone by use of fire off a sheer rock face several metres above ground level. The stone extraction for axe making is not a regular and repetitive routine but an infrequent event. The technology appropriate to
achieving the task involved input for the output of workable stone attained. The purpose of the detachment was not efficient as a high rate of output.

6.13 Predictions about extraction

In Chapter 2 I predicted the extraction stage of the reduction sequence as a value-adding decision process detach stone in a useable form. With efficient practices at the quarry extraction is expected to maximise the amount of raw material available for making axes. With less effort (Zipf 1949) the aim was to maximise the number of axe pieces available from any one extraction event, and these actions would reduce wastage and the need to extract more stone.

Predictions about extraction techniques and the physical conditions of their use are based on the appropriateness of the technology to the problem presented. It is possible to hypothesise conditions when certain exploitation techniques would occur. This might be expressed in the following set of expectations. Firstly, where faces had been carved out by stone knappers in wedges or blocks, long and deep, then leverage would have been important. Secondly, if ledges with a horizontal orientation were being exploited, then they would have been extracted by firing back along parts of their sloping edges and continuing to nibble at the rock until its slope was vertical.

Because leverage and firing are difficult to establish with archaeological material, a more fruitful line for investigating extraction may be in terms of the debris and rock outcrop features on archaeological sites. The exploitation techniques were tools in the Aboriginal working of stone. As tools they were set alongside the hammerstone, which was used as a direct percussion impact tool. The hammerstone appeared at all stages of the reduction sequence. Hammerstones come in a range of sizes. In a tool where size and inertia of mass is important, the range and scale of the hammerstones was a feature of the axe maker's tool kit. The role of hammerstones as part of the organisation of technology is discussed in Chapter 8. I can now consider three main tools in the Aboriginal quarrying of stone: (1) lever; (2) fire; (3) hammerstone. I will discuss the prospects and appropriateness of these tools in the making of axes where efficient behaviour guides economic transactions, and extraction is an important point for value-adding decisions about further processing. I will do this through the three forms in which raw material is found outcropping for each of Gulgong and Warren.

Once the places of extraction of raw material have been identified at the quarries, the extraction of material at Gulgong and Warren must be analysed. But
different types of outcrop will have different potentials for extraction. For example, suitable materials may be in the form of surface boulders or emerging bedrock with an extraction face. How are these to be evaluated such that the qualitative assessment of 'ease' or 'difficulty' can be used to understand decision-making at the quarry? Here the activity of extraction must be judged not only in relation to ease or difficulty of access to raw material, but by the degree of efficiency in the activity. For example, the emerging bedrock may be more difficult to extract for workable raw material than the surface boulder. But the labour-intensive and technologically more sophisticated extraction process from the bedrock face may yield more units of axe material and this may be from a higher quality source than the boulder material (as judged by the selection of material). So the appropriate technology for extraction will yield more units of axe material.

6.14 Method for extraction

My approach to the study of extraction at the quarries was to identify and investigate the forms of raw material described above, in terms of their potential for extraction. To study these forms of raw material, I used (a) surface survey data and (b) the results of excavation to compare with experimental stone working.

Quarry stone is found at the sites in the following three forms: (1) detached blocks in piles or scatters on top of bedrock, varying in size from boulders to cobbles; (2) sheer faces of rock from which blocks or tabular pieces must be extracted; (3) outcrops of country rock, often occurring all over the surface of a quarry area (these may require some sub-surface extraction, that is, removal from below ground level).

The surface surveys of selection discussed in the previous section were also used to identify extraction features. I expected that the rock outcrops across the site at Gulgong would give some indication of the kinds of raw material extraction, in the same way that they provided information on raw material selection.

Table 6.8 gives the number of rock outcrops in Area B.X of the main flake mound area at Gulgong with extraction marks. The same recording of extraction marks was done for the rock outcrops across the whole site at Gulgong (see Table 6.5). At Warren my survey of the surface along the transects recorded the rock outcrops and any signs of extraction. Table 6.9 gives the outcrops recorded from the transects and Table 6.13 shows the bedrock in the random metre squares at Little Mount, Warren. The
incidence of loose blocks and fissures in the bedrock gave indications of the extraction technique at the quarry.

