AN ANALYSIS OF THE INGALADDI ASSEMBLAGE:
A CRITIQUE OF THE UNDERSTANDING OF LITHIC TECHNOLOGY.

by

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EXCEPT WHERE OTHERWISE ACKNOWLEDGED,
THE WORK CONTAINED IN THIS THESIS
IS BASED ON MY OWN RESEARCH.

Barry J. Cundy
ABSTRACT

Despite the changes in method and theory which have occurred in the study of prehistory over the last one hundred and fifty years the understanding of lithic technology has been dominated by a single perspective. This has been based on three central assumptions: (1) the form of an artifact reflects prior mental or cognitive processes which supply the formal cause, (2) the clear delineation of products as ends and (3) the neutrality of the experience of the production process which converts the cognitive into the material. This thesis presents a critique of these assumptions and demonstrates the utility of applying an alternative perspective to the problem of understanding technological change in north-western Australian stone assemblages. This is carried out via an analysis of the Ingaladdi site.

The central component of the criticism of the 'traditional model' is that it has failed to recognize lithic technology as a form of practical knowledge or 'knowing how'. The implication of the alternative understanding of lithic technology as 'knowing how' is that stone artifacts were not and should not be seen as a series of materialized ideas or products but as a series of experienced manufacturing processes. It is the organizational structure of these reduction processes which constitute lithic technology in time and space of the archaeological record.

This approach to the understanding of prehistoric technology, when applied to the Ingaladdi material, reveals two previously unrecognized elements. Firstly, the early underlying material, previously characterized as a crude and amorphous flake and core 'industry' is seen to reflect a complex organization based on a two tiered structure utilizing both local lithic materials and that which maintains a relationship termed the 'standing reserve'. It is suggested that the amorphous nature of the early assemblages derives from their inability to separate lithic reduction from wider production processes and that it was the inherent disjunction between the structural and situational 'logic' which preconditioned the later technological change.

The second major aspect of the analysis shows that, despite their marked typological difference from the underlying, the major component of the later assemblage, the lancet flake, can be derived directly from the earlier flake production process. The transformation follows a major shift from 'on-site' to 'off-site' primary core reduction - the principal organizational difference between the early and later assemblages.

Some implications for the understanding of technological, economic and social relations in Australian prehistory are discussed and the thesis concludes with a more detailed examination of the origins of the 'traditional' and alternative models of lithic technology.
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A Commonwealth Post Graduate Research Award made the research project possible and provided necessary financial assistance for part of the completion time.

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CHAPTER ONE

INTRODUCTION

The answers given to the question What is technology? are appallingly superficial; and what is worse, this cannot be blamed on chance. The same happens to all questions dealing with what is truly human in human beings.

_Toward a Philosophy of History_ (p108)
Ortega y Gasset

1.1: The Place of (Lithic) Technology in Prehistory

The interactions of humans within the world are inextricably technological in their ordering of things through time and in space towards human needs, which beyond those defined by the necessities of biological survival are largely defined, in proportion but not in importance, by the structures produced by the ordering process. These structures are both the "medium and outcome of the practices they recursively organize" (Giddens 1984:25) and as part of the world both facilitate and restrict human action.

Technology is not, therefore, simply the neutral process of innovation answering rationally determined ends in accordance with remote processes of human improvement, the reproduction of social norms nor the opaque sub-system
for coordinating the adaptation of culture to an external environment. Although it has been seen in prehistory to perform all these ends, technology is much more central to human experience than any of these, and as such, requires a more clearly defined place as a subject of investigation in prehistory. Through the actions of making artifacts the separation of self and the technological structure is less clearly defined in hunter-gatherer society.

Moves away from evolutionism and positivist epistemology which have dominated archaeological theory over the preceding decades have renewed awareness of the historically contingent nature of human behaviour, including that of archaeologists (Trigger 1989a:776). This has highlighted the limitations of these earlier approaches in dealing with the problem of defining a past which was more grounded in understandable human experience; one not limited to the remote forces of evolutionary or behavioural "laws". Because of their high representation in the archaeological remains of hunter-gatherer societies it is argued that the study of the artifactual remains of lithic technology can take a primary role in this reorientation.

The understanding of lithic technology as it is meant in the title of this thesis has a dual aspect. Firstly, it is aimed at the development of an approach to lithic technology which is more firmly based on the manner in which lithic reduction was apprehended by its human agents. The failure to do this constitutes the works'
primary criticism of the representation of lithic technology in prehistory. Secondly, at the practical level, it is aimed at the development of an approach to lithic analysis which can reflect on current problems in the characterization of technology in a specific prehistory, in this case, Australian prehistory.

1.2: The Problem of Change in Australian Lithic Technology

The role of technology and technological change in Australian prehistory is not easily defined. Upon first inspection it appears to be a central theme with Mulvaney (1983:68) in a recent review of White and O'Connell (1982) noting, like criticism of his earlier A Prehistory of Australia (Mulvaney 1969, 1975), that "stone tools remain the chief prop of prehistory". The discussion of stone artifacts does not, however, of itself constitute an understanding of technology, although the equation appears to be consistently made (e.g., Lampert 1980, Lorblanchet and Jones 1979, White and O'Connell 1979). Change has been seen as a combination of two phenomena. Firstly, the early appearance of new tool types and their later spread from relatively restricted geographic areas, and secondly, the late and widespread appearance of new tool types with little apparent historical precedents in the early assemblages (Kamminga 1982:103, White and O'Connell 1982:105). Both phenomena have been viewed as supplemental to a conservative and relatively simple flake and core tool industry which remained both synchronically

These processes of change were first organized into two historic periods defined by the appearance of hafting technology by Mulvaney (Mulvaney and Joyce 1965, Mulvaney 1966) following his analysis of the Kenniff Cave assemblage and later into two major traditions: the earlier and underlying 'Core Tool and Scraper' (Bowler et al. 1970) which incorporated the restricted appearance of some early tool types, and the later 'Small Tool Tradition' (Gould 1969) characterizing the technological changes of the middle to late Holocene period.

Although both traditions have played a vital role in structuring the historical narrative of Australian prehistory the division of lithic assemblages into two units and the characterization of change has been questioned. In north-western Australia, early assemblages dominated by small flakes, lacking the strong representation of standard scraper and core components of the Core Tool and Scraper Tradition have argued for a reconsideration of the characterization of these assemblages which pose a persistent counter to the pan-continental unity of the tradition (Allen and Barton n.d., Barton 1979, Kamminga and Allen 1973:98) (see also Wright [1975] and Draper [1987] on southern assemblages). The integrity of the later Small Tool Tradition has also been affected by inconsistencies in the temporal and spatial distribution of tool types incorporated into the tradition
(Kamminga 1982:102-3, Jones and Johnson 1985:296, Smith and Cundy 1985, White and O'Connell 1982:106). Along with these inconsistencies in appearance, distribution and character, the real changes in Australian stone technology during the Holocene, whether regarded as a single entity or a series of technically separate events, present Australian prehistory with a considerable interpretative problem.

Gould (1978:291) followed by Lampert (1980:201) suggest that the appearance of new artifact types in the Small Tool Tradition is correlated with an expansion of inter-group relations. These widened social relations had adaptive significance in "overcoming uncertainties of food and water resources in this arid, nonseasonal habitat" (Gould 1978:289). Lampert (1980) expanded this as an explanation of the continent wide changes in technology observed after 6000 BP, supported by exchange networks of the type observed ethnographically (see also Mulvaney 1976).

Jones (1977:197) in contrasting Tasmanian technology with that of the mainland argued that the new tools present in mainland prehistory were more specialized and extractively efficient than the simpler forms possessed by the Tasmanians. Lampert (1980) also viewed the new tools as more specialized and sophisticated (see also Mulvaney 1966, 1969:110). In contrast the underlying assemblages have remained poorly defined as the negative of the latter (Lampert 1980:201, Mulvaney 1975:125).
White (1977) has argued that the resulting view of the early assemblages as being 'crude', 'underdeveloped' and representing a comparable state of cultural development was based on poorly founded assumptions that the measures of progress used by prehistorians correlated closely with the general level of cultural achievement. While his cautionary point is well made, White in effect supports the initial characterization of the assemblages and concludes by seeing them as representative of "simplicity" in the cultural mode (see White and O'Connell 1979, 1982:124).

The tendency to see the underlying and later assemblages as representing some form of cultural dimorphism is also repeated in Lourandos' (1987:159) use of Binford's (1980) forager/collector model to suggest that the archaeological patterns of Pleistocene Australia reflect a different economic organization to that of the later Holocene, implying increasing socio-economic complexity. The earlier organization is equated with a simple 'mapping-on' strategy with more immediate consumption, the later with more complex 'logistic' procurement and delayed consumption.

Both groups of suggestions rely on arguments of inferred significance addressing questions of what the formal changes represent rather than discussing as White and O'Connell (1982:124) point out, the more historical question of why the changes occurred. Luebbers (1978) goes some way to supplying a more detailed technological mechanism in his argument that the development of more
effective spear armatures, associated with the adoption of the spearthrower, could account for the development of points and backed blades, two of the components of the Small Tool Tradition. This argument, not only suffers from a number of technically incorrect assumptions about the performance of spearthrowers (Cundy 1989), but simply shifts the focus of innovation back on the appearance of a technology (i.e., the spearthrower) which has no known archaeological visibility and is not exclusively associated, in its ethnographically recorded distribution, with either tool type.

White and O'Connell (1982) rejected the argument for greater extractive efficiency and suggested "that the spread of these tools is perhaps best seen as a stylistic phenomenon analogous to Solutrean points in the French Palaeolithic or the Clovis and Folsom points in northern America" (White and O'Connell 1982:124). This analogy does not, however, clarify how the new tools functioned as a "stylistic phenomena" because White and O'Connell do not define what they mean by the term beyond the implication from White (1977) that it represents a diachronically distinct non-utilitarian elaboration of material culture; possibly a form of iconological argument (see Sackett 1982:80). This suggestion also raises the problem of the cultural sub-system in which artifact types operate; a research program which Binford (1972:17-18) abandoned with the admission that his attempt to translate Leslie White's three sub-systems into broad artifact functions failed to capture the complexity of their roles within a cultural
system.

Essentially White and O'Connell's structuring of the understanding of artifactual change continues the debate at the level of opposing cultural traditions, utilizing stone tool types as the basic unit of discussion. Their approach has received little formal discussion in Australian prehistory beyond Kamminga's (1982:103) empirical solution that functional (i.e., use-wear) studies should enable style/function distinctions to be made with more accuracy.

Subsequent discussion of the problem of technological change has been incorporated into a more general debate concerning a wide range of mid Holocene changes in which assemblage variation is used as an index of more complex social and demographic patterning (see Lourandos 1983, 1984, Beaton 1983). This debate has centred on the degree to which these changes may be seen as the product of an intensification of economy and settlement, through the development of more complex social relations and their relation to population growth. The discussion of intensification has not led to any firmer understanding of the underlying structure of technological changes and the central assumptions of a relatively simple relation between this structural change and an apparent rise in discard rates has been criticised as premature by Hiscock (1986).
The propensity for higher level culture-historic generalization has been criticised by McBryde (1986:23) for its failure to, among others, relate technology to typology, and to discuss the causes of change, particularly technological change, and the significance of regional variation (see also Hiscock 1986:48). The consequence of this failure is that the ethnographic and ethnoarchaeological works describing stone working and its organization relative to materials, tasks and settlement pattern, although far from an ideal record, has yet to be extensively integrated into the examination of the more specific problems of Australian prehistory.

The characterization of the earlier and later traditions and the ensuing 'explanations' of change have been persistently based on a typological picture of technology where problems are seen to require the development of more effective types (see Lampert 1980:202). White and O'Connell (1982:85) argue that this typological focus is derived from a now unnecessary concern for 'temporal order'. This also appears to be a product of the perception that the explanation of Australian prehistory should be maintained on a continent-wide level (McBryde 1986:20) forcing the utilization of methods which allowed (in principle) broad temporal and spatial comparison. As a consequence, the technology of prehistoric Australian societies is, beyond its disputed typological representation, disturbingly intangible; lacking a sense of any underlying human reality.
The viewing of the transition between the two stone tool traditions as primarily a technological change requires a more detailed examination of the question of what the typological differences reflect in terms of the organization of lithic reduction. For example, the degree to which assemblages mirror Lourandos' (1987) suggestion of major differences in economic structure between the early and later record remains to be tested. Similarly, although Lorblanchet and Jones (1979) and Lampert (1981:160) have viewed the appearance of the Small Tool Tradition as part of a long term evolution towards increasing variety and efficient use of stone the correlation with underlying reduction processes remains problematic. Shifting the focus of analysis away from the comparison of formal typologies in an attempt to investigate the underlying organization is not only a response to these specific questions but, it is argued, necessary in order to address the apparent insubstantiality of lithic technology in Australian prehistory.

1.3: The Critique: the Primacy of Practical Knowledge to the Understanding of Lithic Technology

The difficulty in articulating the role of technological change in Australian prehistory is not simply a consequence of the historical development of the discipline in the continent, but a problem which derives from a failure at the very heart of the conceptual
framework of prehistory to grasp adequately the significance of technology as knowledge. The conception of technology as a set of products brought into being by an act of reification (i.e., the materialization of an idea or mental structure) on the part of the maker remains the central (though often implicit) tenet underlying much of the discussion of technology and technological change in prehistory. Central to this view is the assumption that the prehistoric artifacts which represent technology are direct reflections of the mind which constructed them and that it was this mind which apprehended the nature of its products in a manner more real than that of the archaeologist. While this approach, underlying culture-historic, cognitive and the 'New' archaeology, has proved useful in creating a narrative structure for prehistory and correlating material remains and cultural dynamics, it has been less successful in dealing with problem of defining technology and technological change as a specific theme of historical inquiry (see section 7.1a, b and c). Examples of this may be seen in the Bordes/Binford debate over the interpretation of variation in Mousterian assemblages and the White and O'Connell's characterization of the problem of technological change in Australian prehistory discussed above.

The strong appeal of technology as the product of a process which reflects ideas, or other mental events and structures is not the result of perceived "common sense" but derived from the application of a sophisticated model of the relation of thought and action which derives from a
now traditional component of western philosophy and literature. Its continuing paradigmatic role in prehistory is largely a product of its association with the concept that individual behaviour must be reflective of, or relatable to, higher level "cultural" behaviour, which remains the primary interest of both the 'New' and 'Old' archaeology (see Binford 1972:195-201). This relation is achieved via the assumption that the categories of evidence used in prehistory are representative of past knowledge structures and that the static categories which describe technology and structure problem investigation (ie., types, techniques and industries even the concept of technology itself) also reflect the makers understanding and doing at a primary mental level. If this is not assumed there appears, under conventional approaches, no relation between the archaeological, systemic and cultural context. Although it has been acknowledged that it can not be assumed that there was a single prehistoric apprehension and understanding of artifact forms there remains an implicit assumption of some relationship between archaeological typology and prehistoric knowledge being retained or revealed in the process of classification devised by the archaeologist (eg, Binford 1972:200, Dunnell 1971: 194-5, Hill and Evans 1972, White and O'Connell 1982:85). The extension of this problem to the higher levels of categorization (ie., industry, culture, system) has been circumvented by the equation of these higher level categories with knowledge systems which individual
behaviour reproduces, enabling the conversion of individual to cultural behaviour. This has served to perpetuate the view of manufacture as reification, where by individuals reproduce artifacts which conform to higher order cultural structure and of the process of production, of which artifact manufacture is part, as meaningless and neutral. As "participants in culture" (Binford 1972:198) there can be no other mechanism by which humans produce artifacts which reflect culture, the primary subject of study. As Dunnell (1971) clearly states the archaeological artifact is a product of a shared cultural idea:

It is assumed that if a set of objects share the same features, and that if that feature is artificial, then the objects share that feature, because the people responsible shared the same idea. A simple equation is made between recurrent feature and shared idea ... this is the only plausible account for shared artifactual features. While never explicitly stated in the literature, this is the most universal operation in prehistory, one which provides such coherence as the discipline has.

Dunnell (1971:193)

While Dunnell and contemporary prehistorians wishing to provide the discipline with a scientific basis for the study of culture may use this equation as if it were of paradigmatic importance it is not unquestionably fundamental to an understanding of prehistory.

An alternative approach derives from arguments against the neutrality of the experience of the process of manufacture which the act of reification implies. These
arguments propose the logical priority of knowledge manifest in action, "knowing how" over knowledge as idea (Ryle 1945/6). This is consistent with an approach which sees the archaeological record as the product largely of the direct human experience of actions at its most immediate level, rather than the reflection of superimposed cultural systems. This is not an argument for methodological individualism, which among other points asserts that only individuals are real and easily defined (Giddens 1984:214-221) but a recognition of the possibility that "culture", as it is used in prehistory, is an artificial construction for dealing with evidence, not an overriding organizational principle of human behaviour.

The perception of technology as a series of meaningful products (reflecting ideas) as opposed to meaningless process is based on what Dewey (1922:265) has criticised as a misleading distinction between means and ends or, "the subordination of activity to a result outside itself" such that:

This conception holds ends to be fixed somehow in advance, yielding normative criteria by which technical instrumentalities i.e., means, are to be judged.

Scheffler (1986:229)

Dewey (1922:269) goes on to argue that the distinction of products (ends) as separate from process (means) is an artificial distinction between a continuum of means and ends. Products or ends are not fulfilments
but themselves means which may be used as instruments in further action. Once the artificial distinction between product and means has been removed it may be seen that it is the process of manufacture which constitutes the primary understanding of technology not its products, which are always apprehended in a second hand abstracted form.

It is argued here, that it is the primary understanding of technology as process rather than product which gives structure to the archaeological record. This represents a major epistemological break from the manner in which prehistorians have represented the knowledgeability of their human objects. Knowledgeability is in this context equivalent to 'knowing how' or what Giddens (1984:xxx) describes as "practical consciousness". As noted above it is knowledge manifest in action separate and distinct from the individuals capacity to describe their actions. While the New Archaeology, for example, has emphasized the importance of process it has not entertained the idea that at a fundamental level this constituted the mode of understanding in the past and that the formation of artifacts in the archaeological record represents the reaction of individuals to the restricting and enabling features of the structure which their behaviour produced. As Giddens (1984:26) points out, this "structure has no existence independent of the knowledge that agents have about what they do in their day-to-day activity" and that this knowledge is primarily manifest in "practical consciousness" of process itself.

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In investigating technological change the prehistorian is not primarily dealing with a problem of change in artifact function or functional improvement based on human ability to conceive ends and produce more elaborate means of realizing these ends. Nor is it simply the result of random product variation conferring adaptive advantage on the individual/culture in which the "innovation" occurred, but the interaction of individuals with behavioural structures which, in a fundamental way, constitute their apprehension of the world.

While all human behaviour involved in the manipulation of objects, concepts, language and people may be seen as technological, lithic technology, as defined here, is confined by the points where the wider production process involves the manufacture of stone artifacts, or more correctly in the light of the above argument, the reduction processes which result in artifact forms. The approach places the logical priority of explanation at the level of individual knowledgeability manifest in these processes not in the reproduction of culture or the functioning of artifacts within a system.

1.4: The Problem of Sequential Models in Lithic Analysis

Although the theory outlined above can be applied using many existing methodologies it requires an
alternative to the conventional ends dominated mode of representing the reduction process. This section deals with this problem as a preliminary to their presentation in the following chapter.

The process of reduction is used in this essay to describe the ordered succession of actions which constitute chipped stone technology. The key structural elements of lithic production are sets of actions which form a reduction sequence. Although these reduction sequences may constitute all of the five general categories of process defined by Schiffer (1972, 1976:46) as part of an artifact's "systemic context": procurement, manufacture, maintenance, use and discard, those that constitute procurement, manufacture and maintenance (which may be seen as remanufacture) are of primary interest in this thesis. Use, if related to the process of manufacture (i.e., a hammerstone) is considered part of the process, otherwise it will be seen as an external component. Discard is considered as a process which structures assemblages and is derived from the operation of factors which restrict and structure the reduction process (see section 7.2).

The use of typological descriptions of lithic technology have resulted in little formal recognition of the central importance of ordered actions as opposed to ordered products in the representation of reduction processes. Sequences defined predominantly by a series of products (Bradley 1975, Fowler et. al. 1987, Sheets 1975, Stevenson et. al. 1984) follow the representational
convention established by Holmes (1890, 1894). Although Holmes (1890:12, 1919:289) also correlated the underlying sequential action to products, current usage either does not do this (ie., Bradley 1975, Fowler et. al. 1987), mixes process and product stages (Flenniken and White 1985:132), or represent process as an adjunct of a purely product structure (Sheets 1975). Sequences as a series of actions like, "remove cortex > remove ridge > remove cortex covered sides..." (Leach 1984), have been presented in quarry studies where the manufacture of single products have produced a range of remains related to different stages of reduction (see also Schiffer 1976:48).

In his general model of the relationship between the "lithic technological system", product groups and the physical environment Collins (1975) represents a primary sequence as a series of stages defined by a sets of actions ie., acquire raw material, prepare core-begin reduction, primary trimming, et cetera. Various products (product groups I,II,III etc.,) derived from this sequence are not connected directly to each other, only to the central sequence of actions. The division between process and product is also the division between the "cultural system" in which processes take place and the "physical environment" in which products and raw materials exist as part of the archaeological context. Collins (1975:24-25) sees this division as an application of Schiffer's (1972, 1976) distinction between systemic and archaeological contexts. Although it is the most compatible of the available structures to the arguments forwarded in the
preceding section, the division of process into stages in Collins' scheme shows its derivation from a product based model and imposes a directionality of flow which the process of manufacture does not necessarily imply. While there is an obvious direction in material reduction, sequences may be discontinuous, resulting from a set of differing reduction behaviours through time or identical processes of flake removal may be used on cores in primary reduction and on the resulting flakes in secondary flaking. The underlying recursive patterning to the process can also be seen, at the level of practical consciousness, in the successive nature of flake removal.

There is also a logical problem inherent in the representation of process as a series of discrete stages (A_n). In models which use products as stages the relation between them is designated by an arrow indicating a transition (t_n) between the stages.

In Collins' model the transitions (t_n) are processes (P_n) (ie., P_1 - acquire raw material, P_2 - prepare core, P_3 - primary trimming, P_4 - secondary trimming) which produce products (A,B,C).
The central sequence of this scheme is structurally identical to that of the product defined process and is open to the construction of a second primary sequence which connects the process stages \((P_1 \sim P_n)\). This procedure of replacing transitions with a further set of processes is logically possible, given the first transformation between product and process, and is capable of an infinite regression. The structure is analogous to the regression possible in the cognitive approach where formalized mental processes underlie the physical (see section 7.2).

The logic of this scheme is further flawed by its connection of products to transitions. Once the transitions are themselves made into static products, the relation between \(A, B, C\) and the processes \(P_n\) is unclear.
because products are related to processes not to a second set of products, unless these are both processes and products.

These problems are the result of the incompatibility of a theoretical construction and the schemes used to illustrate the structural relations within it. It is suggested that a scheme which utilizes separate structures for product and process is necessary to avoid this logical regression. This can be achieved by representing process and products in a two dimensional framework in which process and transitional relationships are represented on different axes. In this form processes are delineated by a line with a beginning and end label. Products are related to processes at 90° and processes are related to each other by transitional relations normal to the process axes.

In this form, the products relate directly to processes and processes relate to each other only via transitional relationships. The structure maintains the essential directionality of reduction but not the lineality inherent in the product models.
Having established a scheme which adequately reflects the separation of process and products the second major problem with the modelling of manufacturing process is that there is little discussion of how process should be broken down in models. Sets of action have been described by labels i.e., 'bifacial tool manufacture', 'biface preform manufacture' (House in [Schiffer 1976:48]), or 'acquire raw material', 'prepare cores begin reduction', 'primary trimming', 'secondary trimming' (Collins 1975). Although such labels are useful in describing complex sets of actions which surround the reduction process their application to it contains some limitations. Firstly, descriptors like those used by House (Schiffer 1976:48) contain both process (bifacial manufacture) and product (i.e., tool or preform) continuing the means ends confusion inherent in product models. Secondly, terms like primary and secondary trimming used by Collins (1975) say little about the reduction processes involved, which may be identical, and are understandable only in relation to the complete structure; secondary trimming as a stage in a process has significance only in relation to primary trimming.

A third problem is that these descriptions of process do not go far enough in correlating behaviour with the mechanical variables which structure the flaking process. A model which is based on these variables is necessary because hypothetical models of the reduction behaviour in an assemblage must be capable of generating descriptions
of expected variable states which can be tested against the those found in the assemblages. The primary variables which will be used to describe reduction processes are the direction and location of force application and the external core geometry. As Cotterell and Kamminga (1987:698) describe these as being the variables under direct control of the knapper the sets of actions which define reduction should be directly related to the control of these variables. The analysis concentrates extensively on the active interaction between the knapper's control of force and core geometry in relation to the restriction of reduction brought on by the mechanics of reduction, i.e., decreasing inertia and over-stabilization. This is possible because there is now sufficient understanding of the relation between the mechanical factors governing reduction and the morphological variables for this correlation.

1.5: Outline of the Critical Procedure

In practical terms the development of alternative theoretical perspectives are of little effect on disciplines which deal with material evidence unless they can be translated into hypotheses and procedures effective in resolving problems of interpreting this evidence. The analysis of the stone assemblage from the site of Ingaladdi which forms the substantial proportion of this work is, therefore, equally part of the critical thesis. The structure of this analysis will be outlined in this
The following Chapter Two places the site of Ingaladdi in the context of a discussion of the Core Tool and Scraper and Small Tool Traditions in north-western Australia. This is principally aimed at the definition of models of the reduction processes which underly the typologies presented in the major excavation reports of the region. These models will be further tested and refined in the analysis of the Ingaladdi assemblage which follows in Chapters Three, Four and Five.

Chapter Three presents Ingaladdi in Aboriginal and archaeological context, including an interpretation of its stratigraphic and cultural sequences. Chapters Four and Five contain the detailed analyses of the lithic material in relation to the reduction models developed above for the earlier (underlying) and later (overlying) assemblages respectively. These are followed in Chapter Six by an interpretation of the on and off-site organization of lithic reduction and its change through time. The results of the analysis suggest two important departures from the current understanding of lithic technology in Australian prehistory:

1) The underlying assemblage at Ingaladdi, which has been equated with the Core Tool and Scraper Tradition, revealed a complex two tiered organizational structure which appears to have been highly reflective of the local procurement facility. The analysis suggests a disjunction between the two levels of this lithic organization which
appears to result from the persistent disposition on the part of the knapper to discount the future role of the cores reduced on-site in the higher level off-site organization of lithic materials. It will be argued that this myopic behaviour is a product of the manner in which the lithic reduction process was enframed by the manufacturing activities in which it was incorporated. This may also account for the typological amorphousness of the early assemblages in general.

2) The later overlying assemblage at Ingaladdi exhibited a wider range of reduction processes accompanied by what appears to be a less complex but more rigid organization of lithic material. The new reduction processes centre on the working of a standardized flake which appears to have been used for a wide range of purposes. A comparison of the variable relationships underlying the morphology of these standardized "lancet" flakes with the earlier flake form, shows them to be derived from the amorphous flakes of the earlier underlying assemblage, demonstrating local development.

An assessment of the wider implications of these findings for Australian prehistory conclude the chapter.

The final chapter of the thesis, Chapter Seven, returns to a more detailed exposition of the theoretical points made in section 1.3. The thesis concludes with the suggestion that many of the problems surrounding the understanding of prehistoric lithic technology derive from the uncritical projection of modern technological
perceptions of process, product and time in to the interpretation of past human behaviour.
CHAPTER TWO

ASSEMBLAGE STRUCTURE AND ITS RELATION TO REDUCTION PROCESSES IN N.W. AUSTRALIAN STONE ASSEMBLAGES.

This chapter introduces the Ingaladdi assemblage in the context of a discussion of other sites in north-west Australia. Brief descriptions of the types of artifacts which have been used to characterize the underlying and overlying assemblages along with their dating will be followed by a more detailed analysis of the assemblage structure in terms of the reduction processes presented for a selection of the more comprehensively reported sites. From this analysis two models of the general reduction processes in north-western sites will be presented.

Throughout the work the terms 'underlying' and 'overlying' are generally used in preference to 'early' and 'later' assemblages because they express more effectively a relationship between the assemblages which may not be simply chronological but also structural. This relationship will be discussed in further detail in following sections (see Chapter Six).
The technological changes present in north-western Australian stone assemblages have been divided into a two-part sequence which is seen as broadly reflective of the two traditions which structure the discussion of technological change in other areas of Australian prehistory (Allen and Barton n.d., Barton 1979, Dortch 1977a, Jones and Johnson 1985, Mulvaney 1969, 1975, Sanders 1975, Schrire 1982). As these traditions in north-western assemblages are culture-historic entities defined (in more recent works) principally via the presence or absence of artifact type the problem of change in these assemblages, as it is presented in the literature, has centred on questions of characterization and dating. The former is especially true of the older underlying assemblages which do not contain the array of formal types necessary for this operation.

2.1: The Underlying Assemblages: typology, dating and a problem of identity.

The underlying assemblages in north-western Australia are represented on four sites from the eastern Kimberley (Miriwun, Anvil Hill, Monsmont [Dortch 1972, 1977a, 1977b] and Philchowski Crossing [Bradshaw 1986:35]), three from the Victoria/Katherine Rivers region (Ingaladdi, Kintore and Katherine [Mulvaney 1969:150][Sanders 1975]) and seven from the Kakadu region of western Arnhem Land (Malangangerr, Nawamoyn, Jimeri II [Schrire 1982], Ngarradj Warde Djobkeng [Allen and Barton nd, Barton 1979,
Kamminga and Allen 1973], Malakunanja II, Nourlangie I
[Kamminga and Allen 1973] and Nauwalabila I [Jones and
Johnson 1985])(see figure 2.1).

Mulvaney (1969:150) initially described the underlying assemblages from the sites of Ingaladdi,
Kintore and Katherine sites as being composed of primary flakes, and cores which had been utilized as core scrapers. Dortch (1977a) described a similar "early phase" assemblage from Miriwun which included: modified flakes, cores, core scrapers, an axe, utilized pebbles and numbers of small primary flakes. The artifact forms were dominated by small retouched tools with notched or denticulated edges and adze flakes.

The assemblage from the lower levels of the Kakadu site of Ngarradj Warde Djobkeng (Barton 1979) contained small flakes (<2.5cm²), cores and small numbers of utilized flakes. Kamminga (Kamminga and Allen 1973:48,96-98) also described the sparse material from the sites of Malakunanya II and the Lindner Site (re-excavated by Jones and Johnson [1985] and renamed Nauwalabila I) as mostly composed of primary flakes and cores with little change throughout the deposits. A reanalysis of this site (Jones and Johnson 1985:196-198) added steep edged scraper, rejuvenation flake and generalized scraper categories to this picture. Similarly, Schrire (1982:254) described the 'early industry' from Malagangerr, Nawamoyn and Jimeri I and II as composed of scrapers, core scrapers, utilized flakes, grindstones and ground edged axes. The dominant artifact type in these assemblages was
Figure 2.1: Archaeological Sites, north-western Australia, referred to in the thesis.

again small unmodified flakes (see Schrire 1982:199, table 144).

In his discussion of the Ingaladdi, Kintore and Katherine material Mulvaney (1969:150) noted that the lower assemblages showed a similarity to the generalized flake production which characterized the assemblages of other Australian sites prior to 5000 BP. Mulvaney (1969:151) described these assemblages as products of a flake and core technology.

The subsequent defining of the "Core-Tool and Scraper Tradition" by Allen and Jones (Bowler et al. 1970) brought a subtle but significant change in emphasis which contributed to the formation of the current problem in discussing the underlying assemblages in north-western Australia in terms of reduction processes. Unlike Mulvaney's characterization which used assemblage composition as a whole, including both 'product and producer' artifacts, the "Core Tool and Scraper Tradition" emphasized products only; resetting the characterization of assemblages firmly on typological grounds. The implicit message of "tradition" was also one of continuity and relatedness which had not been adequately demonstrated.

As shown in section 1.3 the culture-historic model of prehistoric technologies views them as sets of products which reflect cultural norms. Steep edged scrapers, horsehoof core and core-tools have, for example, been seen as indicative of the Core Tool and Scraper Tradition in
that they are interpreted as distinct products of the cultural norms which constitute the tradition; no further exposition of underlying mechanism being deemed necessary. The ensuing problem of whether the underlying assemblages in north-western Australia conform to the Core Tool and Scraper Tradition as a whole, stems largely from the application of this inadequately defined culture-historic model of technology to the region.

In his discussion of the Lindner Site (Nauwalabila I) Kamminga (Kamminga and Allen 1973:98) states that the assemblage of small flakes that dominated the lower levels of the site did not resemble the conventional picture of the Core Tool and Scraper assemblages and suggested that this technology may not be as uniform as previously believed. The dominance of small flakes with little formal regularity in secondary modification in the Ngarradj Warde Djobkeng assemblage also lead Barton (1979:69) to argue that the Core Tool and Scraper Tradition was not well represented in the Kakadu region of Western Arnhem Land.

In contrast Sanders (1975:14) saw the underlying 'Industry 2' from Ingaladdi as equivalent to the tradition and in her extensive revision of her earlier work in the Kakadu region Schrire (1982) took issue with Barton's conclusion. In Schrire's (1982:237) definition the lower 'industry' contains: scrapers, core scrapers, utilized flakes, grindstones and edge ground axes. Of these, only scrapers and core scrapers are not represented in the
upper industry. Schrire (1982:254) argues that Barton concentrated too much on the morphological continuua within the assemblage denying "the presence of distinct 'archetypal' forms that point to cultural relationships". The presence of horsehoof cores and steep edged scrapers in the lower 'industries' of her sites of Malangangerr, Nawamoyn and Jimeri II are in Schrire's (1982:254-5) view sufficient to show a relationship to the wider Core Tool and Scraper Tradition.

In moving towards a resolution to this problem Jones and Johnson (1985:215-6, 297) have suggested that the typologically distinct core tool and scraper component of early assemblages in Australia may be dated to the earliest period of occupation between 30,000 and 17,000 BP. A period represented in Schrire's sites of Malangangerr and Nawamoyn, and at Nauwalabila I but not Ngarradj Warde Djobkeng. The overlying levels from Nauwalabila I dated to 16,000-6000 BP contained, Jones and Johnson argue, a retouched flake assemblage with little formal distinction. Jones and Johnson's suggestion, however, calls into question both Schrire's attribution of the Jimeri II (<6700 BP) assemblage (her best representation of the lower 'industry'), and Sanders' 'Industry 2' (<7000 BP) as representative of the Core-tool and Scraper Tradition. The Miriwun assemblage, dated to between 19,350 and 16,810 BP (Dortch 1977a:109) remains a borderline case with Dortch (1977a:121) classing it as 'early phase' only.
Although both Jones and Johnson (1985) and Schrire (1982) affirm the relationship of the underlying Kakadu assemblages to the Core Tool and Scraper Tradition the ground on which this is based, in terms of absolute assemblage size, is quite small. At Nawamoyn, Malangangerr and Jimeri II Schrire uses only 10%, 1% and .25% of the lower assemblage's artifacts to affirm this relationship with absolute numbers ranging from 8 to 12 artifacts in each case. In their analysis of Nauwalabila I Jones and Johnson (1985) use approximately .3% of the assemblage from units 51-67 which contain the four diagnostic steep edged scrapers and flaked cobble. A single small horsehoof core-tool from Kamminga's (Kamminga and Allen 1973) earlier excavation and four rejuvenation flakes from cores are also cited as diagnostic. The four steep edged scrapers, however, represent only one third of the twelve examples represented in the total assemblage.

With the low numbers of diagnostic artifacts used to identify the "Tradition" representing only a small percentage of the total assemblage there is some question of how statistically valid the presence or absence of a type from any individual excavation unit might be. The presence of steep edged scrapers higher up the Nauwalabila I sequence (Jones and Johnson 1985:table 96), not considered by Jones and Johnson to be archetypical Core Tool and Scraper Tradition, indicates that there remains some undefined quality which separates the majority of the steep edged scrapers in the site from those of the "Tradition".
As the distinctness of both horsehoof cores and steep edged scrapers has been questioned by both Kamminga (1982:212) and Hiscock (1979:112), Jones and Johnson (1985:212) justify the view of the Nauwalabila I horsehoof as a produced tool by reference to the edge damage on rejuvenation flakes and the absence of flakes consistent with core reduction in the lower deposits. The evidence for this is, however, equivocal. The production of rejuvenation flakes on exhausted cores requires careful edge definition and consolidation. The process tends to undercut edges and can produce edges with small nibbled flake removals similar to those illustrated from Nauwalabila I (Jones and Johnson 1985, fig.9:23). The absence of large numbers of flakes consistent with core reduction in the site can also only be demonstrated and used to support the contention that the core is a tool if some model of the type of core reduction processes used in the technology and its on-site organization has been presented. In any case the absence of flakes consistent with core reduction is not inconsistent with the artifact being primarily a core because of the complexity of factors which may govern the discard of an artifact relative to the general degree of reduction represented on site. These factors may cause discard or off-site transportation after very little reduction. Jones and Johnson's (1985:212) argument, however, becomes more abstruse when they state that having a potential to function as a heavy duty core-tool is sufficient to separate these items from the "discard products of flake
manufacture".

In summary the underlying assemblages dated to greater than 3000 - 6000 BP in north-western Australia may be characterized by cores and amorphous flakes some of which have been further modified. The process of distinguishing type products over production processes has generated a 'classic' culture-historic debate in which the abstracted characterization of assemblages assumes more significance than the structure of the assemblages themselves.

2.2: The Overlying Assemblages: typology and dating

Those assemblages which have been grouped into the "later industries" in north-western Australia present a more immediately complex picture than the underlying assemblages. Generally characterized by the appearance of two classes of artifacts, points and adzes, the assemblages have been similarly associated with the pan continental "Small Tool Tradition". The expression of the tradition in the region is not, however, uniform, showing spatial and temporal variation in assemblage composition as well as in component types. Although at one level the problems of characterization appear less pronounced than in the underlying assemblages principally because of the appearance of more formally standardized artifacts, the problem of a variable nomenclature remains.
In his eastern Kimberley sites Dortch (1977a:113-123) characterizes the overlying assemblages as 'blade and point'. These are divided into several forms including bifacial, unifacial and backed points. The majority were made on 'leilira' type blades (Spencer and Gillen 1899:223,652; 1904:752) (discussed in more detail in sections 2.4 and 5.2a) which ranged from prismatic in form to what Dortch suggests are "classic Levallois points", some showing light retouch only. The assemblages also included Levallois, prismatic and discoidal cores, axes and small numbers of burins and tula adze flakes as well as denticulate and notched pieces and retouched flakes. While Dortch's identification of a Levallois technique has been questioned (Binford and O'Connell 1984, Bradshaw 1986:263), the widespread use of the term 'leilira' to describe the distinctive pointed flakes with strongly defined dorsal ridging found in the region has also produced confusion. Both these terms will be discussed in more detail below (sections 2.4 and 5.2a).

Dortch (1977a:119) notes in conclusion that although amorphous denticulated and notched pieces make up approximately 50% of the tools in the overlying assemblage from Miriwun the assemblages should be regarded as 'point and blade' because this gives the "later phase assemblages their special character". Dortch (1977a) sees both techniques of production and types as transmitted cultural traits and with the absence of economic evidence from the eastern Kimberley sites views the change from the "early" to the "later phase" as a direct continuity augmented by
the adoption of externally derived traits.

Bradshaw (1986:284) also describes points and adzes as the primary artifact types characterizing the five east Kimberley assemblages excavated by Clarke (Kununurra Arched Shelter, Philchowski Crossing, Thompson Cave, Moochalabra Dam and The Grotto). She utilizes sixteen types grouped into the major categories of retouched/utilized pieces, scrapers, points, cores and other (including grindstones, choppers and axes). The retouched/utilized category is dominated by retouched flakes and flake fragments but also includes blades, core fragments, chunks and trimming flakes. The assemblages also retain high proportions of waste material ranging from 99 to 86% of the total assemblage.

The blade category appears to incorporate most of Dortch's leilira blade type including the Levallois component (Bradshaw 1986:280). Blades with substantial scalar retouch are included in the scraper category. These are similar to the utilized blades but less variable in size. The scraper category also includes a small number of cores, miscellaneous and flake scrapers which make up almost half the category. Adzes are also classified as scrapers and comprise both rectangular and pointed forms. The latter, constituting the majority of adzes, were made on blades and initially classified as points. From the illustrations (Bradshaw 1986:128) these appear comparable to Dortch's backed and obliquely truncated types. Although the retouch on the pointed adzes does not appear to have been as steeply undercutting
nor as regular as that associated with more conventionally recognized adze types Bradshaw (1986:129) suggests that these artifacts represent a category of hafted as opposed to handheld scrapers.

A date of 3640±110 BP from Clarke's site of Philchowski Crossing provides the earliest date for the overlying assemblages in the region (Bradshaw 1986:301). Dortch (1977a, table I:109) provides a range of comparable, if less consistent, dates from three of his Ord Valley sites. The underlying assemblage dated to 2980±95 BP at Miriwun is considered by Dortch (1977a:109, 1977b:29) to be too late to be a terminal date for the underlying assemblage when compared with dates of 3110±85 BP for the lower part of the overlying assemblage at Kununurra and 3560±100 BP from Crawford's site of Martin Gap. The latter is, however, stratigraphically higher than a date of 2660±90 BP suggesting some dating problems with the Martin Gap site (Bradshaw 1986:301).

In the Victoria Rivers Region to the east Davidson (1935) constructed a two part sequence based on an unknown number of excavations on Delamere and Willeroo Stations. These appear in character to be two diachronic components of a single overlying assemblage. The lower deposits yielded assemblages of adze points, small cores and scrapers with the upper level assemblage dominated by large blades, adze points and a small number of scrapers. Surface sites also yielded edge ground axes. Davidson's
'adze point' category included a wide range of point forms ranging from unmodified flakes similar to Dortch's Levallois points through to various unifacial and bifacial forms similar to Bradshaw's 'adze point' (the term is derived from Davidson) and projectile point categories.

In comparison 20kms to the north of the Davidson's Willeroo sites Mulvaney's excavation of Ingaladdi yielded a large overlying assemblage containing adze flakes (including tula adzes), bifacial and unifacial points as well as burins, adze points and edge ground axes (Mulvaney 1969:114,116,129; 1975:217,234,235). Mulvaney (1969:115,147; 1975:184,235) dated the upper assemblage to the last 3000 years noting a peak of bifacial point manufacture between 1000 and 2000 BP with the gradual introduction of "massive points" in the upper levels (Mulvaney 1969:115-116,121; 1975:219,235).

The assemblages described by Davidson (1935), and Mulvaney (1969,1975) and Sanders (1975) for Ingaladdi show broadly similar type lists to those described for the east Kimberley sites (Dortch 1977a, Bradshaw 1986) although proportionally the types shows some differences. From both Davidson's general description and Sanders' (1975:16) report on the Ingaladdi assemblage the proportion of modified flakes (including scrapers) to modified point forms is lower at 1:3 for Ingaladdi compared with 5.5:1 for Miriwun and 3:1 for Clarke's sites (Bradshaw 1986:239). Davidson (1935:159) commented on the apparent scarcity of scrapers in his assemblages, attributing this to the lack of skin working and the widespread use of a
small hafted "chisel or adze" for general purpose scraping and cutting functions. Davidson's (1935:160,162) Aboriginal informants emphasized the various cutting and woodworking roles of the small points in his assemblages, including a fine pressure flaked example which Davidson considered to be a more ideal spear head (Davidson 1935: fig.11). The appearance of large blades in the upper part of the Delamere/Willeroo and Ingaladdi assemblages presents a further point of difference from Bradshaw's (1986) assemblages, but less clearly from those described by Dortch (1977a). Davidson (1935:166-167,172-178) discussed the high percentage of these leilira type "spear heads" in relation to the widespread use of similar blades as knives and spearheads in northern and central Australia and presented their appearance as largely a problem in the chronology of diffusion.

The Yarar shelter, approximately 250kms west of the regional centre of Katherine, excavated by Stanner in 1958-59, and analysed by Flood (1966, 1970), yielded an assemblage with a basal date of 3350±90 BP (Flood 1970, Bermingham 1972). Bifacial and unifacial points dominated the assemblage, comprising 95% of the modified artifacts. The remaining material included edge ground axes, scrapers, retouched flakes, burren adzes, cores, primary (unmodified) points, bifacial blanks and a single leilira butt. No change occurred in the types of points present in the assemblage although bifaces were proportionately
better represented in the lower levels of the deposit.

In relation to the points the other artifacts make up slightly more than 5% of the modified component of the assemblage. Of these, retouched flakes (70) and scrapers (46) comprise the highest element followed by cores (31). The bulk of the assemblage is composed of some 43,000 flakes approximately 69% of which Flood (1966:129) sorted into four size ranges from, >1cm² to <9cm². Over 90% of the sample were under 4cm² with the highest densities in the middle levels of the site.

The undated assemblage from Tandandjal (approximately 100kms east of Katherine) was concentrated in two levels separated by relatively sterile deposits. The upper Group I assemblage contained 227 "implements" the lower Group II only 10. In the upper assemblage the majority of points are classified as unifacial with a small number of tula adze flakes, burins, cores, axes and a high proportion of scrapers (45%). Both Macintosh (1951:199) and McCarthy (1951:211) noted that this assemblage was unique in being based on large leilira blades which functioned as blanks for adzes, scrapers and knives. McCarthy (1951:200) attributed this to "some local functional response" but provided no further discussion of what this might be. Macintosh (1951:200) saw the presence of both bifacial points and large leilira blades in the Group II assemblage as demonstrating their contemporaneity in reply to suggestions (Davidson 1935) that the latter was an earlier form. Macintosh (1951:200) also took issue with the idea of the development of complex point typologies claiming a
single continuum of form in the Tandadjal assemblage.

The upper assemblages from the Kakadu region of western Arnhem Land although well represented on surface sites have been best described for the plateau outlier site of Ngarradj Warde Djobkeng (Barton 1979) and the plateau valley sites of Jimeri I and II (Schrire 1982) and Nauwalabila I (Jones and Johnson 1985). Typologically these assemblages are dominated by points and artifacts variously characterized as scrapers (Schrire 1982), adzes (Barton 1979) and adze/chisels (Jones and Johnson 1985). The assemblages also contain small numbers of polished flakes, large blades (usually broken), various retouched flakes, axes and cores (including bipolar [Schrire 1982]) in variable proportions.

At Ngarradj Warde Djobkeng points constitute 66% of the retouched material with adzes making up 19%. From Jimeri II level I points maintain only 20% of the retouched component with scrapers making up a similar 23%. At Nauwalabila I points made up 43% and adze/chisels 36%. The relatively low point count at Jimeri II may be a product of Schrire's retention of a high proportion of the bifacially and unifacially worked pieces in a separate classification of retouched fragments (37% of the retouched).

Unlike the sites to the south-west the dominant point type in these assemblages is bifacial (Schrire 1982:246) and the relative proportions of unifacial and bifacial points show variable relationships through time. At
Jimeri I Schrire (1982:247) describes a rise in unifacial points while Barton (1979:56) notes a rise in bifacial working in the upper levels of Nagarradj Warde Djobkeng. Barton (1979:100) also argues for a significant rise in the size of points through time. Schrire's (1982:247) challenge to this trend on the basis of a reanalysis of Barton's data is supported in section 5.4c below, despite the questionable assumption which her analysis makes about the distribution of data within Barton's size categories. Neither Barton nor Schrire, however, discuss the reasons for the changes through time in bifacial and unifacial working. For Nauwalabila I Jones and Johnson (1985) do not distinguish between the two point types illustrating and discussing bifacial forms only.

The upper levels of Nauwalabila I, Jimeri II and Ngarradj Warde Djobkeng all contain high proportions of waste flakes ranging from 99.6, 98 to 96% respectively of the total assemblage (excluding chips, et cetera). In two of these sites there appears to be a general rise in the numbers of flakes <1cm² (Schrire 1982:199, Jones and Johnson 1985:204-205) through time. The Ngarradj Warde Djobkeng evidence is more equivocal with comparable numbers of small flakes in the underlying assemblage (Barton 1979:87-90).

The dating of the upper assemblages in the Kakadu region remains a point for further definition. In her initial report Schrire (White 1967) suggested that a date of 5980±140 BP from Malangangerr dated the upper
assemblage. Subsequent reanalysis and dates from Jimeri II of 4770±150 (Schrire 1982:239) and the Leichardt site of 5180±130 BP (Kamminga and Allen 1973:87) have been taken as more secure estimates by White and O'Connell (1982:119) who suggest 4470–5070 BP for the introduction of the point component of the upper assemblage. Schrire (1982:239) noting the less certain date of 5180±130 BP from the Leichardt site also opted for the more secure time span of 4000–5000 BP for the introduction of the points.

On the basis of the rise in numbers of small quartzite flakes and the presence of a bifacial butt Jones and Johnson (1985:206) argue that a date of 5860±90 from Nauwalabila I places the introduction of the points in the time period 6100–5700 BP. This time span appears to predate the appearance of points in the south-west of the discussion area (i.e., the Kimberley, Victoria River and Yarar sites) by more than 2500 years. Jones and Johnson (1985:208) further date the introduction of "adze/chisel technology" at Nauwalabila to approximately 3500 BP some time after the introduction of the points.

2.3: Models of Production Process and Organization: underlying assemblages

It can be seen in the above analyses that it is the presence or absence of artifact types which is significant. The various types are presented as separate
entities; related only as type lists. Jones and Johnson's (1985:212) discussion of horsehoof cores as tools exemplifies the way in which the examination of technological structure in the underlying assemblages has been cast in terms of typology and potential function with only limited reference to any wider behavioural context. As, for example, steep edged scrapers and core-tools are, when viewed in relation to reduction processes, both primarily cores, the question of their form and presence in sites becomes less a culture-historic one of traditional industrial products but a number of questions related to the modes of reduction used, the representation of these modes on-site and their relation to discard behaviour.

Although the analysis of reduction processes has not been the primary aim in the current investigations of north-western Australian assemblages all discussions of assemblages make some use of reduction processes and their organization in defining assemblage structure. The structures derived from the discussion of Miriwun, Jimeri II and Nauwalabila I assemblages will be used in this section to illustrate the way these processes have been reconstructed for these sites.

In his preliminary report on the "early phase" assemblage from Miriwun Dortch (1977a:121) described the assemblage in terms of seven major classes of artifact form: flake, modified flakes, core-scrapers, pebble tools, blades, axes and cores. These were further divided into a
series of sub-types: modified flakes into adzes, utilized and notched which included denticulates as a sub-type; pebble tools appear to be separate from utilized pebbles and cores were further divided into amorphous, multiplatform globular, discoidal and bipolar.

Of the seven major classes Dortch treats four as separate products (pebble tools, core-scrapers, axes and blades) suggesting a more complex set of relations for the flake and core components only. The larger amorphous and smaller multiplatform cores were seen as products of an on-site process of core reduction which "possibly" produced most of the small flakes and bladelets in the assemblage. These were further modified into utilized flakes. Discoidal core reduction was also carried out on-site producing distinctive flake forms. Although all modified flakes are small, Dortch does not explicitly relate the notched or adze flakes to any specific process. These are illustrated in figure 2.2 as an unrelated group along with bipolar cores. Discoidal cores were also unrelated as a group to any other process beyond their own reduction leaving their origins as a group undefined.

In comparison, Schrire (1982) in her analysis of the Jimeri II (level III) assemblage, divides the 64 implements into eight groups: scrapers, core-scrapers, utilized flakes, utilized lumps, miscellaneous, retouched fragments and axes. The approximately 2,600 waste flakes are separated as a further category. In her discussion Schrire treats all these groups, except for scrapers and axes, as independent products (figure 2.3).
Figure 2.2: Miriwun, underlying assemblage, reduction structure (Dortch 1977a).
Figure 2.3: Jimeri II, underlying assemblage, reduction structure (Schrirre 1982).
As the scrapers in the assemblage retained some core characteristics Schrire (1982:219) suggests that they are derived from an earlier core reduction process. Although it is not clear whether this reduction process was carried out on-site the presence of rejuvenation flakes in the assemblage indicates the possibility of on-site reduction of scrapers. From the presence of axes and igneous waste flakes the suggestion for either the maintenance or manufacture of axes is Schrire's only other reference to a reduction process. She (1982:224) does, however, conclude that the implements in the assemblage were fashioned "on the spot", arguing that a general tool to waste ratio of 1:41 suggests on-site manufacture and that a ratio of 1:14 for chert indicates frugal use of the material. This conclusion is not, however, related to the model of assemblage structure presented in her discussion and does not appear to be derivable from it.