I surveyed Area B.X at Gulgong and recorded the rock outcrops for features suggesting particular firing techniques. I looked for rock outcrops of fine-grained material classified as suitable for axe making. In the course of the surface survey a rock outcrop in the main flake mound area was found with what appeared to be a deep extraction face. I decided to excavate this face (EG4). In this excavation I hoped to examine the face of the rock covered by the debris, study the debris for charcoal and extraction features. I was interested in the size of the stone in the excavation square against the face because I expected the extraction stone to be larger than the axe making reduction stone. I also expected the evidence of selection in the stone at the rock face excavation, in that stone would be selected for suitable axe material and irregular shaped pieces would be left as debris at the face. The possibility of finding evidence where detachment has taken place by firing depends on the archaeological context. I hoped to find charcoal in a reliable context of sediment or some matrix in the excavation square (EG4), but I did not (see Chapter 4).

6.15 Results of raw material extraction at Gulgong and Warren

What techniques of extraction were used at Gulgong and Warren? An understanding of the means of detachment must be connected to the form of the rock outcropping. The techniques of extraction are discussed in terms of the form of the raw material available at the quarry site. The classification of physical features as loose boulders, ledges and outcrops emerging from bedrock, and in situ blocks with fissures, has been constructed to cover the range of raw material found at Gulgong and Warren. Loose surface blocks can be expected to have cortex in the way that unexploited outcrops of rock at Gulgong and Warren are weathered by exposure. Exploitation of faces and ledges at the quarries reduces the number and form of these outcrops to the point where they may be difficult to recognise. The in situ blocks of raw material with fissures can be levered out of place and reduced by smashing large blocks into smaller and more manageable pieces.

With quarry stone described as either (1) detached blocks; (2) outcrops; or (3) sheer faces, then the ranking of extraction properties for the types of deposit at the Gulgong and Warren quarries can be rated as easy or difficult (in relation to each other). For example, sorting through detached blocks for suitable pieces is an 'easy' rating compared to extraction from a sheer face. I classified the three forms in
ascending order of difficulty; (1) detached loose surface blocks; (2) rock outcrops as in situ blocks; (3) sheer faces and ledges from bedrock

The classification of the form of raw material occurring on quarry sites and a ranking of the difficulty of exploitation as an economic transaction (through value-adding) provided an excellent framework for investigation. I will now summarise the results by looking at each type of extraction.

6.15.1 Loose surface blocks

Gulgong. My evaluation of extraction at Gulgong involved a test excavation at EG3. Figure 6.8 shows the location of a hollow on the ridge above Area B.Z. This hollow or scoop in the surface is grass covered and surrounded by deeply fissured rock outcrops. The surrounding rock outcrops are both coarse grain and fine grain material. My survey of the raw material potential of the quarry rock at Gulgong did not identify this type of rock formation as being likely to be selected for axe-making. Yet research from other quarries suggests there are circumstantial reasons for investigating the pit-like feature on the hillside.

McBryde (1984) at Mount William in south-east Victoria, Houlder (1961) at Mynydd Rhiw in North Wales, and Edmonds (1989) at Great Langdale in Cumbria, all observed hollows at quarries which may have been old workings. McBryde did not excavate the 250 circular and oval pits at Mount William, some of which ran along the top of the quarry ridge (1984, 281). When Houlder (1961) excavated the hollows in the Welsh quarry, they were found to be stone extraction areas which had been filled in by sediment and debris. Bradley and Edmonds (1993) also found extraction pits at Great Langdale.