Some indication of the potential complexity of the reduction structure represented at Jimeri II may be gained by examining the relation between product and producer artifacts and material type. Although chert artifacts account for 50% of the secondarily modified material (producer artifacts) on-site it accounts for only 14% of the unmodified flakes (product artifacts). Conversely, quartz accounts for only 14% of the modified but 40% of the unmodified flakes. Quartzite and volcanic materials show more intermediate patterns with quartzite accounting for 27% of the modified and 30% of the unmodified flake
material and volcanics accounting for 8% and 17% respectively. The raw materials (chert and quartzite) which contribute 77% to the modified category can only account for 30% of the primary flake material which is dominated by quartz. These variations are not accounted for in Schrire's model which deals only with the reduction of axes and the production of igneous flakes in detail. In relation to Schrire’s general ratio (1:41) only quartzite with a tool to waste ratio of 1:46 is close to the range indicating, Schrire argues, on-site reduction. As chert and quartz materials are not directly correlated with the production of any specific tool type the model must explain how ratios varying from 1:14 for chert to 1:115 for quartz can result from the reduction organization presented in the model. These data suggest that the reduction (and discard) of artifacts of raw materials differed so much that Schrire's highly generalized discussion may not apply specifically to any of the material types represented in the assemblage.

The discussion of the Nauwalabila I assemblage by Jones and Johnson (1985) presents a more detailed model of assemblage structure, with no artifact types unrelated to either an on-site or off-site reduction process (figure 2.4). Jones and Johnson (1985) divide the lower assemblage into five general categories: scrapers, core-scrapers, cores and core fragments, flakes and rejuvenation flakes. Flaked cobbles were included in the core-scrapers and rejuvenation flakes from horsehoof cores were distinguished from those of scrapers.
Figure 2.4: Nauwalabila I, underlying assemblage, reduction structure (Jones and Johnson 1985).
The main components of the assemblage structure presented by Jones and Johnson (1985) are a series of three rejuvenation processes for general scrapers, core-scrapers and horsehoof cores. From the presence of igneous chips they infer the use of edge ground axes on the site - the only other evidence for their presence being highly weathered igneous chunks found in the lower units (Jones and Johnson 1985:217).

Flakes were derived from the reduction of cores as were core fragments. Jones and Johnson (1985:215) argue that the absence of large cores in the assemblage indicates that most of the primary flaking was, however, carried out elsewhere and that already reduced cores were being transported to the site. Although Jones and Johnson (1985:193) gained the impression that there was not extensive on-site core reduction and that preformed flakes had also been brought in to the site, it is not clear whether this impression applied to all flakes or only those of quartzite, leaving the bulk of the flakes in the assemblage to derive from on-site manufacture, as in the production of quartz flakes (Jones and Johnson 1985:214). Allen and Barton (nd:112) suggest that the apparent absence of cores in the assemblage is largely a product of Jones and Johnson's classification of the cores as scrapers. While it is true in terms of reduction processes that scrapers are cores, it is not clear whether their reduction would produce the size range of flakes in the assemblage. It is the perception of a low proportion of small flakes which leads Jones and Johnson (1985:212)
to argue for limited core reduction on-site although flakes <1cm² rarely fall below 50% in the lower levels of the site.

One core-scraper is seen as deriving from core reduction, but its relation to the primary off-site flaking is not discussed. A single flaked cobbie derived from off-site is also described. As quartzite for cores was readily available in the nearby escarpment Jones and Johnson (1985:212) suggest that this pebble was probably intentionally brought to the site to function as a tool.

As with Schrire's Jimeri II site the proportions of material in Nauwalabila I point to a more complex organization of reduction than Jones and Johnson's model. In the lower levels (spits 48-80) of the site quartz predominates (accounting for 72% of the flakes), followed by quartzite (17%) and chert (10.5%). The majority of the modified material is, however, made on quartzite flakes (63%) with quartz accounting for 24% and chert 12.5%. The modified to unmodified ratios of 1:4.2, 1:46 and 1:13 respectively are generally lower than those at Jimeri II suggesting differences in the organization of reduction represented on the two sites.

It may be argued that the Jimeri II and Nauwalabila I assemblages are not directly comparable given the suggestion (Jones and Johnson 1985) that assemblages prior to 17,000 BP will be distinctly different to those like Jimeri II dated to >6700 BP. If the assemblage from the 12,000 to 6000 BP period at Nauwalabila I (levels 48-28)
is examined the differences between the two sites becomes less pronounced. There is a rise in the absolute amount of flake material deposited in Nauwalabila I during this period, in the order of a 300% increase over the lower levels. Of this, chert records a substantial 1640% increase to account for the highest percentage (48%) of material followed by quartz (45%) and quartzite (7%). Like Jimeri II chert also accounts for the highest proportion of modified at 43%, followed by quartzite (37%) and quartz (21%). The modified to unmodified ratios for chert (1:55), quartzite (1:96) and quartz (1:109) show a rise over the lower assemblage, especially for chert, indicating a change in the depositional rates of both modified and unmodified.

While there is not the space here to present a detailed interpretation of these data there are two points which can be made about the descriptions of reduction structures presented in the analyses of the three assemblages discussed above. If the structures are taken as they stand the apparent typological similarity between the assemblages overlies considerable variation in the manner in which these types are related to reduction organization. Dortch argues for an on-site reduction of cores and the secondary modification of the flakes produced, Schrire suggests high levels of tool manufacture but does not relate this in detail to core and flake production on-site while Jones and Johnson see most of the primary reduction being carried out off-site with extensive transport of reduced material to the site.
The validity of taking these as models descriptive of actual behaviour remains to be tested. They are not, however, based on a detailed examination of reduction processes and their organization on and off-site but via ad hoc explanations for individual artifact types. For example, at Jimeri II Schrire's data reflect variation between the reduction and depositional behaviour related to the raw material type. Of these, only the process producing igneous chips is presented in her description. Jones and Johnson (1985) faced similar problems with the Nauwalabila I material in their presentation of a single model to account for the substantial changes in behaviour associated with the earlier and later facies of the underlying assemblage.

As a basis for a more coherent understanding of the underlying assemblages in north-west Australia it is necessary that a basic model of the reduction process which structure the assemblages be developed. From the typological descriptions and the analyses of the assemblage structures it is suggested that the underlying assemblages contain three fundamental reduction processes (figure 2.5). The most significant of these is characterized by the reduction of a single platform (A-1-1). The products of the first part of this process are flakes and single platform cores. The transitional state between it and the second stage (A-1-2) is core rotation <R1> resulting in the initiation of a new platform. The products of this second process which can be extended
Figure 2.5: General model of underlying reduction structure.
through further rotations \( <R_n> \) are flakes and multiplatform cores. If the core is rotated about an axis running transversely to the length of a previous platform allowing the angle between the free face and the old platform to be removed as the initiating flake on a new platform a redirecting flake is produced.

Flakes from the core reduction may be further reduced via a A-1-1 process to produce modified flakes which stand in relation to the flakes produced as cores. The model, therefore, incorporates no systematic differences in the behaviour sets producing core and modified flake forms in the assemblages. The need for applied force differences between core and secondary flake reduction are not seen as discriminating variables. This process appears fundamental to the production of most flakes and cores, including the horsehoof and the various scraper types described in the assemblages above.

The second reduction process is a bifacial core reduction (A-1-1/2). This is a systematic single platform process in which cores are rotated such that the flakes scars from the previous sequence provide the platforms for subsequent removals. The process is present in Dortch's Miriwun material and possibly forms the basis of the early axe manufacture in the Kakadu sites. The third process is a bipolar core reduction (E-1). Although the reduction is highly structured in the point of force application (PFA) via its simultaneous employment of two static platforms the reduction process is controlled only by the dynamics of flake formation in strong compression fields (Cotterell
and Kamminga 1987:698) and relies on no systematic modification of core geometry. This appears to be principally associated with the quartz component of the Kakadu material.

Flakes from both bifacial and bipolar reduction may be further reduced via single platform (A-1-1) process and flakes from the single platform reduction may be secondarily reduced through the bifacial and the bipolar. From the analysis above it appears that the latter two options were not, however, extensively utilized.

This model is simple and is no more than a formalization of the processes used in the analyses of the underlying assemblages discussed above. Despite its simplicity it contains considerable room for variation in the manner in which each process is controlled and combined in individual assemblages. It is also argued that attempts to understand an assemblage in terms of these processes and their organization in time and space will develop a more vital picture of the underlying assemblages than that produced via the construction of typological relationships.
2.4: Models of Production Process and Organization: overlying assemblages

The 'models' of production structure and organization used for the overlying assemblages exhibit an increase in the number of both products and processes relative to those for the underlying. Dortch's model for the east Kimberley region (figure 2.6) illustrates this with its fourteen products and eleven processes in comparison with the nine products and three processes of the underlying assemblage. Of the new products the appearance of a "point and blade" technology has been seen as central to the definition of these assemblages.

In his preliminary discussion of the "Later Phase" assemblages of the east Kimberley Dortch (1977a) gives most attention to the character of the point and blade component. He distinguishes bifacial and unifacial point types (by the presence of invasive retouch) which appear to have been produced by both hard hammer and pressure techniques. Intermediate forms between the two types are characterized by the presence of bulbular trimming. It is uncertain, however, whether these intermediate forms represent a unifacial process with some platform preparation or the preliminary stages of bifacial production. Dortch (1977a:117) notes that a high proportion of these points were made on blades of the leilira type. Blades also appear to have served as a basis for a range of points characterized by semi-abrupt unidirectional flaking which Dortch (1977a:117) terms backing. Backed points grade into an obliquely truncated
Figure 2.6: Miriwun, overlying assemblage, reduction structure (Dortch 1977a).
form which along with some of the unifaces retain wear patterns consistent with woodworking. Although Dortch (1977a:117) considers most of the unifacial and bifacial point types to have derived from a single blade form he does not present a discussion of how the types are related to reduction processes. For this reason all the point types derived from the blade form are shown in the diagram (figure 2.6) as being on the same level in relation to the degree of reduction, except for bifacial invasive points which are products, Dortch (1977a:119) suggests, of an on-site process of bifacial trimming.

The blades which form the basis of the technology Dortch (1977a:117) terms "leilira" (discussed in more detail below) after the Aranda knife and argues that the production of these blades comprises both prismatic and Levallois production techniques. Dortch's identification of both techniques follows Bordes' (1969:3) suggestion, based on morphological similarity, of the presence of both Levallois points and pointed blades in the leilira blades illustrated by Spencer and Gillen (1927:543). This identification of Levallois reduction technique in an Australian assemblage has been criticised by Binford and O'Connell (1984:427) on the grounds that Bordes did not base this on an examination of the specific reduction process described, which was not Levallois. Bordes in his 1969 paper appears to have been aware of Spencer and Gillen's (1927) description of a non-Levallois reduction sequence and used the term at that time as a description of an artifact type only, without appearing to assume the
correlation between the presence of Levallois points and the use of Levallois reduction techniques. Later, Dortch and Bordes (1977:2) suggest that the presence of "blade and Levallois techniques" in the east Kimberley assemblages was indicated by the appearance of both Levallois and prismatic cores. The distinction between the core morphologies is, however, unclear and Dortch (1977a:119) states that although both techniques could be linked under the same leilira production process this would mask the usefulness of both as culture-historic traits. The security of this argument is, however, undermined by his earlier observation that the difference between prismatic and Levallois techniques in the east Kimberley may have been a function of raw material, with prismatic blades produced on quartzite blocks and Levallois points on chert pebbles (Dortch and Bordes 1977:3). The presence of both prismatic and Levallois type cores and points on both quarry sites and gravel bed sources (Dortch and Bordes 1977:4) suggests that the difference between the two forms is also reflective of primary core geometry and only indirectly of material type.

The production of point/blades on the quarry sites located on the cliff walls and gravel beds of the region is also associated in the Miriwun assemblage with a less formalized flake technology. Many of the shelter sites provide quartzite which had been worked on-site. At Miriwun a high proportion of the flakes in the overlying assemblage were derived from either the flaking of the
shelter walls or blocks of roof fall.

Although, as noted above, the most common artifact types in the Miriwun assemblage are denticulate and notched flakes it is not possible from Dortch's discussion to relate these to the flakes produced on-site. The question of on-site and off-site flake production is also related to the structure of point reduction as many of the backed and some of the unifacial and bifacial points were in Dortch's view made on flakes (Dortch 1977a:113,117). Dortch's model, therefore, contains parallel reduction processes for the same set of artifact types.

A directly comparable model of east Kimberley reduction structure is supplied by Bradshaw (1986). In her discussion, Bradshaw (1986:263) rejects the appropriateness of Levallois as a term describing blade production in the overlying assemblages and suggests that 'leilira' be confined to describing the central Australian knife. Although no large blades of the type used for these knives were found in the assemblages examined, the production of smaller blades is seen by Bradshaw (1986:284) to dominate the east Kimberley 'industry'. These blades formed the blank for a range of artifact types including some of the various point forms which are defined according to the type and degree of marginal retouch. Five "definitive point" types are identified: unifacial unilateral non-invasive, unifacial bilateral non-invasive, unifacial bilateral invasive, bifacial bilateral non-invasive and bifacial bilateral invasive.
Three further forms are also described as unfinished versions of these five types. These include a unilateral invasive seen as an unfinished version of a unifacial unilateral (Bradshaw [1986:144] probably means bilateral invasive point), a bifacial bilateral with invasive flaking on one face only, forming an early stage of a bifacial bilateral invasive, and a reverse trimmed form with non-invasive flaking on both margins and opposed faces related either to unifacial or bifacial non-invasive types. As seen in the typological discussion Bradshaw (1986) also identifies a range of retouched blades, blade scrapers, adze points and rectangular adzes based on blade blanks.

The structure of the point/blade reduction processes, as Bradshaw (1986) reconstructs them, can be modelled as a series of eight separate reduction sequences culminating in eight finished products (see figure 2.7). The structure of reduction is not discussed in detail except for the observation that the invasive point forms where more frequently made on non-blade blanks. This is the opposite to Dortch's observation, but it does suggest the presence of a similar parallel set of reduction processes based on flake blanks.

Despite their typological prominence the point component presented a high degree of interpretative difficulty. Analysis of the size ranges within the point category produced no clear trends indicative of a reduction sequence. The tendency for bifacial points to be larger than the unifacial is attributed by Bradshaw
Figure 2.7: East Kimberley, overlying assemblage, reduction structure (Bradshaw 1986).
(1986:164) to differences in raw material although there appears to be no direct correlation between point form and material type. There is also little evidence for any chronological variation in point types as only the Kununurra Arched Shelter showed a diachronic difference in point proportions with bifaces increasing through time (Bradshaw 1986:288).

The small number of cores in the assemblages were divided into non-prepared and prepared categories. The former includes small discoidal and bipolar cores and the bulk of miscellaneous cores (56%). The remaining prepared cores are described as conical bladelet and blade cores. Although Bradshaw (1986:188) sees these as representative of the special techniques utilized for blade production the size of the cores, with masses ranging from 3 to 152 gms, appears too small for them to have been directly related to the blanks used in point production. The absence of prepared cores in assemblages with high blade components may result, Bradshaw (1986:188,251) suggests, from two processes; either the off-site production of blades, or the further reduction of cores on-site to other forms, mainly discoidal or bifacial blanks. Without substantial evidence of blade production on-site Bradshaw (1986:283) could say little about the nature of blade production in the technology beyond the suggestion that it conformed to a process already described for the production of larger forms by, for example, Spencer and Gillen (1904:641).
At the level of inter-assemblage variation the proportions of artifact types present in the sites examined by Bradshaw (1986) showed some complex patterning. The size of flakes on all sites was consistently small (below 2.25cm²) and ranged between 44 and 90% of the assemblage totals (Bradshaw 1986:236). Although points and adzes received most discussion retouched/utilized flakes and scrapers dominate all assemblages ranging from approximately 60-90% of all modified material. Bradshaw (1986:256) suggests that the "variable predominance" of scraper to point types in assemblages is in some way reflective of functional differences. This is not, however, used to explain the absolute dominance of retouched and utilized flakes in all assemblages examined (Bradshaw 1986:239).

In considering factors which have contributed to assemblage variation Bradshaw (1986:249) argues that raw material type and availability affected both the type of artifacts present and the method of manufacture. A comparison between The Grotto assemblage dominated by quartz sandstone, showing the highest proportion of retouched flakes, and the Philchowski Crossing assemblage with its high proportion of pointed adzes and fine grained material "suggests that raw material influenced the types that were made" (Bradshaw 1986:249). The connection is not, however, easily maintained in the light of the high proportion (85%) of adze points not made on fine grained siliceous material and the poor correlation between that material and adze points in the assemblage with the
highest proportion of fine grained material, Kununurra Arched Shelter. This also appears to be at variance with Bradshaw's (1986:251) later suggestion that quartz sandstone at The Grotto was particularly favoured for the production of blades which are only minimally represented in that assemblage.

Manufacturing techniques showed only a general relation to material, with bipolar flaking being associated with quartz working and blade production principally, but not exclusively, on quartzite material. Similarly, neither "environmental factors" like seasonality, or depositional processes showed any consistent correlation with assemblage composition.

Like Dortch's model Bradshaw's leaves a number of categories unrelated to any reduction process. These include the modified flakes, unprepared cores, core fragments, and core-scrapers. The majority of these artifacts (including some adzes) appear to be related to the parallel flake reduction system noted in the discussion of point production, but not extensively discussed in Bradshaw's analysis. The absence of the burins and tula adzes, noted by Dortch (1977a:119), from her discussion is probably more related to the persistent problem of typological definition which surround these forms than to any real technological differences between the two assemblage groups (see Cundy [1977] for discussion of the burin problem and Sheridan [1979] for that of the tula adze).
Both Bradshaw (1986:281,284,309) and Dortch (1977a) have characterized the east Kimberley assemblages as point and blade based and with the exception of burins and tula adzes described similar type lists. The actual structure of reduction implicit in this characterization remains less clear, with Dortch's argument for the presence of two blade production techniques (prismatic and Levallois) and Bradshaw's preference for a single process. Although both indicate a range of artifacts made on both blade and flake blanks, neither examines in detail the specific reduction processes represented and the relation between the various artifact types and these processes. The absence of clear evidence for a reduction sequence in the point forms does not preclude the possibility that some of the point types represent stages in a series of reduction processes (see section 5.4c). The relation between the various blade based artifacts and the predominant retouched flake component also remains to be determined in the region.

In the region further east, neither Davidson (1935) in his discussion of the Willeroo/Delamere site nor the preliminary reports on the Ingaladdi assemblage (Mulvaney 1969,1975; Sanders 1975) discuss the structure of point production in the overlying assemblages in the Victoria/Daly Rivers region in any detail. Although Davidson (1935) referred to Spencer and Gillen (1904:640-656) for a description of the manufacture and use of large blades in northern-central Australia and noted their high numbers on workshops in the region he saw both the large
blades and the recent adoption of pressure flaking techniques among the local Wardaman as part of a general process of trait diffusion from outside the area.

Consistent with this approach Davidson (1935) presented the occurrence of large blades as separate to the presence of the smaller 'adze points' in his assemblages. Statistical evidence presented in Davidson's report, however, suggests that there is no clear size boundary between the two forms. The small unmodified point form continues throughout the upper levels at both the Willeroo/Delamere sites and Ingaladdi, and appear from Davidson's measurements to overlap with the range of the larger form. Davidson (1935:168) also noted that some of the large blades showed retouch consistent with their use for general woodworking, similar to that ascribed to the smaller 'adze point', suggesting some continuity in modification and possible function within the blade/point forms.

In her analysis of the scrapers from Ingaladdi, Sanders (1975:15) (noting the low levels of core and flake deposition in the overlying assemblage) suggests a shift from on-site to off-site flake production in the assemblage with flakes being brought to the site and retouched as needed. Sanders (1975:9) also defines the upper assemblage by the presence of an 'end struck' flake technology which indicated a different form of tool manufacture (Sanders 1975:13). She, however, uses these observations only as contributors to a discussion of typological variation which reflects functional and
In her analysis of the Yarar assemblage Flood (1966, 1970) concentrates principally on a detailed examination of the point component. Her initial classification follows the general approach of sorting according to the position of retouch into bifacial and unifacial categories. The bifacial group is subdivided into ten groups (1-10) approximating the degree of retouch with groups 1-5 representing the more bifacially reduced forms. The groups show considerable metrical uniformity with the differences between dimensional means in the order of only 3-4mm.

The degree of retouch also shows no consistent correlation with mass which varies less than 2gms between the means of all 10 sub-categories (Flood 1966:88). Qualitative differences between the groups in terms of cross-section symmetry and tip type appear to be related to the general degree of retouch, with the more bifacially flaked examples (groups 1-5) exhibiting more standardized lenticular cross section and symmetrical tip form (Flood 1970:table 3).

Groups 6, 7 and 8 with ventral trimming confined mainly to the bulb retained features closer to more unifacially worked points and are combined into an intermediate group. Group 9 artifacts retained only a small degree of retouch and is seen as either an early stage of bifacial reduction or a "naturally pointed tip"
needing only slight modification (Flood 1970:43). Group
10 with reverse trimming on opposite margins and opposed
faces, similar to a form described above in Bradshaw's
analysis, is described as an "idiosyncrasy".

Comparison of the bifacial (A) and intermediate (B)
point groups with the predominant unifacial (C) category
in the assemblage again shows little metrical separation
with differences of <2mm between mean dimensions and
approximately 1gm in mean mass, with all categories
averaging 35*22*10mm in size. Attempts to arrange the
points from larger unifacially flaked to smaller
bifacially worked forms failed to demonstrate the presence
of a reduction sequence and as a consequence Flood groups
the majority of the intermediate points (B) as forms of
unifacial point. On the basis of the size difference
(although small) and the apparent lack of a common
that the contrast between bifacial and unifacial point
types may have been related to function; unifaces being
used as adze and spear points and bifacial points serving
ritual functions. Although Flood supplies no statistical
tests for these data, she appears, from the writer's
calculation of the standard error of difference, to be
statistically justified in arguing that unifacial points
are generally larger than those in the bifacial sample.
The small size of this difference retains, however, an
ambiguous technological significance.
Unlike those discussed above, the Yarar assemblage contains only a small number (25) of primary pointed flakes which Flood (1966:126) does not consider as a blank for the points in the assemblage. Most points she argues (on the basis of experimental evidence) were produced on less regular primary flakes (Flood 1966:125). A number of artifacts classified as bifacial blanks, Flood suggests, support the interpretation that only the final stages of point manufacture are represented on the site. If this is the case, the Yarar assemblage shows evidence of a different reduction structure to those of the Kimberley and Daly/Victoria River sites above.

The cores in the assemblage are predominantly multiplatform with low mean mass (33.3gms). The presence of redirecting flakes indicates that a core reduction was carried out on-site, although, Flood does not discuss this further. She (1970:34) also suggests that the small size and large number of waste flakes combined with the small number of cores in the assemblage supports the hypothesis that only the final phases of point reduction are present on-site.

As noted in section 2.2 the bulk of the Yarar assemblage comprises over 43,000 flakes, the majority of which are less than 4cm². Flood (1970:34,49) correlates these with the final "trimming of implements" from flakes which had been brought to the site from a quartzite source approximately 15kms to the west. Flakes are not evenly distributed through the deposits with the highest density of flakes less than 4cm² in level 3 and larger flakes in
level 2. Flood (1970:49) uses the correlation between peak bifacial point deposition and small flakes in level 3 to argue for the predominance of bifacial production in the lower levels of the site. Level 3 also sees the peak of core deposition and general flake modification.

Compared with the reduction structures of Dortch (1977a) (figure 2.6) and Bradshaw (1986) (figure 2.7) Flood's (figure 2.8) is substantially simpler, concentrating on the production of bifacial and unifacial points. As the reduction processes are not discussed in detail their similarity to the parallel flake sequence noted in the east Kimberley models remains to be tested.

Like the preceding assemblage structures, Flood's analysis also leaves a number of types unrelated to any reduction process. The presence of bifacial blanks, for example, is unrelated in the discussion to any of the major point groups. From their description and illustration (Flood 1970:39) the use of these 'blanks', with their irregular form and full bifacial flaking, appears difficult to reconcile with the 'final form'- the majority (81%) of which retain only partial trimming. The primary points in the assemblage (Flood 1966:plate 19) also appear to lack the regularity seen in the Kimberley and Victoria/Daly River assemblages. Their relation to partially trimmed forms illustrated in the same plate appears sufficiently close to incorporate them into the general flakes used for the production of these forms.
Figure 2.8: Yarar, overlying assemblage, reduction structure (Flood 1966, 1970).
Similarly, the various scraper and utilized flake forms may be related to processes of on-site core and flake reduction. Although the presence of core rejuvenation flakes may indicate that some core reduction was being carried out on the site the degree to which this has contributed to the amount of flake discard is undetermined. As 61% of the flakes in the assemblage have lengths (>1cm) over one third the average lengths of the finished points (3.5cm) it seems unlikely that Flood's suggestion that the flakes are directly correlated with final trimming can account for the majority of the flakes in the assemblage. Available data on the size distribution of debitage from bifacial point production (Stahle and Dunn 1982) shows that flakes larger than 1cm² constitute less than 10% of the waste from all stages of "medium size" biface production on flake blanks (from the type reproduced in Stahle and Dunn's experiment the biface's length must be assumed to have ranged from 4-8cms).

The production model described for the Tandandjal assemblage by Macintosh (1951) and McCarthy (1951) shows similarities to both the Yarar and east Kimberley. The assemblage was unique at the time of excavation for the high proportion (86%) of "implements", classified as scrapers by McCarthy (1951), which had been produced on 'leilira' blades. These blades were also blanks for some of the trimmed points. Burins and knives were also produced on blades, although it is not clear whether these
were of 'leilira' form (McCarthy 1951:205).

Despite the high modified to unmodified ratio of 5:1 Macintosh (1951:199-200) argued for the on-site production of the artifacts in the assemblage. The wide range of points showing continuous overlapping of so-called 'types' was seen as important, although the its significance was not discussed further. Macintosh (1951:200) also noted that the morphology of point forms ranged from narrow blades to broad flakes and that the generally smaller 'pirrioid' or unifacial form was also duplicated on some of the larger blades. Most of the highly modified unifacial 'pirri' and bifacial point types appeared, however, to have been made on flake blanks. A similar range of blank forms was also seen in the production of the scrapers.

Macintosh's (1951) rejection of formal types within the point and scraper categories is not accompanied by any account of how this could be interpreted. It is uncertain whether he saw this as a product of a single reduction process resulting in a highly varied range of forms or the products of a set of separate manufacturing processes with a wide range of intra-product variation. Macintosh's assemblage structure relates blank type and product in a general manner but not the connecting reduction process to either.

In summary, at both the level of intra and inter-assemblage comparison there appears a series of parallels
in the use of separate blank forms to produce similar products. The separation of flake and blade/point blanks is present in both the east Kimberley and Tandandjal assemblages. The relation of blanks to products in each shows, however, some variability. In Dortch's model a range of point forms are produced both on 'leilira' blades and general flakes, although not in the same proportions. From a directly comparable set of assemblages Bradshaw (1986) also sees a similar range of point forms produced on blade blanks. These are also paralleled by a similar range made on flakes which were also used to produce a separate set of less well defined retouched artifacts. In addition there is an unrelated bifacial blank which is derived from core reduction. Macintosh (1951) and McCarthy (1951) described the Tandandjal assemblage as a wide range of scraper and point forms derived from both flake and blade blanks. Unlike the east Kimberley assemblages, most of the scrapers were made on blades not flakes. In contrast the Yarar assemblage appears to be strongly flake based with a separation of unifacial and bifacial point forms and a second example of an unrelated bifacial blank.

The feature common to all the models of assemblage structure is the lack of any detailed discussion of reduction processes and their relation to products. Like those describing the underlying assemblages this feature is a product of the ad hoc way in which the structure is assembled in discussions which are generally aimed at the description of products and their meaning as types.
There are two ways in which the variation between the structures seen in the discussion of the overlying assemblages can be approached - typologically or technologically. The former, based on the primacy of type as product, would proceed from the premise that the variation in structure is basically a problem of typological comparability. Bradshaw (1986:263), for example, uses such an approach when she suggests that Dortch's identification of the Levallois technique within a 'leilira' blade technology is an inappropriate use of terms following from poor type definitions. A number of similar arguments could be mounted against some of the more problematic areas of definition found in the structures. As a further example, the separation of discoidal cores and bifacial blanks appears potentially questionable, as does the problem of core and scraper differentiation. Similarly the definition of point types sees inconsistent classifications with reverse trimmed blades being categorized as points by Bradshaw (1986) and scrapers by McCarthy (1951). The relation between McCarthy's scrapers on blades and the point types in other classification schemes also remains to be clarified.

There are a number of points which can be made about the use of such approaches to interpret the variation in the assemblage structures presented above. The first of these is related to the way in which the models are themselves constructed. As the reduction processes central to the structure of technologies are not discussed in the various analyses, the models are not defined by a
series of processes but by a series of products related via a set of unspecified shadow process. The structure of these models is identical to reduction as product sequence discussed in Chapter One (section 1.4). As the primary structure is defined by the inter-relation of products its form may be modified by typological reclassification. This approach will, however, simply realign products and continue to leave the underlying processual relationships undefined. The variation in types defined by Schrire (1982) and Jones and Johnson (1985) in comparable underlying assemblages did not, for example, substantially improve the coherence between the product structures and the dynamics of discard and material selection in their interpretations of the assemblages. Attempts to make the models more internally coherent and more externally comparable by reducing or increasing the typological complexity of the products may also be self-defeating in terms of the aims of typology itself—producing too few types to describe variation or too many to comprehend.

It is argued that typological approaches to problems of assemblage variation will be a substantially self-limiting exercises because the variation in the models reflects variation (if not directly) in the structure and organization of the underlying reduction processes. The problem with the models relying on types to describe the structural relationships within assemblages is that their lack of technological structure leaves large areas of incoherence between product and process. In the upper assemblage this occurs most clearly between the forms of
blank, the products produced and the reduction processes used. Even where specific processes have been identified with product forms the relation of the two is poorly defined.

In four assemblages blades formed the blanks for a range of products. Both Dortch (1977a) and McCarthy (1951) have identified these as the 'leilira' form widespread in northern and central Australia. While Bradshaw (1986) disputes the terminology, the use of similar blade forms is confirmed in her analysis as is the metrical gradation between similar blades and adze points in Davidson's (1935). The problems which arise from this are to what extent these blades derive from a specialized production process, and to what degree they can be associated with the leilira blade production as it is currently understood from the ethnography. While it will be assumed for the purposes of the model presented below that the production of these blades derives from a specialized core reduction process the assumption will be tested in the analysis presented in Chapter Five. The second problem of their archaeological and ethnographic correlation can be discussed more directly.

Generally classified as a variety of point (White and O'Connell 1982:106, Jones in McKenzie et. al. 1984, Jones and White 1988) 'leilira' are defined as either a long and pointed or square ended blade with triangular or trapezoid (trigonal) section and plain striking platform (McCarthy 1976:35) often with overhang removal on the proximal end.
The term 'leilira', derived from the use of these flakes in the hafted Aranda knife described by Spencer and Gillen (1899:223,652; 1904: 752; 1912:374,376,447-8), is still widely used to denote the distinct flake despite the argument that the term be restricted to a hafted knife (Casey, Crawford and Wright 1972:109-110, Mulvaney 1975:74). To avoid this confusion the term 'lancet flake', initially used by Roth (1904), will be used in this thesis to describe the flake form because it retains comparable historical claim, avoids the 'leilira' confusion and describes the form more accurately (see figure 2.9).

The wider incorporation of lancet flakes into the assemblage structures of some north-western sites is at some variance with the organization of their production derived from the ethnography. The ethnographic picture (Eylmann 1908:331, Spencer and Gillen 1904:641 1912:374,376, 447-8, Thomson 1949a:55, 1949b:87, 1983:71-3) is one of specialized production, carried out at a few large quarries, which is fed directly into an extensive exchange network. These artifacts performing specific roles as knives, fighting picks and spear heads would appear not to have been incorporated into artifact production at any other level. A recent investigation by Paton (pers. com.) of the Kungiridja quarries in northern central Australia has confirmed that this appears still to be the case for that region.

The apparent wastefulness of the production, noted by Roth (1904:16), Spencer and Gillen (1904:643) and Thomson (1949a:55) has been used to argue that the process was not
Figure 2.9: Lancet flakes from the Ingaladdi assemblage.
Thomson's (1949b) description of the exchange system in which these flakes were circulated is one of restricted access to the products and the quarry sources which appear to have been worked by only a small number of men (Thomson 1983:70-72, Torrence 1986:52-3). Paton (pers. com.) also found that the right to work quarries in the Newcastle Waters area is controlled by men who have direct affiliation with the site; its importance determined by its mythological associations rather than its production potential. The flakes produced at these quarries rarely occur as whole artifacts on surface sites in the region. Paton (pers. com.) suggests that surplus production was deliberately broken and discarded in order to maintain the value of the remaining artifacts.

The inconsistencies between the production organization seen in the ethnography and that presented by the archaeological analyses may suggest firstly, that the conventional model of lancet flake production is only one aspect of a much wider set of structures associated with their manufacture and use, and secondly, that there is more extensive regional variation in this organization than previously realized. There is, however, only limited evidence for either of these proposals. Surveys by the writer in the region of the Renner Springs quarry (see also Eylmann 1908:331, Hill
1951, Linklater and Tapp 1968, Spencer and Gillen 1912) and Baker (1983) of the Pine Creek quarries (Eylmann 1908:331) showed a wider range of sources than those described in the literature. Both Jones (McKenzie et. al.[1984]) and Binford and O'Connell (1984) (see Binford [1986]) also report the use of similar small quarry sites for the procurement of lancet flakes. From the Victoria River region Baines (1865/7) reconstructed the manufacture of lancet flakes associated with campsites along the water courses. Basedow (1907:32) also noted extensive quarries along the Victoria River, and although in the context of exchange, Stanner (1933/4:162) has discussed one in the Daly River region.

Evidence that the products of these quarries played a larger role in further reduction processes is confined to Roth's (1904:16) suggestion that the 300 odd flakes produced in order to select a suitable lancet flake could have been utilized for scrapers, Binford's (1986:554) that the blades of men's knives in central Australia could be reworked to provide flakes for cutting and Baines' account which makes no mention of any role in exchange. Although Roth's suggestion does raise the possibility that discarded flakes from the process could be further reduced the only reference in the literature to the systematic use of blades as blanks is in Jones and White's (1988) account of the production of retouched points from the Ngilipitji quarry. There is, however, some doubt judging from the illustrated products of this ethnographic reconstruction whether the blanks conformed to the lancet flakes shown by
Thomson (1949a, 1949b) to be the main products of the quarry.

Some clarification of the problem of the archaeological and ethnographic role of lancet flakes depends on a more detailed examination of the processes of 'point' production and their relation to blank form. In the assemblage structures discussed above this has been confined to the handling of forms which do not fit the conventional typology, as in the suggestion that reverse trimmed points were an unfinished form (Bradshaw 1986:158) or that partially trimmed points were an unfinished bifacial form (Flood 1970:43).

The manner in which specific point forms might be related depends on the type of reduction processes utilized - there are two models available:

In their overview of Australian lithic technology Flenniken and White (1985:147) state that from a technological perspective "the different point 'types' found throughout Australia form a single, uninterrupted continuum...". This formal continuum is the product of a single "technological sequence" or reduction process. The sequence begins with a blade form (linked to lancet flakes via a reference to Thomson [1949a:55]) which is reduced by scalar flaking to a point with partial butt and tip modification and then to one with full marginal retouch classifiable as unifacial. The third stage in the process is a unifacial 'pirri' type with complete invasive flaking on the dorsal face and the fourth a bifacial 'Kimberley'
type with full invasive flaking on both faces. Reduction is structured as two unifacial processes in sequence, with any bifacial flaking occurring in the initial unifacial stage attributable to platform preparation.

The model suggests that many of the separate forms defined in the overlying assemblages may be unfinished products of a single reduction process culminating in a bifacial form. Although the degree to which this is the case for each assemblage remains to be tested there are a number of problems inherent in the use of this sequence as it is presented. Although sufficient as an initial hypothesis of sequential relationship between point forms, the Flenniken and White (1985) model, is too highly formalized to be directly applicable to north-western assemblages on three levels. Firstly, the inclusion of lancet-like flakes as the only defined blank form appears to exclude the possibility of less well defined flake forms being used as blanks, although technically there are reasons to suggest that these might have been preferable for point manufacture (Crabtree 1973:11, Patterson 1979). In its exclusion of these flakes the model can not account for the parallel flake sequences suggested by Macintosh (1951), Flood (1970), Dortch (1977a) and Bradshaw (1986).

The model also repeats the error found in the analyses of assemblage structure in its presentation of reduction as a sequence of product forms connected by shadow processes. The formal association, for example, of a well defined and geographically restricted point type,
'pirri', with a stage in reduction suggests that all bifacial points pass through a 'pirri' form. This correlation of type and production stage is potentially misleading as northern unifacial points are not generally defined as 'pirri' and could only be done so by the broadening of the original definition (Flood 1970:47). The relation of the by-products of the sequence to the archaeological material is also problematic. It is not clear if the identification of points as adzes, scrapers, et cetera, in northern assemblages can be explained by this model as incorrectly assigned failures of a single point reduction process, or if they are derived from a separate 'non-point' reduction of pointed flakes.

The third problem with the Flenniken and White (1985) model as a complete explanation is that it is inconsistent with the most detailed ethnographic descriptions of point manufacture from north-western Australia. An examination of the literature on the production of the bifacially pressure flaked Kimberley point (Elkin 1948, Love 1936, Mahony 1924, Rainey 1973, Tindale 1985) showed it to be a highly specialized process similar to that of the biface reduction sequence described for the underlying assemblage. In the manufacture of the Kimberley point bifacial flaking is not confined to the final stages of the process but begun from the outset as the principal mode of reduction. The primary forms used range from leaf shaped flakes struck from bifacial cores (Tindale 1985), primary decortication flakes and whole pebbles (Rainey 1973) to irregular cores (Elkin 1948). In all sequences a
preliminary round of bifacial flaking with hard hammer is used to produce a bifacial blank. This is followed by several further rounds of pressure flaking to create the final form. The sequence can be used as a second model of a point production process and may go some way in explaining the identification of 'bifacial blanks' in some of the north-western assemblages.

In summary, we have a number of assemblages in which blades/lancet flakes are reduced to produce a range of forms which have been defined as points, scrapers and adzes. The ethnography suggests, however, that lancet flakes are highly specialized exchange items without an extensive role in domestic production. The available reduction model supports the typological unity of all pointed artifact forms by linking them in a single point reduction process which is not supported by the most reliable and consistent accounts of point production.

The resulting picture is confused principally by the limited ethnography and the correlation of 'points' as a type and points as simply products of a process. This is seen most clearly in the Flenniken and White (1985) model where the reduction of pointed flakes is treated as equalling the production of points; the equation of all pointed flakes with the type 'points' related by a single reduction process can, however, not be assumed.

Clarification of this problem requires a more complex model of flake reduction in the north-western assemblages than has been hitherto produced. As an initial hypothesis
it is suggested that there are a number of separate reduction processes involved in, firstly, the manufacture of 'points', and secondly, the reduction of pointed flakes and the less specialized retouched component in north-western assemblages, and that these processes are definable in terms of two primary and two secondary sequences (figure 2.10).

The primary sequences are divided into an unspecialized (A-1-1) and specialized single platform (B-1-1). The product of the B sequence is a lancet flake, the 'leilira' component of which is a sub-set of lancet flake production associated with the manufacture of large flakes serving as prestige trade goods in some areas. The size range of these artifacts and their association with complex socio-economic behaviours precludes them from a wider role in reduction processes. The smaller end of the lancet flake range are further incorporated into a second level unifacial invasive reduction process (C) and a bifacial invasive sequence (D). Flakes from the unspecialized (A) sequence may also be incorporated into both the unifacial and bifacial process.

The specialized single platform B process differs from the A in its more systematic location of PFA relative to core geometry, i.e., the use of guide ridges, overhang removal and platform preparation. The resulting lancet flakes exhibit greater elongation, more restricted striking platforms and more standardized cross-sections.
Figure 2.10: General model of overlying reduction structure.
The unspecialized A process is the same as that described in the model of the underlying reduction structure and is accompanied by limited modification of core geometry. Both flakes from the A and B sequences may be further reduced via the A process to produce a range of modified flake forms. This flake reduction may incorporate a series of parallel sequences characterized by differing reduction modes (A-n-1) producing the differing forms.

The unifacial sequence (C) is divided into an initial dorsal (C-1-1) and a second ventral sequence (C-1-2) (the actual dorsal>ventral sequence may be reversed). The end product of the C-1-1 sequence is a unifacial invasively retouched point. This may be further incorporated into the second ventral sequence C-1-2 the end product of which is an invasively flaked bifacial point (see section 5.5). As the process produces a standard product it should be associated with invasive flaking and with well defined reduction sequences. This will be tested in Chapter Five where it will be shown to be possible to distinguish between the production of 'points' via the C sequence and the less well defined reduction of pointed flakes via the A.

The second bifacial sequence (D), utilizing a range of flake forms, initiates bifacial reduction from the outset producing bifacial blanks, preforms and points as products. Typologically the final forms would be classified with those from the unifacial sequence despite their different origins.
From the assemblage structures presented in the discussion it may be seen that the organization of these reduction processes does not appear to be congruent between assemblages. The east Kimberley and Victoria River assemblages both show the use of lancet flakes in unifacial processes, but the former is dominated by a retouched flake component which is only marginally represented in the latter. Dortch (1977a), Bradshaw (1986) and Sanders (1975) have all suggested that the lancet flake production is carried out off-site indicating, for example, in the Ingaladdi assemblage a change in the logistics of lithic transportation between the underlying and overlying assemblages. On the other hand, the Yarar material suggests an on-site core reduction although few cores remain in the assemblage. The point production appears also to be carried out on flake blanks with only marginal representation of lancet flakes, while the low modified to unmodified ratio in the assemblage suggests even less on-site production than Flood (1970) initially suggests. The Tandandjal sequence shows the differential incorporation of both lancet flake and less standardized flake blanks into an indeterminate series of reduction processes. The lancets appear related more closely to unifacial reduction while the flakes appear to be more closely correlated with a bifacial process. The low product to producer ratio in the assemblage also indicates either little on-site reduction generally or extremely high discard in relation to reduction.
As a summary to this chapter, it has been shown that the conventional understanding of the north-western assemblages has been principally governed by the concerns of typological description, relegating technological processes to the role of ad hoc explanations of specific artifact types. The result has been a persistent incoherence between the artifact form and reduction processes with little analysis of the organization of these processes on specific sites. Despite this, there is sufficient evidence to suggest that the different structures seen in both the underlying and overlying assemblages in north-western Australia are not simply the product of typological inconsistency (although that is certainly a component), but reflect real differences in both the form and degree to which reduction processes are represented in assemblages and their differential organization in time and space.
3.1: Introduction to the Site

The archaeological site of Ingaladdi (15°12'20"S by 131°24'5"E) lies approximately 110kms south-west of the major regional centre of Katherine in the north-west corner of the Northern Territory, Australia (figure 2.1). The site was excavated by D.J. Mulvaney in two field seasons in 1963 and 1966. Although a major report is not yet available for the site Mulvaney (1969, 1975; Mulvaney and Joyce 1965) has outlined its broad structure in several publications. 'Scrapers' from the assemblage have also been studied by Sanders (1975) and the site continues to be referenced in the general surveys for both the lithic material (Lampert 1980) and for its art (Flood 1983). As a major excavation, centrally located in the region, the Ingaladdi material provides an opportunity to test the application of the thesis' principal critique (section 1.3) to the understanding of lithic technology in
a specific archaeological context, outlined in Chapter Two. Before this can be done, however, it is necessary in this chapter to outline the archaeological context of the assemblage. Further details on the environmental and ethnographic context are provided in Appendix C.

3.2: Ingaladdi Environs: Aboriginal and Archaeological

The archaeological site of Ingaladdi is located in a sandstone outlier approximately 1.7km east north east of the northern end of the waterhole after which it is named (figure 3.1). The waterhole, over 2.5km long, provides permanent water and is the most important of a series of water sources along the line of Price Creek which forms one of the southern tributaries of the Flora River to the north. At its southern end the creek cuts through sandstone gorges until it breaks at a fault line into the more open country of the Antrim Plateau Volcanics. The Ingaladdi waterhole straddles this break and provides the last such waterhole before the creek's course devolves into a series of dry channels running through black soil alluvium to the east.

Within 5-10kms of the waterhole a number of land systems occur, ranging from the fringing forests of the watercourses to low hilly country with low open woodland and grass understorey of the basalts, to the tall grass plains of the black soil creek channels. Although these changes are not highly developed the area is ecologically
Figure 3.1: Ingaladdi Environments - the dotted line indicates the extent of black soil grass plain about the creek lines. The distribution of major sandstone outcrops is shown by darker stippled areas. [1] Ingaladdi, [2] SS/1, [3] SS/2, [4] SS/4
diverse relative to the large regions of sandstone and lateritic plateau to the west and east.

Running to the north-west and the south-east of the downstream end of the waterhole is a series of sandstone outcrops which have weathered into low ridges and outliers. The extensive Aboriginal occupation of the area is recorded in the stone artifact scatters and the rock art of the sandstone shelters (see Mountford and Brandl 1968). The sandstone outcrops are also the centre of a complex mythology which can only be briefly outlined. The line of Price Creek and the Ingaladdi waterhole are part of the Moon 'dreaming' (see Lewis and McCausland 1987) which plays a central role in Wardaman cosmology. Despite its importance as a waterhole Ingaladdi is, according to Harney and Elkin's (1949:114-115) poetic reconstruction, where the Moon-man's breaking of a marriage law brought death into the world of man. The area is also associated with the Lightning Brothers mythology (Arndt 1962, Chaloupka 1978, Davidson 1936, Harney and Elkin 1949). The archaeological site of Ingaladdi is named Nimdji (Chaloupka pers.com.) and is part of the body of a rainbow serpent speared by a hawk (Harney pers. com.) (see Stanner [1961] for a similar rainbow serpent v's flying fox myth which is more consistent with the outcrop's other mythological associations).

Besides their strong mythological relations the sandstone outcrops on the northern side of the creek also provided good hunting grounds for kangaroo which used the shade provided for midday shelter (Arndt n.d.).
method of hunting was to surround the outcrop and rush the prey. Permanent water sources like Ingaladdi would be most extensively utilized during the late dry season when more ephemeral waters had dried. During this time the attractiveness of the waterhole to large game would facilitate the type of hunting described by Arndt. Because of their size and permanence the success of exploiting some of the aquatic resources of isolated waterholes like Ingaladdi can be, and is today, affected by the presence of a salt water crocodile population which both directly compete for food resources and through familiarity pose a direct threat to the hunters.

Despite what appears on first contact to have been an arcadian setting, the waterhole with its mythological associations of violence and loss, and the threat of physical danger not present at smaller less spectacular water sources, present a resource which may have been utilized with a degree of circumspection by traditional Aboriginal groups.

The archaeological site of Ingaladdi lies on the southern most outlier of two distinctive parallel sandstone ridges running south-east from Price Creek some 2kms downstream of the waterhole. The site faces south-south-west and comprises an area 20m wide and 10m deep bounded on the northern, western and eastern sides by near vertical walls between 9 and 12 metres high. These walls provide good shade throughout the day but the overhang of only 4m at the rear of the site provides little wet season
protection (plate 3.1).

The site was investigated by Mulvaney in two field seasons in 1963 and 1966. In the first season an excavation 8*1.5m divided into 8 squares was opened along a line running 12° north. This was followed in 1966 by a second trench running at 90° to the 7.5 and 8.9 metre mark of the 1963 zero line. This second trench was 6.1m (20') on the north side by 1.4m (4'6") wide and divided down the long axis into two columns of 13 squares designated A (north) and B (south). Each square was .68m(2'3")* .47m(1'6"). Two pits A and C were placed to the west of the zero line and a third trench (E) was extended from A1 and A2 along the back wall (figure 3.2). The deposit which ranged from 95cms in A1 to 192cms in squares 6-10 was excavated in 25 3"(7.6cm) spits.

The deposit contained an extremely dense stone assemblage which was divided into two components. The overlying one was characterized by edge-ground axes, adze flakes and flaked points (see Chapter Two). This overlies stratigraphically a flake and core assemblage. The industrial change coincided with what appeared to be a stratigraphic break between the lower units containing an orange rubble in the basal deposits and an even dark grey sand in the upper layers. Mulvaney (1969:147, 1975:184) suggested that the lower deposits were laid down at a time in which weathering conditions differed from those of the upper units and that the break took place between 3000 and 5000 BP (Mulvaney 1969:115). The upper assemblage dated to less than 3000yrs with a peak of bifacial point
Figure 3.2: Ingoladdi 1963 and 1966 trench layout from the original site plan. The hatched area indicates the squares analysed in this work.
production between 1-2000 BP. The underlying assemblage dated from 5-7000 BP.

Mulvaney (1969:180-181) published four dates supporting this sequence. Three for lower unit (ANU-60, 6800±270; CX-104, 6255±135 and ANU-58, 4920±100) and one for the upper unit (ANU-57 2890±73). ANU-60 and 58 bracketed the lower 'industry' while CX-104 taken from the 1963 excavation confirmed this estimate. ANU-57 taken from near the base of the upper unit provided the basal date for the later 'industry'.

Sanders (1975) in her analysis of the Ingaladdi scrapers illustrated both the 1963 and 1966 trench layout and a schematic stratigraphic section of squares 5-8 of the 1966 excavation and square 8 of the 1963. From this section the depth difference between the 4920±100 and 2890±73 dates of approximately 25cms, suggested a substantial slowing of the accumulation rate over that period. Sanders' section also showed that the transition between the lower rubble and upper sandy layers was not even but dipped sharply in squares 5 and 6 to the point where 5 contained no rubble material. Sanders (1975:13) interpreted this feature as the product of systematic clearing of the rubble from the back of the shelter. Her illustration also shows the ANU-58 date (4920±100) to be above the rubble in a transition zone between the rubble and the dark grey sand.
Concern over the dating of this intermediate zone prompted the submission of two further charcoal samples from A10 and A8 (Mulvaney pers. com.). The results proved indecisive with ANU-1261 the stratigraphically deeper of the two returning a date of 3450±110 compared with ANU-1260 of 3740±80. The latter was over 1500 years younger than ANU-58 which was approximately 20cm higher in the deposit (these will be discussed further below - section 3.6).

This anomaly and evidence from Mulvaney's field notes indicated substantial disturbance had occurred in the transition between the upper and lower units near the back wall of the site. To better understand the relation of the cultural and stratigraphic sequence of the central squares (AB8-10), this portion of the 1966 trench was reopened in 1986 as part of the fieldwork for this study (plate 3.2). The stratigraphic reinterpretation which follows, is based on the original fieldnotes and section drawings combined with new evidence from the analysis of the sections recorded in 1986.

3.3: Stratigraphy

The deposits at Ingaladdi are part of the extensive sand sheet which surrounds the sandstone ridges and outliers in the region. The stratigraphy appears to represent progressive weathering of the sandstone and the collapse of the shelter walls. Two stratigraphic profiles
Plate 3.2: View of the 1986 reopening of squares 8, 9 and 10 of the 1966 excavation from the top of the shelter looking south-east. The "Lightning Brothers" figures illustrated in Mulvaney (1969: pl.68, 1975: pl.84) are in the complex of residuals in the middle distance. The waterhole is out of view to the right.
of the A and B walls of squares 8, 9 and 10 are shown in figure 3.3. The deposits are divided into four stratigraphic units:

Unit I comprises a layer of finely sorted yellow/red sand with an average depth of 70cms. The deposit contains a high charcoal fraction which contributes to its dark grey colour (5YR 2.75/1). The sand is generally clear of roof fall but contains a high density of overlying assemblage material. This layer grades into Unit II.