I looked for signs that extraction from the hollow was by leverage rather than by firing. My method was to place a one-metre wide grid for 12 metres across the hollow and then to excavate four 50 cm. by 50 cm. squares. The test excavations reached a maximum depth of 41 cm., where weathered bedrock was encountered. My test excavation of the hollow at Gulgong did not reveal signs of raw material extraction. The bedrock was not fissured or structured in a way that suggests extraction could be by lever poles. There was only a small amount of archaeological debris and no signs of bedrock extraction. It is likely that the hollow on the ridge top was a geomorphological feature created by slumping and slipping of the surface. The excavation of the hollow did not confirm an extraction area for raw material, although there was circumstantial suggestion from the surface morphology and quarry literature.
Another approach to the investigation of extraction technology in relation to raw material form at the quarries was to compare the results of experimental stone knapping with the stone in the flake mound excavation. The loose surface blocks at Gulgong and Warren have cortex which had to be removed in the production of a preform. Here extraction was easily done with lever poles. In the excavation square at Gulgong there is very little cortex material. This is supported by comparison with material from experimental stone work. My knapping experiment (UNE exp #2) conducted on a cortex block of material from Gulgong resulted in 53% of the 121 flakes having cortex. This result is compared with excavation square GFM1 4C where only 8% of the total flakes in the square have cortex. It seems likely that material for producing axe preforms did not come from loose surface boulders. This part of the study at Gulgong was expected to be important to enable comparisons to be made with the stone axe quarries in the Warren field area.

**Warren.** Loose surface blocks comprise the bulk of the available stone at the Warren Mounts. Survey results from the Little Mount quarry (discussed in section 6.10 on selection) suggest that raw material is ubiquitous at the site and that stoneworkers could select suitable stone from pieces lying on the ground (see Figure 6.9). Table 6.13 column 4 summarises the quantity of loose stone greater than 250mm in length. Since little leverage is needed to make this material available for axe production, a blockfield of uniformly available material is the most accurate means of characterising the raw material resource at Warren.

### 6.15.2 In situ blocks

**Gulgong.** The quarry face of the Gulgong site contains large blocks of stone, more than one square metre in size, and some of these contain surface marks suggesting blocks and pieces of stone have been struck from them. Across the main reduction area of the flake mounds in Area B.X there are large boulders and bedrock outcrops (see plate in Figure 6.3). Table 6.8 shows that of the 30 rocks recorded in the area, 20 had signs of extraction. These extraction marks usually appear on the sides of the rock outcrop as fissure lines and undulations with crests and troughs. My observations from the main extraction area of the quarry can be compared with extraction marks on the rock outcrops recorded across the site. Extraction marks and faces were recorded on very few of the 49 rock outcrops surveyed along the ridge of the site. The four extraction recordings made are on rock outcrops ranked as 'High'. Three of the extraction faces recorded are at the south end of the site in Area A.
fourth extraction face is to be found in Area D at the north end of the site. All the extraction faces are close to rock outcrops with recorded archaeological material.

Experimental work on blocks of stone from a road cutting at Gulgong was conducted to test the potential for large blocks of stone to be reduced by percussion. The results identified many difficult points in the detachment of blocks. McBryde (1984, 273) comments on a similar condition at Mount William where, 'the extreme hardness of the greenstone of this site would make the removal of large blocks by percussion a severe technical problem.' Yet the highest impact and strain factors for detachment are achieved through percussion with a hard hammerstone (Cotterell & Kamminga 1987, 678). This situation suggests that, while fire could have been used to detach the pieces of stone, extraction and reduction of the raw material was mostly done by heavy block reduction with a hammerstone. The reason for the predominance in the use of heavy hammerstones in the extraction and detachment of raw material lies in the versatile and flexible use which can be made of hammerstones. Whereas fire can be set by judgement to give a detachment of raw material from another mass of stone, hammerstones allow repeated impact at many points on the surface and variation in the force with which the block is struck.

**Warren.** The second possibility is that the raw material was extracted from in situ blocks. Some blocks are recorded as having fissures in the material. In this case large blocks may have been levered out of place and reduced by smashing them into smaller and more manageable pieces.

I did experimental work offsite with raw material from the modern quarry at Mount Foster. This work suggested that detachment from large blocks can be difficult. At the quarry there are some places where stone might have been extracted by being struck from the bedrock, but mostly the stone detaches from the bedrock along natural fissures. Very little leverage is needed to make this raw material available for axe production (see plate in Figure 6.9). This situation can be contrasted with the problem at Gulgong, where the favoured raw material appears in a solid block in one part of the quarry. So a blockfield of uniformly available material is the most accurate means of characterising the raw material resource at Warren.

### 6.15.2 Faces and ledges from bedrock

**Gulgong.** The third possibility for extraction techniques at Gulgong, are faces and ledges emerging from bedrock. At Gulgong the few faces left at the quarry show
(from the outcroppings in the main quarry area) what appears to be a high quality raw material suitable for axe making. Edmonds (1989, 169) comments on the presence at Great Langdale in Cumbria of an area where 'extensive vertical quarry faces were created and maintained'. He also observed a number of large hammerstones at this location. This parallels the results of excavation of the extraction face at Gulgong, where a large hammerstone (weighing 4.75 kg) was found in the debris of the extraction face.

Edmonds (1989) also hypothesises that fire was used as a technique to extract stone at Great Langdale, although no evidence was found. Firing to extract hard rock as material for axe making is often suggested (McBryde 1984; Binford and O'Connell 1984). This practice was supported by ethnographic observations from several places (Cook 1982; Ackerman 1979; Petrequin and Petrequin 1993), but archaeological evidence is needed to assess it at Gulgong.

Archaeological inference about the use of firing at Gulgong and Warren will come from the existence and context of charcoal. Some chemical and physical tests can search the problem through thermal alteration to the stone (Cotterell and Kamminga 1979; Vehik 1984) but this was not undertaken here. In the context of a quarry, charcoal can serve two purposes. One purpose is as an indicator of firing, and secondly as a dating device.

My expectation was that if firing was used, charcoal would be found at the base of rock outcrops and faces. I decided to excavate a possible extraction face at EG4 in Area B.X. I established a metre square frame from which the debris at the base of the face was removed. The location of the excavation at the quarry is shown in Figure 6.8, with the base plan of the excavation is shown in Figure 6.10. The excavation did not produce any charcoal, although this result could be explained. There was much loose stone and no sediment as a matrix for holding charcoal. On present evidence, my conclusion was that extraction of selected material cannot be shown to have been achieved by firing. This conclusion was supported by the excavation material including a heavy hammerstone of the coarse grain material found at the quarry.

Evidence of charcoal could be expected against a number of the rock outrops in the flake mound Area B.X. In the excavation of GFM1 1C, I sieved the soil from the square next to the rock outcrop for charcoal particles and recorded any pieces found in the excavation. No significant charcoal was found in this manner.
Warren. Faces and ledges emerging from bedrock are found at Warren, but they are few in number. At Little Mount the surface survey identified four ledges and faces of rock, one of which carried marks of extraction (see Figure 6.11). The sheer faces look inappropriate for extraction by firing, but the use of a heavy hammerstone for detachment by percussion is a possibility. My experimental work offsite with raw material from the modern quarry at Mount Foster suggested that detachment from large blocks (with plenty of inertia) can be difficult, even with heavy hammerstones weighing four to five kilogrammes.

From sheer faces of solid stone many units of suitable size material can be made for further processing. This detachment process should result in the deposition of debris around the extraction face, particularly at the base and immediately downslope. In fact there is very little waste material to be found in association with these bedrock outcrops.

In summary, at the Little Mount quarry there are some places where stone might have been extracted by being struck from the bedrock, but mostly the stone detaches from the bedrock along natural fissures (see plate in Figure 6.14).

In summary, extraction of raw material at Gulgong and Warren was carried out by different techniques. The extraction of raw material from the quarries at Warren was achieved by the selection of loose stone from a blockfield. Blockfields form the surface of the three mounts on which preforms were made. The availability of raw material in this form was demonstrated by my survey of stone on the surface of Little Mount. This diffuse aspect of the available raw material is supported by the transects across the Little Mount site. Partly worked axe preforms, flaked debris, and raw material are found uniformly across the site. At Gulgong the extraction of raw material was from rock faces and outcropping rock. The method of extraction was predominantly by the use of a heavy hammerstone to detach flakes and blocks. It is also possible that fire at the rock face was used occasionally as a means of detachment, although there is no convincing evidence to support this latter claim.

6.16 Conclusion on Selection and Extraction at Gulgong and Warren

The identification of stone suitable for making axes cannot be established from the description and naming of hard rock types, such as greywacke, because these are highly variable even within a single outcrop. My study suggests raw material used for
axes will give high values from tests of rock mechanics, when compared to other rocks of the same type. Consequently, the selection of stone for extraction must be evaluated on the basis of the properties in the individual geological units.