Unit II is transitional between I and III, and is not as clearly defined as either of the adjoining units. It is composed of a yellow/red sand (5YR 3/2) and contains a small number of medium sized rocks between 10 and 20cms in diameter. Unit II averages 30cms in depth and retains low artifact densities of underlying assemblage material. A sloping lense of orientated rubble and stone artifacts appearing in A8 section has been labelled as Feature B (figure 3.3).

Unit III forms the principal component of the lower units. Its matrix is a mixture of orange sand (5YR 3/4) and sub-rounded to sub-angular sandstone rubble (3-10cms diameter). Contained within this rubble is a band of larger angular to sub-angular sandstone blocks. Unit III retains the bulk of the underlying assemblage material and averages 70cms in depth.

Unit IV is a bright orange sand gravel mix (5YR 4-5/6) with a gravel size ranging from 2-6mm. The unit's depth varies from 10-20cms depending on the density of the
Figure 3.3: Stratigraphic profiles of the A and B walls of squares 8, 9 and 10 of the 1966 excavation as re-exposed in 1986.
underlying bedrock from which it appears to be derived. The unit contains low densities of underlying assemblage material.

The mean individual rock mass (>1cm), the density per cubic metre and the percentage of rock of the total sediment mass by depth below surface of the 16 bulk samples (each 1000cm³) taken from the A9 section are shown in figures 3.4, 5 and 6. The figures show that the rock density rises to a plateau of values in the lower part of unit III from 171cms to 151cms were it falls sharply in two tiers to the low values which characterize units I and II. Despite the decline in rock numbers between 151 and 120cms their mass as a percentage of total sediment mass (excluding artifacts) remains high. The tendency for rocks in the deposit to become larger up to the 131-141cms level accords with this trend (Table 3.1).

<table>
<thead>
<tr>
<th>Table 3.1: Mean rubble size in grams by stratigraphic unit</th>
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</thead>
<tbody>
<tr>
<td>unit</td>
</tr>
<tr>
<td>mean</td>
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</table>

The correlation between the stratigraphic units, the bulk sample numbers, the spit numbers from the 1966 excavation and the average depth below surface are given in table 3.2.
Figure 3.4: Mean rock size (gms) by depth below surface (bulk samples).

Figure 3.5: Rock density per cubic metre of deposit by depth below surface (bulk samples).

Figure 3.6: Rock as a percentage of total sediment mass by depth below surface (bulk samples).
Table 3.2: Unit, bulk number and spit correlation

<table>
<thead>
<tr>
<th>unit no.</th>
<th>bulk no.</th>
<th>spit no.</th>
<th>depth* (cms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1-6</td>
<td>3-11</td>
<td>88</td>
</tr>
<tr>
<td>II</td>
<td>6-9</td>
<td>12-16</td>
<td>120-124</td>
</tr>
<tr>
<td>III</td>
<td>10-14</td>
<td>16-22</td>
<td>171-170</td>
</tr>
<tr>
<td>IV</td>
<td>15-16</td>
<td>23-25</td>
<td>192</td>
</tr>
</tbody>
</table>

*depth below surface of unit base

3.4: Sediments

The fine sediments (<0 phi-1mm) which make up from 21 to 98% of the total deposit is composed principally of sand (Table 3.3).

Table 3.3: Sediment Breakdown (%)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>77</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>II</td>
<td>79</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>III</td>
<td>81</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>IV</td>
<td>90</td>
<td>3</td>
<td>7</td>
</tr>
</tbody>
</table>

Particle size analysis of the sand fraction shows it to be well sorted throughout the deposit with means ranging between 1.63 and 1.48 phi. The grains are spherically weathered and there appears to be no trend in size throughout. Comparison with samples of the sandstone showed no significant difference between the grains forming the matrix of the deposit and those of the surrounding rock. The cross-bedded sandstone walls of the shelter derive from Lower Cambrian dune fields. The aeolian origin of these dunes accounts for the weathered
grains and the fine sorting of grain sizes. As the grains were well sorted in the ancient sandstone the possibility of utilizing sand grain size to indicate variable depositional environments appears limited.

Of the finer fraction (<.06phi) only silt size particles show a trend through time with an increase from 3 to 16% of the fine sediments. The silt includes a high charcoal fraction which contributes to the increasingly darker colour of the deposits through time.

Although the rapid decline in rock as a percentage of the total sediment from 120-131cms (spits 16/17) marks the top of the rock fall layer there is no evidence of weathering, sediment sorting or erosional events consistent with a substantial stratigraphic break suggested by the dates as Mulvaney (1969:115) has interpreted them. The analysis shows that the difference between stratigraphic units may be accounted for by two principal factors: the relative size and density of the rock fall and the degree of charcoal content in the fine sediment.

As the sediments show no evidence of there being major shifts in the energy of the accumulative environment through time it seems unlikely that the rockfall layer in Unit III is associated with any substantial erosional events decreasing the accumulation rates of the finer sediments (which constitute <20% of the sediment in Unit III) relative to the rate of rock deposition. The rise in rock in Unit III appears to be a real event which may
reflect a change in weathering conditions as Mulvaney (1975:184) has suggested, or a period of catastrophic instability in the structure of the overhang unrelated to any change in environmental conditions. Lees (pers. com.) has also suggested the occurrence of catastrophic events like the earthquakes experienced northern central Australia in 1987.

A third factor which has mechanically altered the Ingaladdi sediments is a disturbance indicated by Features A and B in the schematic section of the B wall from the 1966 excavation (figure 3.7). Feature A occurs in squares 5 and 6 of the B and 5 and 4 of the A section. The feature consists of a stratigraphic disjunction between Unit III deposits and a darker sand which in the B section appears to derive from Unit I deposits. The A section shows this relationship less clearly with an apparent gradation between the features deposits and the Unit I material above. The feature also shows a varied relationship with deposits to the rear of the shelter with the brown sand of the A section intersecting with Unit I material and the B section with a clear red/yellow sand which also intersects with Unit I deposits. Although the origin of the deposits in the rear of the shelter is not clearly understood their variety and discontinuity appears to indicate substantial disturbance.

Feature B consists of Unit III deposits which occur high in the A and B7 section. The stone material in this feature is sloped towards both the rear and front of the excavation suggesting some mounding. In his notes on the
Figure 3.7: Schematic section of the A wall of the 1966 excavation. The angularity of stones in the B feature is used to represent the slope change and does not indicate a difference in material form.
site Mulvaney (n.d.) posed the possibility that Feature B represented a midden like structure where systematic dumping of material had taken place. As noted above, Sanders (1975:13) interpreted this build-up of Unit III deposits as the product of long term clearing of the back of the shelter. There are a number of lines of evidence which suggest, however, that Features A and B represent an extensive pit excavated into Unit III material at the rear of the shelter and heaped over the remaining deposits to form a mound. This interpretation affords some explanation of the variation in the deposition of stone artifacts in squares 5, 6, 7 and 8 and the apparent stratigraphic break between ANU-58 (4920±100) and ANU-57 (2890±73).

3.5: Artifact Deposition

Artifact densities per cubic metre of deposit vary in the 1966 excavation from 0 in spit 25 to a peak of 89,000 in spit 14 of A7. Figure 3.8 shows two phases of high artifact deposition. The first follows a steady rise from spit 24 peaking in spit 16 and the second a rise from spit 11 culminating in a series of peaks from spit 8 to 4. The first peak is associated with underlying assemblage material and the second series with the overlying. The figure also shows the general order of magnitude difference between the densities at the back of the
Figure 3.8: Artifact numbers by spit depth in squares A5 and A6, and B8, AB 9-10 combined.
shelter (with over 70,000 artifacts per cubic metre in spit 16 of A6) and those of squares further out (with squares B8, AB9-10 combined reaching densities of less than 40,000 in the same spit). Similarly the overlying assemblage material in A6 reaches densities of over 40,000/m³ in spits 6-4 and over 27,000 in 8 while the combined outer squares reach just over 20,000 in spit 8 only.

The artifact counts in the 16 bulk samples show comparable trends to those in the spit analysis. Figures 3.9, 10 and 11 show the mean artifact mass, density/cubic metre and their percentage of the total sediment mass for each sample. The difference between the density levels of the bulk samples and the spit analysis reveals the biasing effect of the standard 1/4" sieves used in the 1966 excavation. The bulk samples contain substantially higher densities of artifacts/m³ in both overlying and underlying assemblages with the upper levels of the deposit between 45-55cms (spits 6/7) recording in excess of 200,000 artifacts/cubic metre. The bulk of this material (72% in sample no.3) consists of flakes smaller than 16mm². In the lower units the peak density rises to 99,000/m³ between 120 and 131cms (spits 16/17). With a 182% rise over the peak densities of the spit analysis the underlying assemblage was less affected by sieve size than the 1150% rise seen in the overlying material. The mean artifact mass rises to an earlier peak between 131-141cms (spits 17/18) then declines to 96-108cms (spits 13/14) where it remains consistently low throughout Units I and
Figure 3.9: Mean artifact size (gms) by depth below surface (bulk samples).

Figure 3.10: Artifact density per cubic metre by depth below surface (bulk samples).

Figure 3.11: Artifacts as a percentage of total sediment mass by depth below surface (bulk samples).
II.

If the results presented above are compared with those for the rock deposition in figures 3.4, 5 and 6 it can be seen that the peak artifact deposition occurs in the layer just above the peak of the rock as a percentage of total sediment mass and well above the peak of rock numbers. As might be expected there is no significant statistical correlation between the deposition of rock and artifact numbers in the bulk samples ($\tau_{up} = -0.07$). This suggests that while artifact peaks may result from a decline in the accumulation rate they are not simply the product of lag surface formation which would leave rock and artifact numbers more strongly correlated. Artifact mass as a percentage of total sediment mass peaks earlier between 131-151cms but declines less rapidly due to the rise in artifact numbers around 131cms. The graphs show a rapid shift in the lower units from the discard of larger to increasingly smaller artifactual material.

Sanders' (1975:15) suggestion that the Unit III and IV deposits resulted from the systematic clearing of the back of the shelter can be sustained only by arguing for the transportation of total sediment. The apparent corresponding rises in rock and artifacts as a percentage of sediment between 151 and 120cms can only be seen as culturally related if some argument can be forwarded explaining why artifacts, on average one tenth the mass of the offending rocks should have been seen as equally in need of removal. As noted above there is also no sedimentological evidence to relate directly artifact and
rock accumulation rates in the deposit via a high erosional component. There is, however, evidence that the creation of Features A and B has substantially affected the artifactual deposition in squares A7-8 (figure 3.12). In comparison with those of squares B8, AB9-10 combined in figure 3.8 A7-8 show substantially higher densities of between 60 and 90,000/m³. Like the graphs for the combined and A6 squares (shown in figure 3.8), the A7-8 plots both exhibit peaks in spit 16 with A7 retaining an 18% increase over the outer square A8, consistent with the rise in artifact numbers towards the rear of the shelter. Unlike the figure 3.8 plots, however, the densities are shifted progressively to the left in both A7 and A8, continuing well into Unit II levels. The A8 material continues to peak in spit 15 and declines to spit 12 while the A7 material peaks again in spits 14 and 12 declining rapidly to spit 11. While the densities of all squares share comparable heights in spit 16 those of squares A8 and 7 continue into what in other squares are deposits of low artifact density. It is argued that this shift in the curves represents the piling of Unit III material from squares A/B5 and B4 on to the upper levels of squares A7 and A8.

The comparatively little apparent disturbance to A6 material is difficult to explain, but may relate to the position of the excavator and the relative force by which material was removed. The pit (Feature A) appears in section to cross the trench obliquely cutting into the inner wall of A6 with most of the material falling on top
Figure 3.12: Artifact density in squares A7 and A8.
of the surface of AB 7 and 8. Without horizontal plans of the spits it is not, however, possible now to plot the relationship between the disturbed and undisturbed material in these squares.

As a result of the extensive nature of the disturbance the analysis of the site will be confined to squares AB8-10, the only squares with a complete stratigraphic record. Due to the presence of what has been interpreted as a part of disturbance Feature B in A8, material from spits 12-16 in the square has been excluded from the analysis in Chapter Four.

3.6: Dating

With the exception of a series of dates from the levels associated with Unit II the distribution of dates from both the 1963 and 1966 excavations is generally consistent.

Unit I is dated by two dates: ANU-57 from the 1966 excavation and GX-103 from the 1963 trench.

<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>GX-103</td>
<td>1545±75</td>
<td>37-48cms</td>
</tr>
<tr>
<td>ANU-57</td>
<td>2890±73</td>
<td>71-79cms</td>
</tr>
</tbody>
</table>

ANU-57 dates the lower levels of Unit I giving an approximate date of 3000 BP for the bottom of this unit. GX-103 taken from the central region of the equivalent of Unit I material in the 1963 excavation is both absolutely and relatively later stratigraphically. Both dates produce comparable rates of accumulation ranging at one
standard deviation from 2.4-2.8cms/100 yrs (ANU-57) to 2.3-3.3cms/100 yrs (GX-103).

Unit II is dated from a series of dates from the 1966 excavation.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Date (B.P.)</th>
<th>Depth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANU-58</td>
<td>4920±100</td>
<td>94-102</td>
</tr>
<tr>
<td>ANU-1260</td>
<td>3740±80</td>
<td>86-93</td>
</tr>
<tr>
<td>ANU-1261</td>
<td>3450±110</td>
<td>102-109</td>
</tr>
</tbody>
</table>

As noted above the proximity of the 4920±100 date to the 2890±73 in depth led Mulvaney (1969:115) to argue for a 2000 year break between the upper deposit and the rubble layer (Unit III). From the field notes (Mulvaney n.d.) the lower rubble first appears in square 7 in spit 12 and in square 8 by spit 13 from which the ANU-58 sample was taken. Mulvaney (Polach et. al. 1968:187) saw the sample as definitely related to the top of the rubble layer although the layer was substantially higher in those squares than those further out. From the discussion of artifact and sediment accumulation above it is argued that ANU-58 dates some part of the disturbed Feature B material and can be discounted as a representative date for either the transitional zone (Unit II) or the rubble layer (Unit III).

The two dates ANU-1260 and 1261 submitted to check the validity of ANU-58 are inverted and statistically indecisive in that they can not be said with confidence to date the same stratigraphic unit. The alternative, however, that they date separate units seems no more likely given the uniformity of the deposits in Unit II. At 2.5 standard deviations the dates span nearly a millennium.
from 3100-3940 BP and are in general accord with the dating of the upper deposit if the real age of Unit II is taken to be between these limits.

Unit III is dated by one date from the 1963 and 1966 excavation respectively.

<table>
<thead>
<tr>
<th>GX-104</th>
<th>6255±135</th>
<th>85-100cms</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANU-60</td>
<td>6800±270</td>
<td>155-163cms</td>
</tr>
</tbody>
</table>

ANU-60 dates the base of the rubble layer (Unit III) in square AB 6 and provides a basal date for the unit of approximately 7000 BP. The GX-104 date provides confirmation of the antiquity of the unit but its proximity to the top of the rubble layer which slopes down from a bedrock shelf 4 metres out from the rear of the 1963 excavation makes its stratigraphic relation to ANU-60 uncertain. A stratigraphic sequence similar to the central squares of the 1966 excavation does not occur in the 1963 trench until square 8, 7-8 metres from the rear wall of the shelter.

There are no dates from Unit IV which appears to be principally decayed bedrock.

3.7: Stratigraphy in relation to climatic change

Although the general impression of the stratigraphy is one of major sediment changes the analysis shows a relatively continuous stratigraphic sequence from >7000 BP. The rubble layer (Unit III) appears to record a period of significantly increased roof (or wall) fall into
the site between 7000 and 4000 BP possibly due to a catastrophic variable like structural instability. The peak lithic discard occurs after the decline of rubble in Unit III at the beginning of the transition zone - Unit II- dated to between 4000 and 3000 BP. Sediment analysis showed no major changes in the energy of the accumulative environment during this period which does not appear to be associated with the stratigraphic break suggested in previous analyses. Unit II does, however, exhibit a significant reduction in artifact density and an increase in fine sediments. Dating from <3000 BP Unit I contains the highest fine sediment fraction and the highest artifact densities demonstrating a shift in depositional behaviour associated with the appearance of new elements in the lithic technology. The increased charcoal content may also reflect wider changes in the local fire regime.

The changes in depositional behaviour and stratigraphy show some correlation with what is known of the late Holocene climatic changes in the region. In an analysis of the coastline changes in the Gulf of Carpentaria Rhodes (1980) noted a correlation between the progradation of the beach-ridge plain and increased cyclonic activity between 6000 and 4800 BP and 2300 and 600 BP. In his critical review of the evidence for climatic change in northern Australia Baker (1981) concluded that a number of sources also pointed to a period of wetter and warmer conditions between approximately 8000 and 5000 BP. Beyond this period the development of chenier ridges in north-western Australia
between 2800 and 1600 BP (Lees and Clements 1985, 1987; Less, Yanchou and Head, in press) independent of local marine conditions suggests a reduction of fluvial input and a rise in aridity during that period.

Fresh water sponge spicules and large phytolith bodies from the Unit II sediments of Ingaladdi indicate a period of considerably wetter local conditions between 4-3000 BP. The intact nature of the spicules indicates low depositional energy and suggests the possibility of periodic inundation of the site during that time. Although the site is not subject to flooding in its present environment it stands less than 10m above the current level of the black soil flats along Price Creek. The creek channel is cutting into these alluvial deposits and becomes braided two kilometres further down stream where the flats become wider. This may, however, be a comparatively recent flow pattern resulting from increased erosion and accompanying runoff due to the introduction of the cattle industry in the 1880's. Under the wetter conditions of 4000-3000 BP a decreased sediment load in reduced runoff combined with an increased vegetation of the alluvial flats may have predisposed the area to more generalized flooding as the creek spread over the flats and onto the adjoining sandsheets.

The low artifactual densities in Unit II and the upper layers of Unit I appear to correlate with wetter conditions about 4-3000 and postdating 1600 BP. The rise in artifact densities between these dates may correspond
with the period of aridity noted by Lees and Clements (1985, 1987) between 2800 and 1600 BP. Similarly the rise in lithic density in the upper levels of Unit III may indicate the decline in wetter conditions after 5000 BP noted by Baker (1981).

If these correlations are correct the density of artifacts in the site may mark the increased use of the Ingaladdi Waterhole and its environs during the periods of increased aridity which occurred in the late Holocene in north-western Australia. As a major permanent waterhole the seasonal use of the resource at the end of the dry season, as described by Spencer (1914:23), would be intensified under conditions of reduced monsoonal activity and reduced under more favourable conditions.

Although the Ingaladdi deposits retain no macro-organic material further work on phytoliths and soil chemistry may provide further evidence of both the environmental changes and the human responses in the area. It will be shown in the following chapters, however, that detailed analysis and interpretation of the lithic assemblage can also reveal complex behavioural changes in the patterns of discard and curation consistent with variation in landscape and site utilization accompanying the broad environmental correlations noted in this section.
CHAPTER FOUR

UNDERLYING ASSEMBLAGE: STRUCTURE AND PROCESS

In Chapter One it was argued that lithic technology may be broadly defined as the process of lithic reduction, not simply as a series of products whose forms provide the process's ends. Technologies are, therefore, structured by factors which both facilitate and restrict the process of reduction. While this perspective draws attention to the dynamic behaviour underlying typological statics it faces the problem of having to observe the operation of the process as it appears in the archaeological record - as a set of disconnected products.

The approach used in Chapters Four and Five is to analyse artifacts as products of reduction processes. The first step in this procedure is to conceptually divide the assemblage into product and producer artifacts, i.e., those that produce flakes (cores) and the flake products. This overrides the various core-scraper, horsehoeof core and scraper categories, recognizing the validity of any further typological distinctiveness only in relation to variation in underlying reduction process. Cores and
retouched flakes, for example, may be reduced via the same single platform procedure and are strictly separable only in terms of primary and secondary reduction in that particular process. As will be discussed below, this analytic rigour is difficult to achieve in practice and for the simplicity of procedure the core and secondary flake reduction will be more conventionally defined.

In Chapter Two a model of the reduction processes underlying the assemblages of north-western Australia was derived from an examination of the assemblage structures presented in the literature. The application of this model to the underlying assemblage will be tested via its capacity to reveal the factors which structured core and flake reduction in the assemblage. These factors divide into two classes: the internal and the external relations of production (see section 7.2). The internal relations derive from within the process of artifact production and take the form of disjunctions between the material, formal and effective components of the process. These can not be examined directly but their effects can be seen in the manner in which morphological variables like platform angle, platform thickness and core mass interact. The external relations derive from disjunctions within the organization of the reduction process and the processes relation to other forms of social and economic behaviour in time and space. These are primarily seen in the interaction of the extent of reduction relative to the local availability of lithic resources and the relation of on-site discard to off-site transportation.
4.1: Underlying Assemblage: introduction

The underlying assemblage at Ingaladdi is defined by the stratigraphic units II, III and IV corresponding to spits 23/24 to 12 inclusive (see figures 3.3 and 3.7). The analysis was carried out on 16,825 artifacts from six squares A, B/8-10, excluding the disturbed material from A8 spits 12-16 and missing material from A8/20, A10/15, B8/12 and B9/12. The artifacts included any material derived from a reduction process and incorporated secondarily modified non-flake debitage, cores and secondarily modified and unmodified flakes.

For general inter-spit comparison of proportions the spit totals are used as they stand, however, for the analysis of change through time and time series correlation modified totals have been used. This was necessitated by the number of missing and excluded spits noted above and the difficulty of excluding squares with missing data from the analysis without greatly affecting the sample sizes of the comparatively rare modified material. A breakdown of the assemblage by the two major material types and artifact categories is given in Appendix A.

Before detailing the analysis, some introductory examination of the underlying assemblage is necessary. This will concentrate on the features which represent specific problems in the behavioural interpretation of the
assemblage.

Table 4.1 presents the total numbers of quartzite and chert artifacts (both modified and unmodified) and the chert percentage per spit. From the table it can be seen that the percentage of chert material ranges from 47-29% with no consistent trend through time. There are significant departures from the mean proportion of 36% in spits 17* to 14* (using zI test [Langley 1970]). These departures are greater than would be expected from sampling error and show substantive changes in the deposition ratio of chert to quartzite artifacts. The departures from the mean in the middle spits is not, however, consistent with a higher than expected proportion of chert in spits 15 to 14 and a decline in chert deposition relative to quartzite in the central spits 16 and 17. As will be shown in the main analyses the departures in proportions indicate a critical transition between what will be described as major behavioural modes.

The percentage numbers of primary (ie., cores, core fragments and redirecting flakes) and secondary (flake and non-flake) modified artifacts (not including use-wear) for both materials is presented in table 4.2. The table again shows the percentage of modified for both materials to be consistently low throughout the the assemblage except for a significant rise in spit 20 (zI test). Although the overall difference in percentage modification between the two materials is low it is because of the large sample numbers highly statistically significant ($\chi^2 = 60.1$, 111
### TABLE 4.1: Total Numbers of Quartzite and Chert Artifacts

<table>
<thead>
<tr>
<th>spit</th>
<th>quartzite</th>
<th>chert</th>
<th>chert %</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>154</td>
<td>75</td>
<td>33</td>
</tr>
<tr>
<td>13</td>
<td>707</td>
<td>393</td>
<td>36</td>
</tr>
<tr>
<td>14</td>
<td>481</td>
<td>366</td>
<td>43*</td>
</tr>
<tr>
<td>15</td>
<td>884</td>
<td>782</td>
<td>47*</td>
</tr>
<tr>
<td>16</td>
<td>2446</td>
<td>1039</td>
<td>30*</td>
</tr>
<tr>
<td>17</td>
<td>2326</td>
<td>959</td>
<td>29*</td>
</tr>
<tr>
<td>18</td>
<td>1297</td>
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<tr>
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</tr>
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<td>21</td>
<td>613</td>
<td>411</td>
<td>40</td>
</tr>
<tr>
<td>22</td>
<td>305</td>
<td>207</td>
<td>40</td>
</tr>
<tr>
<td>23/4</td>
<td>78</td>
<td>58</td>
<td>43</td>
</tr>
</tbody>
</table>

### TABLE 4.2: Percentage Modified Artifacts

<table>
<thead>
<tr>
<th>spit</th>
<th>chert %</th>
<th>quartzite %</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>15</td>
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<tr>
<td>16</td>
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<td>3</td>
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<td>17</td>
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<tr>
<td>18</td>
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</tr>
<tr>
<td>19</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>16*</td>
<td>8*</td>
</tr>
<tr>
<td>21</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>22</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>23/4</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>X</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>
df=1, \( p<0.01 \)). The strength of association is, however, low (Cramer's \( V=0.05 \)) which suggest that this is of little archaeological significance.

As the ratio of modified to unmodified in an assemblage is potentially affected by differences in the disposition to discard on-site and to transport material off-site a more useful reflection of the structure of actual on-site reduction may be seen in the relation of flake to non-flake debitage which comprises the bulk of the assemblage (chert 93% and quartzite 96%). These categories are defined as any material without secondary flake removals on the margins. flakes with overhang removal or platform modification, assumed to have been modified in the process of their manufacture, are included as unmodified (in terms of secondary reduction). The unmodified category included core and flake fragments without clearly definable platform features and the general undiagnostic waste material which derives from reduction. As will be shown later the correlation between flake and non-flake debitage through time is high in both chert and quartzite with \( \tau_u \) values of .8 and .87 respectively. There is also no discernible trend in the ratio of flake to non-flake debitage in either material through time (table 4.3).

The mass of individual non-flake debitage is low throughout the assemblage with an overall mean of 4.7gms for the quartzite and 2gms for the chert. Although both are small the quartzite represents a substantial increase
of 130% in size relative to the chert. There is also a trend towards smaller non-flake debitage through time. This is also reflected in a general decline in flake size. The decrease is more marked in the quartzite in which the mean mass per spit is larger in spits 18-23/4 than in the upper half of the assemblage (spits 12-17). In the chert the tendency is less marked (table 4.4). The quartzite material shows a marked increase in the mean size of non-flake debitage in spit 20 at 17.4gms and a secondary peak in 23/4 of 11.1gms. Chert shows only a minor peak in spit 20 but also increases markedly in spit 23/4. The significance of the spit 23/4 peaks in both samples is, however, affected by small sample size.