How well did the tests of the selection and extraction stages of the reduction sequence work? These Stages 1 and 2 in my general reduction model (Chapter 2) were evaluated by comparing and contrasting the quarries at Gulgong and Warren in the framework of the economic model, and particularly the concepts of value-adding and efficiency. The prediction that raw material would be selected from a single, well-defined source which was geologically distinct was supported by the results from both Gulgong and Warren, although a difference was detected in the availability of the single geologically distinct source. At Gulgong sustained economic exploitation could have been supported by selection of the raw material from a concentrated source of fine grained material, with few flaws and in solid blocks and outcrops. Under these circumstances, the value-adding process would have identified the raw material in exclusion to others. The value-adding process in selection sets the framework for axe making using a raw material which has known working properties. Knowledge of this source would have enabled concentrated and intense exploitation to take place in an efficient and organised manner. Compared with Gulgong, Warren is not a place of concentrated and intense exploitation. The identification of suitable raw material was not a question of choosing between alternative sources or between material types. The raw material is available across the site as a single geological rock type with no flaws. The selected stone could be exploited in a casual manner.

In axe making the selection and extraction of raw materials are connected because the type of selection will in some aspects depend on methods used for extraction. Whether the choice of an easy or difficult extraction method is made will influence the selection process. Methods of extraction at the quarries were tested for the use of percussion, leverage and fire. In her study of the Melos quarries Torrence (1982, 201) concluded that the extraction of stone did not require much equipment or sophisticated technology. I also conclude that sophisticated extraction techniques were not needed at Warren to obtain axe stone. Percussion and leverage could have satisfied the extraction requirements.

The selection and extraction of material at Warren is similar to the situation described by Baker (1987) for Lowes Mount. At Lowes Mount, the stone used for preforms is weathered tabular material with marked cleavage planes. The natural form of the stone gives opportunity to start with material that is close to the desired size of the axe. The same situation exists at Warren. This availability of raw material means
that the early stages of reduction, that is selection and extraction at Warren, were easy.
The emphasis in value-adding axe making then shifts to later stages of reduction.

At Gulgong there are concentrations of stone in mounds which was probably extracted by direct percussion. The method of extraction is important in understanding large scale procurement of raw material. The extraction of stone from in situ rock outcrops allowed large amounts of axe material to be acquired by the same pattern of exploitation. For example, once a suitable rock outcrop had been located and the appropriate method of extraction found, then the procurement for axes could take place on a regular pattern. The selection and extraction of material may have required organisation among small groups of people, leading to routinisation of behaviour in the production activity.

Percussion and leverage may not have been the only extraction technology available for the range of rock types on which it was used. The use of fire as a means of extraction could not be established at either of the quarries. Yet the form of the rock outcropping and the availability of such an appropriate technology is intriguing. Fire could also have been used in some circumstances where hammerstone percussion would also detach stone. But this overlap of tools was limited in that over most of this range of stone detachment by percussion, a heavy hammerstone was appropriate to the task. The appropriate technology was specific, in that heavy hammerstones were used for detachment of axe stone from blocks.

Compared with the casual procurement from a cobble source, such as a beach, river bank or open plain, selection and extraction from a solid outcrop or quarry face was a concentrated activity. The value-adding process gave greater potential for the material selected where it was a single geological type concentrated at one point. Gulgong quarry has these features, where Warren does not. With the opportunity for casual procurement from cobble sources, the extraction from solid rock outcrops should have promoted efficient traits in axe making. To what extent these efficient traits were expressed in knapping control and organisation by the axe makers is not clear. Quarries were capable of producing large quantities of suitable material for axes when the organisation for selection and extraction was in place. Burton's (1984b) ethnographic study describes the organisation of quarrying in Highland New Guinea. The extraction of the valuable rock from the quarry was not done on a continuous basis by a group of specialists, but by expeditions at intervals of three to five years (Burton 1984a, 235). Many people took part in this quarrying expedition, and as a result some organisation was required for people engaged in tasks of work, but there is no suggestion of this organisation having efficient traits.
The next step in the analysis is to examine the products of the quarries in their work-in-progress and abandonment.