As the flake and non-flake debitage numbers are strongly correlated and as already noted, constitute the bulk of the assemblage, their numbers through time are comparable to the density graph presented in Chapter Three (figure 3.8). Figures 4.1 and 4.2 show that the percentage numbers of flake and non-flake material for chert and quartzite rise to spit 16 with a steeper decline to levels comparable to spit 23/4 by spit 12. In comparison to the quartzite, chert numbers stay higher in spit 15 before dropping rapidly to levels comparable to that of the quartzite in spits 12-13. This rise is consistent with the increase in density found in the bulk samples at a similar depth (121-130cms) and as this can not be associated with any evidence for a decline in sediment accumulation rate it will be taken to represent a real increase in the amount of material being discarded.
### TABLE 4.3: Ratio of Flake (a) to Non-Flake Debitage (b): b/a

<table>
<thead>
<tr>
<th>spit</th>
<th>quartzite</th>
<th>chert</th>
<th>quartzite</th>
<th>chert</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>1</td>
<td>1.4</td>
<td>3.3</td>
<td>1.6</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
<td>2.1</td>
<td>1.8</td>
<td>1.1</td>
</tr>
<tr>
<td>14</td>
<td>2.1</td>
<td>1.9</td>
<td>2.3</td>
<td>1.5</td>
</tr>
<tr>
<td>15</td>
<td>1.7</td>
<td>1.9</td>
<td>2.5</td>
<td>1.3</td>
</tr>
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<td>3.0</td>
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<td>1.3</td>
<td>2.7</td>
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<td>1.4</td>
<td>3.3</td>
<td>1.6</td>
</tr>
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<td>1.2</td>
<td>4.9</td>
<td>3.1</td>
</tr>
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<td>1.7</td>
<td>3.6</td>
<td>2.5</td>
</tr>
<tr>
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<td>1.4</td>
<td>1.6</td>
<td>7.8</td>
<td>2.5</td>
</tr>
<tr>
<td>23/4</td>
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</tr>
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<td>(\bar{x})</td>
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<td>1.4</td>
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</table>

### TABLE 4.4: Mean Non-Flake and Flake Debitage Mass (gms) by Spit

<table>
<thead>
<tr>
<th>spit</th>
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<th>flake</th>
<th>chert</th>
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<tr>
<td>12</td>
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<td>3.3</td>
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</tr>
<tr>
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<td>1.6</td>
<td>1.8</td>
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</tr>
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<td>2.7</td>
<td>1.5</td>
<td>2.7</td>
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<tr>
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<td>2.0</td>
<td>3.2</td>
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### TABLE 4.5: Frequency of Core Types

<table>
<thead>
<tr>
<th>Quartzite</th>
<th>Rn*</th>
<th>Ro</th>
<th>lateral</th>
<th>bipolar</th>
<th>total</th>
</tr>
</thead>
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<tr>
<td>Quartzite</td>
<td>37</td>
<td>41</td>
<td>1</td>
<td>2</td>
<td>81</td>
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<tr>
<td></td>
<td>46%</td>
<td>51%</td>
<td>1%</td>
<td>2%</td>
<td>55%</td>
</tr>
<tr>
<td>Chert</td>
<td>44</td>
<td>15</td>
<td>5</td>
<td>2</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>67%</td>
<td>23%</td>
<td>8%</td>
<td>3%</td>
<td>45%</td>
</tr>
</tbody>
</table>
Figure 4.1: Quartzite flakes and non-flakes percentage numbers by spit.

Figure 4.2: Chert flake and non-flake percentage numbers by spit.
From this brief discussion the structure of the underlying assemblage may be summarized into four primary features:

1) The variation in the proportion of chert and quartzite material in spits 17-14.

2) The decline in mean debitage mass through time.

3) The peak of debitage discard in spit 16.

4) The peak in modified discard in spit 20 and the peak in mean mass of non-flake quartzite debitage in spit 20.

The following analysis will show how the application of a reduction oriented approach to an assemblage analysis can be used to place these features into a potentially more useful behavioural context than that provided by primarily typological approaches.

Core Analysis

One of the primary behavioural features of the underlying assemblage is that the pattern of core discard does not conform to that of the debitage seen in figures 4.1 and 4.2. The peak of modified deposition occurring further down in the deposit in spit 20 is dominated by the rise in numbers of cores in that spit and correlates with
the rise in the size of the non-flake quartzite debitage (see figures 4.14/15 and 4.27). Whether this indicates a change in the degree to which cores were reduced on-site, a change in core discard criteria or a combination of both will be examined in this section.

4.2: Core Classes and Reduction Classification

In the model presented in Chapter Two the single platform and bipolar core reduction were the central processes found in the north-western assemblages. As noted above, one of the primary weaknesses of deriving some form of core classification from reduction models is that they do not provide a practical solution to the problem of defining primary and secondary reduction separate from a specific reduction sequence. In principle all chipped stone reduction is the removal of flakes from a core and may be defined as primary, secondary or tertiary et cetera, depending on its place in a general reduction sequence. While primary reduction may be equated exclusively with what may be defined as primary core reduction, secondary can not, if a strict reduction hierarchy is followed, be necessarily equated with retouched flake categories, as the use of large flakes as sources for smaller flakes (ie., secondary reduction in the strict ordering) may be consistent feature of core working in some assemblages. Retouched flakes may in such cases be equated with tertiary or further reduction phases.
For the purposes of this analysis the strict hierarchy imposed by the reduction model will be simplified such that all artifacts which have served as sources of flakes will be divided into either primary or secondary categories regardless of their exact relation to a specific reduction sequence. The classification requires some judgement as to the ordering of modification in the assemblage but avoids the assignment of intention which is associated with typologies which mix classification criteria. For example, the problem of distinguishing cores from core scrapers (see Wright 1983:123) is derived from the use of reduction criteria to define core and end use criteria to define a tool (i.e., scraper) which may be identical in terms of reduction process.

To avoid the problem of distinguishing primary and secondary reduction, in relation to off-site reduction process which are not directly represented in the assemblage, primarily and secondarily reduced artifacts were defined in relation to a less specific reduction model. The producer artifacts derived from primary core reduction were distinguished by the distribution of negative flake scars, the presence of multiple platforms and the general absence of positive scars. The presence of the latter was in some cases discounted, allowing large flakes with sufficient other traits to be classed as cores. The resulting class of artifacts is in practice comparable to the conventional core classification (and includes artifacts which might be normally classified as
'steep-edged scrapers' or 'core tools').

Secondary modification is defined by the presence of small scalar flaking on the margins of flakes and other non-flake material. The former constitute the conventional retouched flake category while the non-flake material incorporates 'flaked pieces' and indeterminate core platform fragments. While this appears to allow for a high percentage of arbitrary assignments into one or other division, in practice the separation in the Ingaladdi assemblage is well marked between flakes which were classified as cores (i.e., primary reduction) and those defined as secondarily retouched.

The division of the Ingaladdi core assemblage into unrotated [Ro] (single platform) and rotated [Rn] (multiplatform) and bipolar cores is derived from the reduction model presented in Chapter Two. The rotated and unrotated forms dominate in both material types (table 4.5) with chert retaining the highest proportion (at 67%) of the rotated/multiplatform cores compared with 46% for the quartzite sample. The difference in the proportion of rotated and unrotated between the the two material types is significant ($\chi^2 = 9.1$, df=1, $p<.01$) and is in general accord with the greater degree of reduction indicated in the chert material although the strength of the association of rotation with chert is only moderate (Cramer's $V=.3$).
Rn* (table 4.5) represents the number of rotations to which a core has been subjected; the n subscript denoting the number of rotations, i.e., R1 for a core with one rotation and R2 a core showing two rotations, et cetera. Rotations are determined by the number of platforms - Ro retains one platform and will be generally referred to by the more familiar term single platform core, while multiplatform cores can be equated with to R1 and R2 cores which retain two and three platforms respectively. This departure from the more intuitively appealing distinction of single and multiplatform cores is a response to the ambiguity in terms of reduction processes of the term 'multiplatform' which can also be used to describe cores from bipolar reduction, although in the following analysis the term will refer to Rn cores only. The sequence Ro>R1>R2 is terminated at R2 in the analysis because of the small numbers of cores with greater than two rotations. These are included in the R2 class which should be read as R2>2. For a convenient translation into the number of platforms on the cores the reader should simply add one to the subscript.

Table 4.5 shows the number of bipolar cores in the assemblage to be small and evenly represented in both materials. The fourth category of lateral cores are seen as the product of a specialized single platform reduction procedure using small flakes as cores. The artifacts are significantly more numerous in chert and have been described in the literature as burins (see Kamminga 1982, Mulvaney 1975:235) occurring in the upper assemblage only.
Their inclusion as cores in this discussion is required by the methodology and by the arguments presented by the writer (Cundy 1977) that examples of this artifact type in Australian assemblages are inconsistent with European examples and should be initially classified as specialized cores (see section 5.8).

Due to the small numbers of bipolar and lateral cores the following analysis will concentrate on the rotated and unrotated examples.

4.3: Core Procurement and Preparation

4.3a: Lithic "Landscape"

Before discussing the on-site reduction of cores an examination of the external factors which would have governed the off-site procurement and preparation of material and how these may have structured their on-site availability is necessary.

As already noted, the underlying assemblage is dominated by quartzite (63%) and chert (36.5%) with a small proportion of basalt, quartz and exotic stone material (mainly pale silcretes). The quartzite is a distinctive dark to mid chocolate brown and derives (as described in Appendix C) from the contact induration of sand dunes by the basalt flows of the lower Cambriam Antrim Plateau Volcanics which dominate the geology of the region. The colour comes from a small proportion (1-2%)
of brown semi-opaque mineral (probably limonite) and clay surrounding the quartz in the original sandstone (Morgan et. al. 1970:128). The weathering of the quartzite has produced pebble pavements and outcrops of poor to good quality lithic material throughout the local region.

Good sources of quartzite have been located on the edges of the low sandstone and basalt ridges to the south of Ingaladdi. Three quartzite sources with evidence of use are located between 4 and 7kms from the site near the current station tracks into the waterhole (see figure 3.1). These sources, other outcrops and pavements in the general area are assumed to have served as the main source for the site. Although no sources were located in the black soil and grass plain to the east and north along Price Creek the creek bed directly adjacent to the site and upstream from Ingaladdi waterhole contained some quartzite pebbles derived from the underlying strata and upstream conglomerates and siltstones of the Jasper Gorge Sandstones to the west. These pebbles are not found in large numbers and require considerable search time. Some poor quality unworked quartzite was also located in the main sandstone ridge to the south of the site.

The chert material appears to derive from a series of sources further from the waterhole. Some comes from the Antrim Plateau Volcanics, and occur as isolated small pieces (from fist size down) in the alluvium of Aroona Creek some 12kms south of Ingaladdi. This material is generally red and highly indurated with a splintered
fracture unsuitable for percussion flaking and has not been identified in its extreme form in the assemblage. More substantial outcrops of this material occurring further south along a tributary of Gregory Creek near Pierce's Spring (approximately 25kms SSW of Willeroo HS) show little evidence of their use. A second form of chalcedony derived from the volcanics occurs as small nodules of banded agate in the black soil alluvium. This material has a good conchoidal fracture but is rare and of consistently small size.

The majority of the chert material in the assemblage appears to derive from the various sources to the east of the volcanics in later geological strata. Of these, the closest is a series of sources in the Tindal Limestone formation to the east along Mathison Creek which runs north-south along the western edge of the Stuart Plateau approximately 30-40kms north-east of Ingaladdi (see figure 3.1). The chert from the limestones varies from solid to banded forms in red, yellow and grey. It retains a good conchoidal fracture and is most easily obtained as pebbles from the creek bed.

Chert also occurs in the alluvium along the creeks of the Stuart Plateau to the south of Mathison Creek. Hughes (1983) identified a series of sources in the region approximately 65kms south-west of Ingaladdi. The alluvium derived from the underlying rock which appears to be principally of the Mullaman siltstone and Tindal formations. The cherts are part of a surface pavements of pebbles from 2-20cms in diameter (Stewart 1970:99). The
sites recorded by Hughes (1983) and those examined by the writer are are not extensive and appear to reflect only occasional utilization of the Plateau during the wet season (due to the poor surface availability of water throughout most of the year).

The second set of chert bearing strata occur further south in the Montejinni Limestones which run along the western edge of the Stuart Plateau approximately 100kms south of the site beyond Kilarney Station and Top Springs. Extensive sources in the Antrim Plateau Volcanics have been noted around the lower reaches of Coolibah Creek where it flows into the Armstrong River near Top Springs (Sweet 1972). Further chert bearing deposits have also been identified on the western side of the Victoria River. The suitability of these southern sources for flaking has, however, not been established.

The small amounts of other stone material making up just over .4% of the underlying assemblage are composed of locally available basalt from the Antrim Plateau Volcanics (.2%), quartz (.12%) and exotic silcretes (.11%), the origins of which are unknown. Comparable pale grey silcretes collected by the writer on Camfield Station over 200kms to the south showed some similarity to the stone material quarried near Newcastle Waters and Renner Springs (Eylmann 1908) a further 350kms to the south-east. Paton (pers. com.) has recorded the use of an important trade route across the Stuart Plateau between Newcastle Waters and the Victoria River communities. Similar quartzites
are also found in the Katherine region approximately 150kms to the north-east of the site (Edwards, R. 1967, Baker and Hughes 1983, Cundy 1987).

The distribution of chert and quartzite about Ingaladdi represents a clearly defined geographical picture. As the chert is well outside local foraging range (which in tropical Australia may be only a few kilometres beyond water) it can not be seen as a locally replaceable material. Quartzite sources within 2-7kms of the site may be considered to be the only locally available stone and appear to have constituted the bulk of the material discarded on-site. Even with the changes in hydrological regime suggested in section 3.7 it is assumed that the major chert outcrops were never easily accessible form Ingaladdi and that this limitation has been fixed throughout the occupation of the site. The following analyses will show, however, that the organization and structure of quartzite reduction on the site appears to become less localized and more like that of the chert in the later phases of the underlying assemblage.

4.3b: Core Preparation

The presence of both chert and quartzite cores in the underlying assemblage implies some transport (both indirect and direct) of these artifacts to the site from the lithic sources noted above. The form of the major lithic materials in the region allows a range of possible procurement and preparation procedures, including the
careful selection of suitable pebbles for immediate transport and later on-site reduction, to the systematic on-source reduction and transportation of pre-prepared cores.

Some indication of procurement procedures and core preparation in the assemblage can be gained by examining the blank types on which cores were formed. Because of the considerable reduction of the cores in both the quartzite and chert the number which retain enough of their initial structure for their original blank form to be identified is low. For instance, only 4 (5%) of the quartzite cores and none of the chert retained sufficient cortex to be attributed, with confidence, to pebble blanks. The proportion attributable to flakes is higher at 25 (31%) for the quartzite cores and 5 (8%) for the chert. These were identified on the basis of the presence of both intact striking platforms and positive ventral face features. Cores without extensive pebble cortex and flake features were classified as indeterminate blank forms.

In quartzite there was no significant change in the proportion of flake to indeterminate blank forms between the upper and lower halves of the assemblage (\(\chi^2 = 0.46, \text{df}=1, p=0.5\)) and with mean masses of 76.5 and 75.8gms respectively there is also no significant size difference between the two blank forms (MW-U \(z=-0.43, p=0.33\)). The chert sample of five artifacts was too small for any such conclusions to be drawn.
Both flake and indeterminate quartzite blanks retained high proportions of cortex. Of the 14 single platform cores (Ro) made on flakes 11 (79%) retained cortex while it was present on only 5 (45%) of the 11 multiplatform cores (Rn) on flakes. The difference is attributable to a significant difference ($\chi^2 = 6.95, \text{df}=1, \ p<.01$) in the proportion of all the multiplatform cores retaining cortex relative to the single platform and a marginally significant decline in the amount of cortex on the cores through time ($\chi^2 = 3.9, \text{df}=1, .05>p>.01$).

The proportion of single platform flake blank cores retaining cortex (83%) is substantially higher than that found generally in the flakes in the assemblage. In quartzite the primary and secondary decortication flakes average 14.3% of the total flake numbers per spit with no discernible trend through time (see section 4:6b). This is also the case for the indeterminate blank forms which at 74% and 46% for single and multiple platform cores respectively show no significant difference in cortex proportion to those found in the flake blanks ($\chi^2 = .122, \text{df}=1, p>.95$).

In the chert sample only multiplatform cores retained evidence of flake blanks, however, the absence of the form in the single platform cores is not statistically significant (required sample size of 30 before 0 is significant). Both 40% of the indeterminate and flake blank multiplatform chert cores retained cortex. This is comparable to the percentages in the quartzite core sample, but substantially greater than the number of
chert primary and secondary decortication flakes in the assemblage, which range from 7-12% of the total chert flakes per spit.

As the proportion of cortex retention in all core blank types is high relative to the flake population on-site it can be concluded that the majority of the quartzite and chert flake blanks derived from primary and secondary decortication flakes and were reduced without any systematic decortication procedure.

To test for a size difference between the core flake blanks and the flakes constituting the bulk of the assemblage the dimensions of the blanks' residual striking platforms and overall thickness were compared with those from a random sample of flakes taken from squares A and B9 (see section 4.6). Of the 25 quartzite cores on flake blanks intact striking platforms were present on 14 examples while only 2 chert cores retained completely intact platform features. Blank thickness was taken as the best measure of the primary flake dimension because flaking of the core had generally used the ventral surface as the principal striking platform reducing length and width.

The comparison between the flake blank dimensions and those of the flake sample for the quartzite are given in table 4.6. The table shows there to be substantial differences in the size values of the core and flake samples (MW-U test results of z=10.8 for thickness, 5.92 for platform width and 6.1 for platform thickness, all of
<table>
<thead>
<tr>
<th>Table 4.6: Quartzite Flake and Flake Blank Dimensions (mm)</th>
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</thead>
<tbody>
<tr>
<td><strong>Platform width (Pw)</strong></td>
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<tr>
<td>cores</td>
</tr>
<tr>
<td>flakes</td>
</tr>
<tr>
<td><strong>Platform thickness</strong></td>
</tr>
<tr>
<td>cores</td>
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<tr>
<td>flakes</td>
</tr>
<tr>
<td><strong>Platform angle</strong></td>
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</tr>
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<tr>
<td><strong>Thickness</strong></td>
</tr>
<tr>
<td>cores</td>
</tr>
<tr>
<td>flakes</td>
</tr>
</tbody>
</table>
which are significant at p<.00003). These data confirm that the core blanks were drawn from a population of substantially larger flakes than those represented on-site. The core blanks also exhibit higher platform angles and in all four variables retain absolutely less variability.

Of the quartzite flake blank sample only 2 (14%) examples retained cortical platforms of the remainder 11 (78.6%) had plain and 1 (7.1%) combined platform flaking and cortex. This variation in platform type shows there to have been a variety of approaches to the initial platform preparation on the rocks from which the blanks were derived. This may be expected given the irregular sub-rounded to angular forms in which the quartzite occurs in the landscape. Plain platforms are, however, predominant, suggesting the systematic removal of unsuitable cortical surfaces from the primary core before producing the large flakes which served as core blanks. The high percentage of cortex retention on the single platform quartzite cores (78%) also suggests that systematic quarrying of unweathered material from the outcrops of vain quartzite in the region was not a significant feature of quartzite procurement in the underlying assemblage.

In the case of the quartzite some indication of the differences between the process producing core blanks and that of the larger flake sample can be gained by examining the relationships between platform variables and flake
thickness. It has already been seen that the original platform angles on the core blanks are on average 20° larger than those of the flake sample. The comparison of platform thickness and flake thickness ratio (t/Pt) also shows the core blanks to be substantially thicker in relation to platform thickness (t/Pt: $\bar{x}=1.9$, $Cv=29\%$) and less variable than the flake sample in which the thickness/platform thickness ratio is closer to unity (t/Pt: $\bar{x}=1.2$, $Cv=40\%$). The shape of the striking platform also tends to be squarer in the core blanks (Pt/Pw: $\bar{x}=.51$, $Cv=25\%$) compared to the flakes ($\bar{x}=.4$, $Cv=48\%$). The blanks also exhibit a different set of best platform predictor variables for flake thickness. Because of their structural similarity it would be expected that there should be a strong correlation between platform thickness and flake thickness in the core blanks as is the case in the flake sample ($r=.72$, $p<.01$). This, however, is not the case with the blank sample which shows no significant correlation between the two variables ($r=.03$, $p>.2$).

The breakdown in the expected correlation of platform thickness and flake thickness in the core blanks may reflect their relative uniformity of size and is also in accord with Dibble and Whittaker's (1981:295) experimental finding that increases of platform angle caused the relationship between platform thickness and flake thickness to become less predictable, although the production of larger flakes still resulted. Dibble and Whittaker (1981:295) also found that as platform angle increased the values of the platform thickness which would
produce a flake become more restricted, which may account for the substantial amount of overhang removal present on some of the core blanks and the high t/Pt ratio. These data are consistent with attempts to maximize the size of flake produced from a given core. This is also supported by a marginally significant negative correlation in the blank sample between the platform thickness and platform angle ($r=-.51 \quad 0.05>p>0.01$) which, as will be discussed in detail in section 4.7b, is also consistent with the presence of high input forces and relatively low core mass.

Although the cores on pebble blanks tend to be larger than those on the flake blanks with a mean mass of 157gms compared with 77.7gms this is not statistically significant ($MW-U U=12 \quad p>0.05$). The pebbles selected for direct reduction do, however, appear to be more variable in size (ranging from 70-370gms) compared to the flake blank's range of 22-190gms. Due to the reduction of the cores the relation of these masses to those of the initial selection criteria is, however, problematic. Examination of the manuported material in the deposit shows that masses of up to 5-600gms were carried onto the site in the form of poor quality quartzite pebbles which is comparable to the mass of the largest core of 633gms. This core retains substantial pebble cortex, and although not classed as a definite pebble blank, may stand at the upper limit of the pebble size considered suitable for transportation.
Of the pebble based cores, 3 (75%) retained cortical platforms from which flakes had been removed. This is substantially higher than the 12.4% recorded for the total core sample. A binomial test shows that the probability of obtaining this difference by chance is 0.0067 suggesting a significant retention of cortical platforms on the pebble blanks in the initial stages of reduction. This is consistent with the selection of pebbles with surfaces suitable for use as striking platforms without further modification.

In summary, although the number of the quartzite cores attributable to an original blank form is low, the evidence of these cores is that pebbles or surface material, in a range of sizes, were used as sources for the cores in the assemblage and that the type of reduction procedure used in the preparation of these was principally determined by the size of the piece selected. If large and without suitable platform surfaces, cortex was removed to prepare a plain platform which was then used for the striking of a large flake suitable for use as a core. In some cases considerable overhang removal was carried out to raise the platform angle and produce the reduced platform thickness necessary for the production of flakes of the required size. The resulting flake may have been minimally trimmed to reduce transported mass but there appears to have been no systematic decortication of the core blank. Pebbles <600gms with already suitable striking platforms also appear to have been simply selected and transported with little further modification.
4.4: Core Discard and the limits of Reduction

4.4a: Threshold conditions controlling reduction

The following analysis will examine the threshold conditions which limit reduction and test for their effect on the core sample. The factors will be examined in two parts: those which restrict individual platform use and those which limit overall core reduction.

As the variables controlling flake formation have been extensively discussed in the literature (see Cotterell and Kamminga 1979, 1987; Cotterell, Kamminga and Dickson 1985, Dibble 1981, Dibble and Whittaker 1981, Faulkner 1972, Hiscock 1979, Lawn and Marshall 1979, Phagan 1976, Speth 1972, 1974, Tsirk 1979) it is not necessary to precede the analysis with an extensive review of the variables and their interaction. In summary, Phagan (1976:9-10) has grouped these factors into three categories: core variables (material, platform surface, point of force application [PFA] and core geometry), force variables (angle, amount and duration) and interaction variables (relative masses and hardness). Of these, three have been seen as primary determinants of flake form: core geometry (Bucy 1974:6, Cotterell and Kamminga 1987:698, Faulkner 1972:127, Hiscock 1979:51), PFA location (Cotterell and Kamminga 1987:698, Dibble 1981, Dibble and

Of critical importance to flake production is the dynamic interaction of these variables with the mass of the core. Where the core mass (as a measure of the reactive inertia force) is low relative to the applied force, a proportion of the force will be converted into the kinetic energy of core motion, reducing the amount of energy available for the formation of flakes. At its simplest, the effect of the decreased energy available on fracture is either the rapid termination of the process resulting in step or hinge fractures (Cotterell and Kamminga 1987:700-701, Phagan 1976:25) or the failure to initiate fracture altogether. As will be seen in the discussion of the internal relations of flake formation (section 4.7) the knapper's response to these conditions is complex, but for the purposes of this discussion, these limitations will be sufficient.

The amount of force required for flaking is directly proportional to the PFA location and the geometry of the core. The further from the free face of the core (ie., the greater the Pt) and the higher the platform angle (Pa) the greater the energy required for fracture (Cotterell and Kamminga 1987:700-701, Dibble and Whittaker 1981:295). The point at which these variables reach values requiring greater energy input than the reduced core mass and increased force application can deliver (because an
increased proportion of the available force is being converted into core motion) has been termed the "inertia threshold" by Hiscock (1979:fig.2:4).

A general model of the threshold has been described by Hiscock (1979:54) as a hyperbolic curve when inertia is plotted against some measure of the required force (eg., platform angle) and the direction of increase is toward the origin when plotted on the x axis. The function is more accurately drawn as a power expression, as increased platform angles require a greater core mass if the problem of low core inertia is to be avoided. The function's form is governed by the requirement that the measure of required force be dimensionally equivalent to the fracture energy of flake formation which is a square function of flake dimension (ie., $E=ML^2T^{-2}$). The model is, however, only partially correct in its correlation with the mechanics of flakes formation. Under its conditions it is theoretically possible to remove flakes from platform angles greater than $90^\circ$ and in theory from surfaces greater than $180^\circ$. The model assumes that the mechanics of fracture would be unaffected by such changes which in practice is not the case.

The principle control mechanism of conchoidal and bending fracture is flake stiffness (Cotterell, Kamminga and Dickson 1985:220, Cotterell and Kamminga 1987:698), which is possible near the edge of cores where the applied force has an outward component supplying tensile stress sufficient to initiate crack formation (Cotterell and Kamminga 1987:685-687, Lawn and Marshal 1979:71).
Although Cotterell and Kamminga (1987:692) point out that platform angles >45° are important in controlling initiation, the upper boundary of this angle is not discussed (see also Lawn and Marshal 1979:71). In an earlier discussion of conchoidal fracture (Cotterell, Kamminga and Dickson 1985) the maximum platform angle assumed by their beam theory model is 90°. Extending this model it may be seen that as platform angle increases above 90° the flaking process becomes rapidly over stabilized by flake stiffness to the point where energy requirements exceed the physical capacities of the knapper to impart to the core. Angles greater than 90° create threshold conditions which affect all cores regardless of mass. This is in general accord with the conditions noted in accounts derived from the literature of experimental knapping (see Bordaz 1971:24).

Although high platform angles and core inertia can be seen as separate threshold conditions, both interact during reduction to restrict the process. Unless they are braced, all cores will experience some movement while being struck as some of the available energy is lost in core motion. This loss becomes more critical as core mass is reduced relative to any increase in the force which is required to remove a flake, i.e., as platform angles approach 90° or due to poor core face geometry. As cores become smaller the inertia threshold conditions also intervene to reduce the critical platform angle to sub-90° values in the manner described by Hiscock's model. Although the point at which the critical conditions of
his model become significant have yet to be clarified. Hiscock's (1979:145) investigation suggests that masses of less than 10^-6gms will be affected at increasingly lower platform angles depending on material type.

As Hiscock (1979:54) points out, the form of the inertia threshold may not be a sharp boundary because the conditions governing the interaction of the core and the applied force may not be constant within a general reduction sequence. The form of the threshold will also depend on the independent variable used to measure force requirement. The problem may also be encountered at any stage of core reduction with an increasing likelihood of its conditions ending the process as reduction continues. Hiscock (1979:51) has suggested that platform rejuvenation, rotation, reduction in flake size, bracing the core and bipolar reduction may be solutions to the problem of low core inertia.

As flaking is a reduction process, which by the nature of the flakes produced tends to reduce the core platform at a greater rate than the body of the core (Kamminga 1982:89), the threshold conditions represented by high platform angles and low core mass are inherently more characteristic of the process than the comparatively unstable conditions generally associated with optimal flake production.

Before proceeding to the next section some explanation of the concept of unstable and stable core geometry is necessary. Flake removal via hand held
percussion can occur only within a limited range of core states which are not inherently stable given the shape of flakes removed and the knapper's control of variables like material and input force consistency. As reduction extends the core geometry approaches more natural states of stability which are associated with high platform angles, restricted platform arcs, the increased concentration of core mass to produce stable geometric forms and the onset of low inertia threshold conditions. The unstable conditions favourable to extended reduction do not derive naturally from the process but have to be maintained in the face of the approaching overstabilization which limits reduction.

4.4b: Platform Threshold Conditions

To test for the presence of threshold conditions in the discarded cores in the underlying assemblage the cores were ordered in terms of the number of rotations and their platform angles compared (table 4.7). The table shows that the platform angle threshold (90°) is reached in the R2 cores and is well within one standard deviation of the means of all six samples. Although the effect of over stabilized platform angles appears as a general threshold condition among cores in all samples a high proportion of platforms retain angles of sub-threshold values (table 4.8).
### TABLE 4.7: Mean Platform Angle (°) on Quartzite and Chert Cores

<table>
<thead>
<tr>
<th>Quartzite</th>
<th>X</th>
<th>Sx</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2</td>
<td>94</td>
<td>13.4</td>
<td>21</td>
</tr>
<tr>
<td>R1</td>
<td>86</td>
<td>12.6</td>
<td>64</td>
</tr>
<tr>
<td>Ro</td>
<td>82</td>
<td>10.8</td>
<td>41</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chert</th>
<th>X</th>
<th>Sx</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2</td>
<td>90</td>
<td>15.4</td>
<td>27</td>
</tr>
<tr>
<td>R1</td>
<td>88</td>
<td>12.5</td>
<td>68</td>
</tr>
<tr>
<td>Ro</td>
<td>81</td>
<td>16.4</td>
<td>16</td>
</tr>
</tbody>
</table>

### TABLE 4.8: Percentage of Core Platform Angles <90°

<table>
<thead>
<tr>
<th></th>
<th>Chert</th>
<th>Quartzite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ro</td>
<td>69%</td>
<td>76%</td>
</tr>
<tr>
<td>R1</td>
<td>47%</td>
<td>63%</td>
</tr>
<tr>
<td>R2</td>
<td>52%</td>
<td>38%</td>
</tr>
</tbody>
</table>

### TABLE 4.9: Percentage of Step and Hinge Terminations

<table>
<thead>
<tr>
<th></th>
<th>Chert</th>
<th>Quartzite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ro</td>
<td>69%</td>
<td>71%</td>
</tr>
<tr>
<td>R1</td>
<td>73%</td>
<td>72%</td>
</tr>
<tr>
<td>R2</td>
<td>70%</td>
<td>71%</td>
</tr>
</tbody>
</table>

### TABLE 4.10: Mean Flake Scar/Free Face Length Ratio

<table>
<thead>
<tr>
<th>platform no.</th>
<th>quartzite</th>
<th>chert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ro</td>
<td>1</td>
<td>.65</td>
</tr>
<tr>
<td>R1</td>
<td>2</td>
<td>.46</td>
</tr>
<tr>
<td>R2</td>
<td>2</td>
<td>.49</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>chert</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.61</td>
</tr>
<tr>
<td>2</td>
<td>.49</td>
</tr>
<tr>
<td>3</td>
<td>.49</td>
</tr>
</tbody>
</table>
To test for the possibility that poor core face geometry had contributed to the discard of these cores the length and termination type of the major flake scars were examined. The ratio of the scar length to the core free face length was used as an index of the success of force input and the type of termination as a guide to the force requirement for subsequent successful removals. The presence of step or hinge termination on core faces requires the input of higher flaking forces because these terminations rapidly increase the stiffness of the forming flake reducing the available energy and invariably resulting in the formation of further step and hinge fractures (Cotterell and Kamminga 1987:700).

Table 4.9 shows from 69-73% of the terminations in the sub-threshold samples were of the hinge or step variety. The percentages are remarkably uniform showing no statistically significant difference in the frequency of occurrence between the two material types.

The mean flake scar/free face length ratio (table 4.10) also shows that the majority of flakes terminated at lengths substantially less than that of the available free face. Both the low scar/free face length ratio and the high occurrence of step and hinge terminations point to substantial platform and free face geometry problems in the discard cores. To test whether these conditions were distributed evenly throughout the quartzite and chert core samples the number of viable platforms was determined by firstly comparing the number of platforms with Pa<90° and feather terminations for the three core categories.
Table 4.11 shows the number of viable platforms does not exceed 32% in any of the samples and is particularly low in the case of the R2 quartzite cores. Despite the 16% range of values between the chert core samples the differences between the proportion of viable to non-viable platforms are not significant ($\chi^2 = 1.8, df=2, p>.3$) indicating no substantial link between the degree of rotation and the point at which the cores were discarded. The quartzite sample on the other hand shows a significant decline in the number of viable platforms in the R2 sample relative to the combined Ro and R1 percentages (Fisher's exact probability = .009).

Comparable relationships are also demonstrated if the definition of viability is extended to include the scar/free face ratio. Although the ratio is a less direct indicator of unsuitable core face geometry its inclusion can be used to indicate the presence of persistent difficulties in achieving sufficient force inputs to the core. The limit of scar/free face viability in the analysis has been placed at .5 (although in practice terminations of >.5 can end reduction if the step or hinge termination is large). Including this second definition of viability a marginally significant ($\chi^2=6.6, df=2, p=.04$) difference appears between the Ro and the R1 and R2 chert samples. The decline in viable platforms in the R2 quartzite sample is also still present but, as might be expected given the reduced Ro and R1 values, is of marginal significance (Ro/1 by R2: Fisher's exact probability
These data show that a combination of high platform angles, poor free face geometry and their resulting force input difficulties appear to be strongly associated with the majority of core platforms in both the chert and quartzite samples and probably account for the majority of platform abandonments (i.e., only 36% of the quartzite R1 cores, 11% of R2 and 7% of the chert R2 and R1 samples retained one or more viable platforms). Of these three factors, high platform angles remain the most critical condition. As platform angles approach 90° the relationship between the exterior platform angle (Pa) and the ventral or interior platform angle becomes increasingly divergent resulting in higher probabilities of hinge and step termination (see Dibble 1981:63-65, Dibble and Whittaker 1981:287-288). The presence of scars from previous poor terminations or where flakes have failed to run the face of the core also alter the core geometry to the point where the energy required to take off the thicker flake beyond the scar is greater than that available and the flake rapidly terminates (Cotterell and Kamminga 1986:452). Both the low scar/free face ratio and the high incidence of premature flake termination can be related to poor force input which derives again from the inertia threshold conditions experiences by all cores approaching critical platform angles.

Although the samples of cores in the upper half of the assemblage is small there appears to be no significant change in the proportion of viable to non-viable platforms.
| TABLE 4.11: Percentage Viable Platforms  
(Pa<90°/feather terminations) |
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Ro</td>
</tr>
<tr>
<td>R1</td>
</tr>
<tr>
<td>R2</td>
</tr>
</tbody>
</table>

| TABLE 4.12: Percentage Viable Platforms -2  
(including scar ratio >.5) |
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Ro</td>
</tr>
<tr>
<td>R1</td>
</tr>
<tr>
<td>R2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 4.13: Mean Core Mass (gms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Quartzite</td>
</tr>
<tr>
<td>Ro</td>
</tr>
<tr>
<td>R1</td>
</tr>
<tr>
<td>R2</td>
</tr>
<tr>
<td>Chert</td>
</tr>
<tr>
<td>Ro</td>
</tr>
<tr>
<td>R1</td>
</tr>
<tr>
<td>R2</td>
</tr>
</tbody>
</table>
Figure 4.3: Quartzite cores from the underlying Ingaladdi assemblage.
in any of the core samples through time (table 4.12).

The analysis has to this point established that threshold conditions are associated with the abandonment of the majority of platforms in the core samples. However, the relationship of platform abandonment to that of the core abandonment requires some further discussion. A selection of typical quartzite cores is illustrated in figure 4.3.

4.4c: Core Threshold Conditions

Table 4.13 shows that the quartzite cores which experience the highest number of rotations (R2) have higher mean masses than those with one or none. The difference between the R2 and R1 quartzite core means is highly significant (MW-U z=-2.64 p=.004) and indicates that the R2 core sample is drawn from a population with higher mass values than that of the R1. The Ro are also not heavier than the R1 (MW-U z=1.64 p=.051). The chert R2 sample has been strongly affected by the presence of a single large core and when this is removed shows no significant difference to the chert R1 and Ro samples (see table 4.18).

Figure 4.4 plots the means and their 95% confidence limits of all six core samples against the hypothetical threshold conditions imposed by inertia and platform
Figure 4.4: Inertia threshold conditions - plots of mean platform angle and mass - 95% confidence limits of the means.
angle. The figure shows the chert samples to be tightly clustered against the lower corner of the curve at the point where Hiscock's threshold model delimits unsupported hard hammer reduction. The operation of this threshold is powerful enough to terminate reduction once the critical conditions of mass and platform angle are reached, regardless of the number of rotations applied to the core. Hiscock (1979:145) shows bipolar reduction to be necessary beyond the threshold. Graphs of the mass distribution of the chert samples show similar restricted (leptokertic) unimodal curves with mean and mode values in the 0-20gm range (figure 4.5).

The majority of the quartzite cores, on the other hand, have been discarded with masses more than three times heavier than the chert. A second aspect to this is the possibility that the quartzite Ro and R1 samples do not represent a homogeneous population. Figures 4.6 and 4.7 show the mass distribution of quartzite Ro and R1 cores to be bimodal with strong positive skews (sk = .73 and .61 respectively). The modes differ between the samples with the more pronounced R1 peaks at 0-20 and 40-60gms grouped to the left of those in the Ro distribution which shows a less marked modality but retains a high number of extreme cases.

Although the statistical significance of these bimodalities is difficult to assess they indicate the possibility of heterogeneous populations making up the Ro and R1 quartzite samples. The modalities may reflect a change in the discard behaviour through time or the
Figure 4.5: Distributions of Chert core masses.
Figure 4.6: Distribution of Quartzite Ro core mass.

Figure 4.7: Distribution of Quartzite R1 core mass.
presence of persistent variation in discard criteria. (To test for the former possibility the distributions of the Ro and R1 cores in the lower and upper halves of the assemblage are compared in section 4.5). The R2 quartzite distribution also shows modalities at 100 and 180gms and one example situated in the 0-20gms class, however, the small number of artifacts in the R2 sample reduces the meaning of these peaks.

While the quartzite cores in the smaller modal groups, which will be termed Mode I, approach the same inertia threshold conditions as the chert cores the majority of the second mode (Mode II) cores in both Ro and R1 samples retain masses well above this threshold. Figure 4.8 illustrates a selection of Mode I quartzite and comparable chert cores. Those in figure 4.3 are classed as Mode II.

Rotation of cores, as noted above, has been seen as a response to threshold conditions where core geometry does not allow further reduction of an overstabilized platform. In the case of the chert cores the limits of this response has been reached. While the quartzite cores retain comparably high proportions of non-viable platforms the absolute limitations on reduction have not been approached in the larger Mode II cases.

Although the establishment of new platforms via rotation may be seen a solution to threshold conditions the formation of new platforms alters core geometry and thus becomes a self limiting procedure. This may be seen
Figure 4.8: Chert and Mode I Quartzite cores from the underlying assemblage - Ingaladdi - Chert: a, b and f; Quartzite: c, d and e.
in its restriction of the usable platform once it is established, and the restriction of the number of potentially usable platforms generally.

The amount of usable platform in rotated (R1/2) and unrotated (Ro) cores can be compared by analysis of the platform arc utilized. Platform arc, the amount of platform edge which has been used for reduction, was measured by dividing the platform into four quadrants of 90° each and recording the number of quadrants which had been used for flake removal. Quadrants were orientated such that the maximum amount of edge was located in any one quadrant, with the origin positioned as near as possible to the platform's centre. Table 4.14 shows the number of platforms in each quadrant for rotated and single platform quartzite cores. The predominance of platform restriction to a single quadrant in the rotated cores and the progressive decline in the number of platforms in the higher quadrant numbers is significantly different from the single platform proportions (\( \chi^2 = 13.8, df=2, p<.01 \)) and retains a moderate degree of association (Cramer's \( V = .33 \)). A similar restriction of platform is also present in the rotated chert core samples (table 4.15).

The progressive restriction of platform arc is a product of the fundamental changes in core morphology produced by rotation. As cores are reduced their mass becomes increasingly concentrated about an axis parallel to the direction of flaking. With repeated rotation the
### TABLE 4.14: Restriction of Platform Arc on Quartzite Cores

<table>
<thead>
<tr>
<th>Quadrant Number</th>
<th>Ro</th>
<th>Rn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21(51%)</td>
<td>58(70%)</td>
</tr>
<tr>
<td>2</td>
<td>6(15%)</td>
<td>17(20%)</td>
</tr>
<tr>
<td>3/4</td>
<td>14(34%)</td>
<td>8(10%)</td>
</tr>
</tbody>
</table>

### TABLE 4.15: Restriction of Platform Arc on Chert Cores

<table>
<thead>
<tr>
<th>Quadrant Number</th>
<th>Ro</th>
<th>Rn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9(56%)</td>
<td>69(72%)</td>
</tr>
<tr>
<td>2</td>
<td>2(12%)</td>
<td>21(22%)</td>
</tr>
<tr>
<td>3/4</td>
<td>5(13%)</td>
<td>6(6%)</td>
</tr>
</tbody>
</table>

### TABLE 4.16: Shape Index (\(\sin [Pa] F_1/m^{1/3}\))

<table>
<thead>
<tr>
<th></th>
<th>(\bar{X})</th>
<th>(S_x)</th>
<th>(C_v)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quartzite</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ro</td>
<td>8.5</td>
<td>2.2</td>
<td>25.9%</td>
</tr>
<tr>
<td>R1</td>
<td>9.8</td>
<td>1.7</td>
<td>17.3%</td>
</tr>
<tr>
<td>R2</td>
<td>8.8</td>
<td>1.4</td>
<td>15.9%</td>
</tr>
<tr>
<td><strong>Chert</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ro</td>
<td>9.9</td>
<td>3.4</td>
<td>34.3%</td>
</tr>
<tr>
<td>R1</td>
<td>10.1</td>
<td>2.1</td>
<td>20.8%</td>
</tr>
<tr>
<td>R2</td>
<td>9.5</td>
<td>1.7</td>
<td>17.9%</td>
</tr>
</tbody>
</table>

cube = 7.0, sphere = 9.0
intersection of these axes will have the effect of further concentrating mass - producing an increasingly stable and intractable shape. As the core geometry becomes more stable the availability of potentially usable platforms decreases and the establishment of new ones requires the application of sufficient force (mainly compressive) to cleave the core into new less stable sections. As this operation requires large force inputs and high core inertia (which may be beyond the knapper's immediate ability to provide), cores with overstabilized geometry may be abandoned before they reach the limit of productive hand held reduction seen in the chert and Mode I quartzite cores.

To test whether the quartzite cores had reached over stabilized states a general shape index was devised by multiplying and longest face length by the sine of the platform angle and dividing by the cube root of mass. Although the resulting index is extremely sensitive to changes in proportions in objects of similar morphology it is less effective when comparing those of differing forms like the core samples and can not, in this case, be used as an indication of a specific shape. It can, however, be used as a measure of the general concentration of mass in the cores and tendency to over stabilized shapes in a given core sample.

From the table (table 4.16) it can be seen that the shapes are distributed about mean values close to those of cubes and spheres of the same mean length and diameter. Values below 7.0 indicate an elongation along an axis
other than that measured and values greater than 9.0 indicate a tendency to elongation along the measured axis. Although the majority of cases showed a trend to elongation along the measured axis, especially in the chert sample, there appears to be no statistical difference between the quartzite and the chert samples in this regard (MW-U Ro: $z=-1.44$, $p=.075$; R1/2: $z=1.42$, $p=.078$).

The coefficients of variation (Cv) show the relative sample variation becoming smaller as the number of rotations increases. Figures 4.9 and 4.10 show the distribution of the shape index for Ro and R1/2 cores respectively. The chert and quartzite samples are combined because of their similar distributions. The Ro distribution is bimodal about the zone of maximum expected mass concentration with cores approaching the zone from both dimensions of elongation. The R1/2 sample, on the other hand, is more strongly distributed within the zone with a slight positive skew. The majority of rotated cores, therefore, retain or approach a geometry with potential for over stability and the subsequent limitation of reduction.

Dividing the quartzite Ro and R1 samples into the Mode I and II populations suggested above by the imposition of an arbitrary division at <40 and <30gms respectively, the shape distributions show no marked differences between the Mode I and II in the Ro and R1 samples. The shape similarity of the Mode I R1 cores to
Figure 4.9: Distribution of shape index \((\sin[F_1]Pa/m^{1/3})\) for all Ro cores.

Figure 4.10: Distribution of shape index \((\sin[F_1]Pa/m^{1/3})\) for all Rn cores.
that of the larger Mode II R1 and that of the Mode I Ro to
the Mode II Ro cores suggests some parallelism of process
between the modes of each of the two rotational groups
(ie., [Ro->R1]-Mode I, [Ro->R1]-Mode II).

While shape overstability is strongly associated
with, and may account for, the high discard mass of the
Mode II rotated (Rn) quartzite cores the Mode II unrotated
(Ro) only approach these conditions. Although threshold
conditions can be associated with the discard of all chert
cores and of the quartzite Mode I and rotated Mode II they
do not explain the presence of unrotated quartzite cores
(in Mode II) which, although retaining high proportions of
over stabilized platforms, retain high masses and unstable
shapes. The possibility that these cores reflect a
structural difference in the disposition to reduce cores
will be examined in the following section.

4.5: Reduction Disposition and Behavioural Modes

4.5a: Blank size and Models of Reduction Trajectory

Using the most fundamental reduction model it could
be expected that cores exhibiting high rotations [Rn]
should be on average smaller than those with fewer
rotations. Analysis has already shown this not to be the
case, with the R2 quartzite cores retaining a
significantly higher mean mass than the Ro and R1 samples
A comparison of all rotated cores (R1/2) with the unrotated (Ro) also shows there to be no significant difference in the mass of both populations which is again not consistent with the model (MW-U z=.6 p=.25).

While the statistical evidence shows the mass distributions of rotated and unrotated cores to be generally comparable as discarded cores, this does not provide any insight into the original populations from which the samples derived. It appears that the rotated and unrotated cores can not derive from a single population and retain comparable reduction trajectories. Either the blank populations are different or the trajectories are dissimilar, possibly a combination of both.

It is argued that this anomaly as well as the meaning of the Mode I material can be seen as reflecting the presence of persistent yet substantially different behavioural modes, related principally to variation in the disposition to reduce cores. This variable disposition may be manifest not only in the degree of reduction but also in the reduction trajectory and choice of material. It is argued that Ro cores represent a low disposition to reduce the core, which will be evident in relatively low concern for the control of core geometry and little concern with utilizing cores beyond the initial onset of platform overstabilization. This is consistent with the Ro sample, which despite retaining a high percentage of
overstabilized platforms, also retain potentially reducible shapes.

The disposition to extended core reduction is manifest in core rotation where core overstability occurs as successive overstabilized platforms are abandoned and new ones initiated. Figure 4.11 illustrates the various behavioural correlates which can be associated with the dispositions as they have been described. First, there is the conventional reduction model which derives all cores from a single population with a single reduction trajectory. As already noted this results in a hierarchical set of expected mass relationships (i.e., Ro>R1>R2) which the data do not support. The second shows the expected relationship between the cores given the operation of two distinct reduction trajectories and the third the relation expected from the presence of two separate blank populations. Axiomatically, two and three produce a separation in the unrotated and rotated cores, the size of which is dependent on the difference between the trajectories and the original blank population. Again, this does not clearly fit these data which exhibit no clear distributional separation - the Ro cores occupy a central position between R2 and R1.

The fourth model which varies both population size and trajectory produces a picture which more closely fits the actual distribution except for the reversed relationship between the R1 and R2 cores. The reversal in the real distributions suggests that the disposition to greater core reduction modifies the expected relationship
Figure 4.11: Behavioural correlates for core reduction.
by reducing larger cores more than smaller examples. The strength of the disposition could, therefore, be modified by the size of the core itself. To incorporate this into these models requires a more behaviourally realistic set of assumptions.

The fundamental weakness of these basic models lies in their assumption of a single point population and single trajectory slopes, i.e., the limitation of using means and the assumption of normal distributions. While it is not certain how realistic it would be to model the original blank population as normally distributed it is less realistic to envisage trajectories as essentially normal. This can be illustrated by reference to figure 4.12 which shows what might be expected to represent the actual reduction trajectories of a given core in terms of mass and platform angle. The A slope shows the expected trajectory of a core with poor trajectory control, the B that of a core exhibiting increased control. The degree of control is defined by the mean slope of the trajectory and the dispersion about the slope; poor control resulting in low slope and high variability and good control in high slope and low variability. In both, the threshold conditions would tend to flatten the trajectories as they approached and became less variable. The variability in trajectories which may change slope through the process ensures that there can be no certainty as to the exact point at which a core will strike the threshold, although in principle a range of points could be determined. These outcomes can be assigned probabilities and the
Figure 4.12: Reduction trajectories - (A) poorly controlled trajectory; (B) well controlled trajectory.

Figure 4.13: Hypothetical probability profile for reduction trajectory outcomes.
distribution of both these sources of variability forms a probability profile (shown in figure 4.13).

As the profiles exemplify the varying degree of knapping control they may be normally distributed as a result random error about a trajectory or skewed in direct relation to the reduction disposition. On normally distributed blank populations the effect of a highly skewed reduction profile is to pull the mean of the discard population in the direction of the skew, and the discard distribution also becomes more platykertic and extended. In populations which are already skewed towards smaller blanks the effect is similar while in populations skewed in favour of heavier blanks the discard population approaches a normal distribution.

The model argues that under average reduction conditions cores approaching platform threshold conditions will show higher mass variability than the original population. This variability also increases as the degree of reduction increases. The probability of cores retaining high mass as a result of poor reduction trajectories is dependent on the strength of the disposition to reduce them beyond the initial threshold conditions (i.e., to rotate the core [Ro>Rl]).

A second problem with the conventional models of reduction shown in figure 4.11-1 is its assumption that the disposition to reduce cores is independent of core size. A more realistic suggestion is that under conditions where reduction sequences are discontinuous, or
where there is a range of material on-hand, the knapper will attempt to maximize the extent of reduction episodes by progressively selecting for larger cores to work. This may be observable in the closeness of the Ro and R1 quartzite core means which results, it is suggested, from the heavier of the Ro cores being selected for further reduction, producing the comparable size ranges in both groups. Where the disposition is increased only the heaviest of the R1 cores are in turn subjected to a second rotation. If the process were continued the difference between the mean values of Ro>R1>R2>Rn cores would increase as the heaviest remaining cores were further reduced.

Using this model there is no necessity to assume that the increased reduction of cores is associated with either a change in the distribution of the blank population or alteration in the trajectory profiles as was originally suggested. This is consistent with the distribution of the Ro quartzite sample which retains a small number of cores substantially heavier than the 110gms class, the limit of the main Mode II distribution, which may form the basis of the R1 and R2 populations.

4.5b: Change in Core Discard

Figure 4.14 plots the percentage number of chert unrotated and rotated cores by spit. The distribution
Figure 4.14: Chert Ro and Rn core percentage numbers by spit.

Figure 4.15: Quartzite Ro and Rn core percentage numbers by spit.
shows the discard of both core groups to be significantly correlated \((\tau = .63, \ p = .0023)\) with a single modal peak in spit 20 followed by a progressive decline towards the top levels of the underlying assemblage. Factoring out the time component produces only minor change in the coefficient \((\tau_P = .59)\) showing the strength of the relationship to be largely unaffected by time trends with Rn cores predominating through time (table 4.17).

The distributions of quartzite cores are shown in figure 4.15. Unlike the chert samples, the quartzite rotated and unrotated cores show less correlation with separate modal peaks in spits 17 and 20 respectively. The correlation is, however, stronger than might be expected at \(\tau = .46 (p = .02)\) and \(\tau_P = .44\). An examination of the distribution shows the correlations to be close except for the spit 17 and 20 peaks. A \(\chi^2\) of the proportions of rotated and unrotated cores in both these spits shows the difference in proportion to be not significantly greater than that expected from sampling error. Similarly, a 50% probability test applied to the proportions of Ro and R1/2 in each spit also failed to disprove the assumption that the proportions of both core types in the parent population was equal. Despite the visual impression, the hypothesis that the R1/2 discard pattern is significantly different form the Ro can not, therefore, be uncritically accepted.

A comparison of the proportions of total chert to quartzite cores (ie., Ro/1/2 combined) also showed no significant change in proportions per spit \((\chi^2 = 6.49\)
TABLE 4.17: Quartzite and Chert Core Number

<table>
<thead>
<tr>
<th>spit</th>
<th>Quartzite</th>
<th>Chert</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ro R1/2</td>
<td>Ro R1/2</td>
</tr>
<tr>
<td>12</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>13*</td>
<td>2.4 1.2</td>
<td>1.2 0</td>
</tr>
<tr>
<td>14*</td>
<td>3.6 0</td>
<td>0 3.6</td>
</tr>
<tr>
<td>15*</td>
<td>1.5 3.4</td>
<td>0 1.5</td>
</tr>
<tr>
<td>16*</td>
<td>2.4 3.6</td>
<td>1.2 2.4</td>
</tr>
<tr>
<td>17</td>
<td>4 8</td>
<td>2 4</td>
</tr>
<tr>
<td>18</td>
<td>5 6</td>
<td>2 10</td>
</tr>
<tr>
<td>19</td>
<td>3 7</td>
<td>3 7</td>
</tr>
<tr>
<td>20*</td>
<td>13.6 6</td>
<td>4.8 16.8</td>
</tr>
<tr>
<td>21</td>
<td>6 5</td>
<td>3 3</td>
</tr>
<tr>
<td>22</td>
<td>3 0</td>
<td>0 0</td>
</tr>
<tr>
<td>23/4</td>
<td>1 0</td>
<td>0 0</td>
</tr>
</tbody>
</table>

* modified numbers due to missing squares

TABLE 4.18: Chert Core Mass (gms) - Change through Time

<table>
<thead>
<tr>
<th>spits</th>
<th>24/3-18</th>
<th>17-12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>Sx</td>
</tr>
<tr>
<td>Ro</td>
<td>14.9</td>
<td>13.6</td>
</tr>
<tr>
<td>R1</td>
<td>13.3</td>
<td>11.7</td>
</tr>
<tr>
<td>R2</td>
<td>43.2</td>
<td>75.9</td>
</tr>
<tr>
<td>*16.6</td>
<td>11.8</td>
<td></td>
</tr>
</tbody>
</table>

* extreme case removed

TABLE 4.19: Quartzite Core Mass (gms) - Change through Time

<table>
<thead>
<tr>
<th></th>
<th>24/3-18</th>
<th>17-12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>Sx</td>
</tr>
<tr>
<td>Ro</td>
<td>94.7</td>
<td>82.2</td>
</tr>
<tr>
<td>R1</td>
<td>99.9</td>
<td>142.9</td>
</tr>
<tr>
<td>R2</td>
<td>162.7</td>
<td>77.1</td>
</tr>
</tbody>
</table>
df = 6 [spits 15-12 had to be combined] p > .3) and a high overall correlation through time with $\tau = .79$ ($p < .0002$) and partial $\tau_p = .79$. The discard of chert and quartzite cores is, therefore, strongly associated with both samples showing a trend towards lower discard numbers from spit 20.

Table 4.18 compares the mean mass of Ro, R1 and R2 chert cores from the upper (spits 17-12) and the lower (23/4-18) halves of the underlying assemblage. The samples show no significant difference in mean size through time, except for the lower R2 sample which was affected by a single extreme case which when removed from the analysis returned the mean to a comparable figure*.

Conversely, table 4.19 shows there to be a tendency towards smaller quartzite cores in the upper half of the assemblage. The trend is, however, more apparent than real with the Ro sample showing no statistically significant difference ($MW-U z = 1.2$, $p = .12$) and the R1 exhibiting only a marginally variation ($MW-U u = 63, .01 < p < .05$). The R2 sample is also not significantly different ($MW-U u = 1, p = .09$) although this may be largely a product of the small sample size. When these are combined with the R1 to make a sample of all rotated cores there is a significant decline in core size in the upper spits ($MW-U z = 2.98, p = .002$).

The picture can also be expanded by an examination of the bimodalities in the quartzite sample discussed earlier. Taking Ro first, we see in figures 4.16 and 4.17
Figure 4.16: Quartzite Ro core mass distribution - spits 23/4-18.

Figure 4.17: Quartzite Ro core mass distribution - spits 17-12.
Figure 4.18: Quartzite Rn core mass distribution - spits 23/4-18.

Figure 4.19: Quartzite Rn core mass distribution - spits 17-12.
that the trend is from a bimodality with a small number of isolated cases in the lower spits (23/4-18) to a low centrally located unimodal curve with no extreme cases in the upper spits (17-12). As the numbers of Ro cores in the upper spits is low the significance of this shift is problematic. In comparison the R1 sample shows a more extreme bimodality in the lower spits (figure 4.18) which is also present in the upper units (figure 4.19). The R1 distributions show, however, a shift towards a more restricted distribution and smaller modal values. While the Ro bimodality can be said to be strongly associated with the lower units where the bulk of the Ro cores were discarded neither of the modalities appear to reflect major diachronic shifts in the discard of Ro and Rn cores.

In summary, both chert and quartzite cores show a decline in discard after spit 20. The chert cores show no size change through time and the quartzite show a tendency towards more restricted size range in the rotated cores principally due to a decline of equivocal significance in the numbers of R2 cores.

4.5c: Correlation of Core and Flake Discard

Figures 4.20 and 4.21 compare the distribution of unmodified flakes and core numbers through time. The figures show there to be little correlation between flake and core discard for either material type with flake
Figure 4.20: Quartzite core and flake percentage numbers by spit.

Figure 4.21: Chert core and flake percentage numbers by spit.
discard rising to a peak in the middle levels of the site between spits 15 and 17 and core numbers generally declining from the lower spits. The bivariate and partial tau correlation coefficients are given in table 4.20.

Of the core samples only the quartzite rotated cores show a moderate but significant correlation on the standard bivariate tau. However, in the light of the equivocal difference between the R1/2 and Ro samples' distribution any extension of this correlation to the parent population remains problematic. The combined sample shows a less than marginally significant correlation.

As might be expected from the distribution curves, the core to flake ratios (table 4.21) also show a pronounced tendency towards high ratios in the upper spits (12-17). The chert sample shows the most extensive variation with ratios comparable to those of quarry sites in spit 20 (see section 5.2b and McAnany [1989:337]), and what has generally been interpreted as secondary modification (as 'tool manufacture') in spit 15 (eg., Schrire 1982:97, White and Peterson 1969:54).

The poor correlation between core and flake discard through time is one of the central problems in understanding the underlying assemblage - there are three possible explanations:

a) Core reduction accounts for few of the flakes discarded. This hypothesis requires either a trend
### TABLE 4.20: Flake and Core Correlation through Time

<table>
<thead>
<tr>
<th></th>
<th>tau</th>
<th>p</th>
<th>tau_p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chert flakes/Ro,n</td>
<td>.22</td>
<td>-</td>
<td>.33</td>
</tr>
<tr>
<td>Quartzite flakes/Ro</td>
<td>.14</td>
<td>-</td>
<td>.26</td>
</tr>
<tr>
<td>/Rn</td>
<td>.53</td>
<td>.008</td>
<td>.55</td>
</tr>
<tr>
<td>/Ro,n</td>
<td>.35</td>
<td>.06</td>
<td>.48</td>
</tr>
</tbody>
</table>

### TABLE 4.21: Core to Flake Discard Ratio

<table>
<thead>
<tr>
<th>spit</th>
<th>Quartzite</th>
<th>Chert</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>1:151</td>
<td>1:261</td>
</tr>
<tr>
<td>14</td>
<td>1:105</td>
<td>1:76</td>
</tr>
<tr>
<td>15</td>
<td>1:180</td>
<td>1:505</td>
</tr>
<tr>
<td>16</td>
<td>1:286</td>
<td>1:169</td>
</tr>
<tr>
<td>17</td>
<td>1:129</td>
<td>1:92</td>
</tr>
<tr>
<td>18</td>
<td>1:75</td>
<td>1:35</td>
</tr>
<tr>
<td>19</td>
<td>1:53</td>
<td>1:31</td>
</tr>
<tr>
<td>20</td>
<td>1:21</td>
<td>1:10</td>
</tr>
<tr>
<td>21</td>
<td>1:34</td>
<td>1:39</td>
</tr>
<tr>
<td>22</td>
<td>1:56</td>
<td>-</td>
</tr>
<tr>
<td>23/4</td>
<td>1:54</td>
<td>-</td>
</tr>
</tbody>
</table>
towards the transportation of flakes to the site or an increase in the secondary reduction of flakes on-site.

b) Core discard does not correlate strongly with on-site core reduction. This suggests a trend towards higher off-site transportation of cores reduced on-site and requires a correlation between on-site core reduction and flake discard.

c) The on-site reduction process has changed such that more flakes are produced per core. Core discard is assumed to be correlated with core reduction but not in a linear fashion. The improved ratio between the number of flakes produced and the absolute amount of individual core reduction may involve either the extension of the process or the modification of the reduction mode via increased control of the flaking process.

Although aspects of these three alternatives will be tested by subsequent analyses the relationship between on-site core reduction and flake discard fundamental to all three alternatives can be examined further by comparing the distributions of two products directly related to on-site reduction (i.e., redirecting flakes and non-flake debitage) to flake discard.
4.5d: Redirecting Flakes, Flake Discard and Core Reduction

Redirecting flakes occur when a core is rotated and the angle between an abandoned striking platform and the free face of a core is used as a ridge to guide the removal of the initial flake from the new platform. These flakes retain remnants of an old striking platform on one side of a dorsal ridge and the truncated flake scars from the previous free surface on the other. They are distinct from crested (initiating flakes with some secondary modification of ridge line) and backed blades in the size of the flakes taken from the ridge and the manner in which the margins of the redirecting flake transect the dorsal flake scars.

The presence of redirecting flakes can be used as a more direct link between core reduction and flake discard because, as an initiating flake, they are less likely to retain any 'ideal' characteristics which may be selected for off-site transportation, either to Ingaladdi or away from it. The main limitation on their use for this purpose is that, while they relate directly to core rotation this may or may not be a feature of on-site core reduction, although it has been shown above to be generally associated with core discard. The redirecting flakes' size and the ridge angle can also indicate the critical points at which rotation took place and their numbers can also be used as a guide to the frequency of critical conditions being reached and the general degree of core reduction.
The number of redirecting flakes in each material type is presented in table 4.22. Although the percentage numbers of these flakes is low in both samples, the proportional difference between them in the two material types is greater than would be expected by chance ($\chi^2 = 8.2$, df=1, $p < .01$) and shows core rotation to be relatively more common in the chert samples, i.e., consistent with the higher proportion of rotated cores in that material (figures 4.22 and 4.23).

Comparing the lengths of the redirecting flakes with the face lengths of both the chert and quartzite rotated cores shows there to be no clear evidence for the on-site reduction of cores substantially larger than those represented in the core samples. The means and ranges of core faces and redirecting flake length are presented in table 4.23. Despite the chert redirecting flakes being significantly smaller than the quartzite ($MW-U z = 4.12$, $p < .01$) the difference of 9mm is low relative to the mass differences between the cores noted above. The quartzite cores, however, exhibit a less effective relationship between face length and mass resulting in much higher rates of change for the mass/face length regression (see section 4.7b). Redirecting flake length also shows no technologically significant change through time (table 4.24).

A comparison of the mean platform angles of the old striking platforms on the dorsal surfaces of the redirecting flakes with the mean core platform angles given in table 4.7 shows the redirecting platform means to
Figure 4.22: Quartzite redirecting flake percentage numbers by spit.

Figure 4.23: Chert redirecting flake percentage numbers by spit.
### TABLE 4.22: Number of Redirecting and Unmodified Flakes

<table>
<thead>
<tr>
<th>redirecting flakes</th>
<th>Quartzite</th>
<th>Chert</th>
<th>percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>63</td>
<td>55</td>
<td>0.94%</td>
</tr>
<tr>
<td></td>
<td>1.60%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 4.23: Core face and Redirecting Flake Length (mm)

<table>
<thead>
<tr>
<th>Redirecting flakes</th>
<th>X</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartzite</td>
<td>38</td>
<td>16-86</td>
</tr>
<tr>
<td>Chert</td>
<td>29</td>
<td>11-51</td>
</tr>
<tr>
<td>Cores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ro</td>
<td>36</td>
<td>14-91</td>
</tr>
<tr>
<td>Chert</td>
<td>22</td>
<td>13-48</td>
</tr>
<tr>
<td>Rn</td>
<td>35</td>
<td>14-93</td>
</tr>
<tr>
<td>Chert</td>
<td>21</td>
<td>9-46</td>
</tr>
</tbody>
</table>

### TABLE 4.24: Redirecting Flake Length (mm) in Upper and Lower Spits

<table>
<thead>
<tr>
<th>spits</th>
<th>X</th>
<th>Cv</th>
<th>R</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartzite</td>
<td>23/4-18</td>
<td>41</td>
<td>40.5</td>
<td>16-86</td>
</tr>
<tr>
<td></td>
<td>17-12</td>
<td>36</td>
<td>30.8</td>
<td>16-66</td>
</tr>
<tr>
<td>Chert</td>
<td>23/4-18</td>
<td>30</td>
<td>32.0</td>
<td>11-51</td>
</tr>
<tr>
<td></td>
<td>17-12</td>
<td>27</td>
<td>30.0</td>
<td>14-45</td>
</tr>
</tbody>
</table>
be within the range of the core samples (table 4.25). As the platform angles were normally distributed F and t tests showed there to be no or only marginally significant differences between the core and redirecting flake samples (quartzite- t=.79, p>.05; chert- t=2.3, 0.05>p>.01).

If the number of redirecting flakes is taken as a direct measure of the frequency of cores being reduced beyond initial platform threshold conditions, they may also be used to test the relationship between core reduction and discard behaviour. Figure 4.24 compares the deposition of chert flakes, cores and redirecting flakes. The impression of only moderate to weak correlation between the distributions of these variables is confirmed by the bivariate and partial correlation coefficients (table 4.26). Although the coefficient is not high the correlation between redirecting and unmodified flakes does relate the latter's production more effectively to core reduction than the core distribution.

A more detailed examination of the distribution of chert redirecting flakes and their correlation with flake numbers shows that the relationship may be more effectively seen as two separate redirecting flake distributions with a major disjunction between spits 17 and 18 (figure 4.23). The correlation of the upper half of the distribution from spits 12-17 with flake numbers (tau=.73) is higher than the overall figure given in table 4.26, as is the coefficient for the lower half (tau=.69). The significance of the correlations, however, declines
**TABLE 4.25: Dorsal Platform Angle on Redirecting Flakes (°)**

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Sx</th>
<th>no.</th>
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</thead>
<tbody>
<tr>
<td>Quartzite</td>
<td>87</td>
<td>22</td>
<td>58</td>
</tr>
<tr>
<td>Chert</td>
<td>83</td>
<td>12.8</td>
<td>54</td>
</tr>
</tbody>
</table>

**TABLE 4.26: Bivariate and Partial Kendall Correlations for Chert Redirecting Flakes, Unmodified Flakes and Cores through Time**

<table>
<thead>
<tr>
<th></th>
<th>tau</th>
<th>p</th>
<th>tau_p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redirecting flakes/flakes</td>
<td>.45</td>
<td>.02</td>
<td>.50</td>
</tr>
<tr>
<td>/Ro</td>
<td>.21</td>
<td>.17</td>
<td>.20</td>
</tr>
<tr>
<td>/Rn</td>
<td>.44</td>
<td>.02</td>
<td>.44</td>
</tr>
</tbody>
</table>

**TABLE 4.27: Bivariate and Partial Kendall Correlations for Quartzite Redirecting Flakes, Unmodified Flakes and Cores through Time**

<table>
<thead>
<tr>
<th></th>
<th>tau</th>
<th>p</th>
<th>tau_p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redirecting flakes/flakes</td>
<td>.68</td>
<td>.001</td>
<td>.65</td>
</tr>
<tr>
<td>/Ro</td>
<td>.19</td>
<td>.19</td>
<td>.28</td>
</tr>
<tr>
<td>/Rn</td>
<td>.47</td>
<td>.016</td>
<td>.53</td>
</tr>
</tbody>
</table>
Figure 4.24: Chert flake, core and redirecting flake percentage numbers by spit.

Figure 4.25: Quartzite flake, core and redirecting flake percentage numbers by spit.
The meaning of these relationships is also complicated by the variation in the effect of time trends in both halves. The partial tau for the upper half (12-17) ($\tau_{up} = .58$) shows the correlation to be moderately affected by the decline in numbers through time. This is even more evident in the lower half where the partial tau ($\tau_{up} = -.068$) shows the relationship to be totally dependent on a decline in both flake and redirecting flake numbers, reducing the certainty of any underlying relationship.

The correlation of redirecting and unmodified chert flakes is therefore potentially stronger than initially presented but substantially more complex. The difference in distributions is due to a rapid change in the ratio of redirecting to unmodified flakes between spits 17 and 18. In the lower half the ratio is low with a mean value of 1:38 while in the upper half the ratio rises to 1:100. The proportional difference is highly statistically significant ($\chi^2 = 12.3$, df=1, $p < .001$). This decrease in relative numbers suggests either an improvement in core reduction control, as more flakes are produced before rotation occurs, or an alteration in the degree of reduction of cores brought onto the site, such that there is less later phase reduction. A third possibility lies in the increase of secondary modification in the upper level adding a second loading of chert flakes. This will be discussed further in section 4.8.

Table 4.26 also shows there to be a comparably weak but marginally significant correlation between the discard of rotated cores and redirecting flakes in the chert
sample which is largely unaffected by time trends. This suggests some relation between on-site core reduction and core discard and provides a link between core reduction and flakes discard. The correlation is not, however, strong and its behavioural significance is difficult to assess. Some explanation of why this might be the case is offered in the interpretation of the underlying assemblage in Chapter Six.

In contrast to the chert distributions the relations between the redirecting and unmodified quartzite flakes and cores is more immediately understandable. Figure 4.25 shows the redirecting flakes to be comparable to both the unmodified flake and rotated core patterns but only weakly correlated with the Ro cores (table 4.27).

Compared to the chert distributions the overall correlations are more widely spread and there appear to be no major changes in the redirecting flake to flake ratio. Although the mean ratio at 1:105 is comparable to that of the chert in later levels the range is similar in both the lower (1:42-166) and upper halves (1:36-156) with no consistent change through time. The correlation of the redirecting flakes and the rotated cores is weakened by the early decline in the deposition of rotated cores in spit 16.

The quartzite correlations show there to be a good relation between the numbers of discarded flakes and the frequency of on-site core reduction as measured by the number of redirecting flakes. The redirecting flake
correlation with the rotated cores also provides a tenuous link between the discard of these cores and their on-site reduction which may also be linked to the discard of unmodified flakes via the redirecting flakes. Of equal importance is the weak relationship between the unrotated cores (Ro) and the redirecting flakes. Although this is technically expected it demonstrates that the discard of these cores was not strongly related to the degree of on-site reduction.

4.5e: Non-flake Debitage in relation to flake discard and core reduction

The agreement between the deposition of redirecting and unmodified flakes, and the rotated cores, links quartzite core reduction, as exemplified by the redirecting flakes, to flake and core discard. These correlations also suggest that the difference in the distribution of rotated and unrotated quartzite cores may be more significant than the statistics (in section 4.5b) indicate. The hypothesized relation between core reduction and flake discard is also supported by the high correlation between flake and non-flake debitage ($\tau = .88$, $p = .00005$; $\tau_{zp} = .87$) noted in the introduction and that between redirecting flakes and non-flake debitage ($\tau = .7$, $p = .0007$; $\tau_{zp} = .68$).

Figure 4.26 shows the distribution of the mass/m³ of the quartzite non-flake debitage to be trimodal with a
Figure 4.26: Quartzite non-flake and flake debitage mass/m³ by spit.

Figure 4.27: Quartzite size - mean non-flake and flake mass by spit.
series of descending peaks in spits 20, 17/16 and 13. Although non-flake and flake numbers are strongly correlated and numbers of both peak in spit 16, as do redirecting flake numbers, the high mass of non-flake material in spit 20 is not accompanied by high flake numbers (compare figure 4.20). This peak is due to a substantial rise in the mean mass of non-flake debitage in spit 20 which otherwise progressively declines from spit 23/4. Mean flake mass also follows a similar but less marked trend (see figure 4.27).

The discard of unrotated quartzite cores (which also peak in spit 20) in the lower third of the assemblage is therefore associated with the tendency to produce large size non-flake debitage and is consistent with a low disposition to reduce material. The upper half of the unit (spits 17-12), on the other hand, sees a decline in both the mean size of flake and non-flake debitage. This section also sees the transition from high to low discard of cores suggesting a progressive restriction of on-site core reduction (see Chapter Six).

Chert non-flake debitage follows the quartzite material in strongly correlating with flake discard ($\tau = .82$, $p < .0001$; $\tau_p = .8$) and retaining a similar but more complex correlations with the redirecting flakes ($\tau = .47$ [spits 12-16] and $\tau = .8$ [spits 24/3-17]). Its correlation with core discard is weak and of no statistical significance at $\tau = .36$ ($p > .05$) and $\tau_p = .43$. 

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Figure 4.28 shows the distribution of chert non-flake debitage mass/m$^3$ of deposit. In comparison with the quartzite, the densities are an order of magnitude lower but retain the peaks in spits 20 and 16. The peaks are, however, reversed in prominence with the highest mass in spit 16, which is more consistent with the flake distribution. The mean size of chert non-flake debitage also remains stable throughout the underlying spits, showing only an aberrantly high mean in spit 23/4 (figure 4.29). This stability is also seen in the distribution of mean chert flake mass through time.

The chert material follows the quartzite in showing strong relationships between core reduction (indicated by the redirecting flakes and the non-flake material) and the discard of flakes on-site. It retains, however, a weaker correlation with the actual deposition of cores themselves.

In summary, while on-site core reduction can be associated with flake discard, the discard of cores appears to be only weakly related to their own reduction. As might be expected, the analysis suggests some correlation between the rotated quartzite cores and that of the flakes, however, the uncertainty of the significance of the differences between the distributions of the rotated and unrotated cores makes these correlations problematic. The most important point to be drawn is that the correlation of both redirecting flakes and non-flake waste with flake numbers makes it unlikely that the flakes were simply transported to the site as
Figure 4.28: Chert non-flake and flake debitage mass/m³ by spit.

Figure 4.29: Chert size - mean non-flake and flake mass by spit.
Jones and Johnson (1985) have suggested for Nauwalabila I, i.e., explanation (a) above. It is unlikely that all the products of core reduction would have been curated in this fashion, brought to the site and discarded in the numbers seen in the assemblage. This makes explanation (a) the least likely of the three posed at the beginning of this section. The third, the improvement in reduction mode, will be examined in the following analysis of the flake component.

4.6: Flake Analysis

The following flake analysis tests the proposition that the shift in the core to flake ratio in the underlying assemblage was the result of major shifts in the form of reduction through time. The section examines five aspects of the flake assemblage:

a) Flake size which shows persistent proportional modalities through time.

b) Decortication - a general test of the relative length of reduction.

c) Breakage - an indicator of variation in force input.

d) Platform modification - indicating the degree of concern for core geometry.

e) Flake shape - a test of change in core geometry.
Flakes in this analysis were defined by the presence of striking platforms or bulbar surfaces. Both partial and complete flakes with these traits were included in the initial categorization which totalled 6665 quartzite and 3380 chert flakes (excluding flakes from A8 12-16).

4.6a: Size Change through Time

It has already been shown in the introduction to the analysis of the underlying assemblage that there is an decrease in flake size in the the upper half of the underlying assemblage. To investigate this trend in more detail the flakes were divided into five size classes bases on ventral surface area: <1cm², 1-2cm², 2-4cm², 4-8cm² and >8cm². Flakes were categorized by their fit within a series of geometric figures of standardized area. The percentage breakdown of flakes by size within and between the material types as provided in tables 4.28 and 4.29.

The tables show the quartzite flakes to be generally larger and comprising the higher proportion of flakes in each of the size classes; the proportional differences become more marked as size increases. Despite this trend the highest proportion of flakes is in the 1-2cm² class for both chert and quartzite. In the chert sample nearly 70% of the sample is below 2cm² while in the quartzite 49%.
TABLE 4.28: Percentage Flake Size between the two major Material Types.

<table>
<thead>
<tr>
<th>cm²</th>
<th>Quartzite</th>
<th>Chert</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;8</td>
<td>88.3%</td>
<td>11.7%</td>
<td>505</td>
</tr>
<tr>
<td>4-8</td>
<td>81.4%</td>
<td>18.6%</td>
<td>1299</td>
</tr>
<tr>
<td>2-4</td>
<td>69.0%</td>
<td>31.0%</td>
<td>2749</td>
</tr>
<tr>
<td>1-2</td>
<td>60.2%</td>
<td>39.8%</td>
<td>3632</td>
</tr>
<tr>
<td>&lt;1</td>
<td>58.0%</td>
<td>42.0%</td>
<td>1861</td>
</tr>
</tbody>
</table>

TABLE 4.29: Percentage Flake Size within the two major Material Types.

<table>
<thead>
<tr>
<th>cm²</th>
<th>Quartzite</th>
<th>Chert</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;8</td>
<td>6.7%</td>
<td>1.7%</td>
</tr>
<tr>
<td>4-8</td>
<td>15.9%</td>
<td>7.2%</td>
</tr>
<tr>
<td>2-4</td>
<td>28.5%</td>
<td>25.2%</td>
</tr>
<tr>
<td>1-2</td>
<td>32.8%</td>
<td>42.7%</td>
</tr>
<tr>
<td>&lt;1</td>
<td>16.2%</td>
<td>23.2%</td>
</tr>
</tbody>
</table>

TABLE 4.30: Quartzite Flake Size Proportions (%) by Spit

<table>
<thead>
<tr>
<th>spit</th>
<th>Mode</th>
<th>&gt;8</th>
<th>4-8</th>
<th>2-4</th>
<th>1-2</th>
<th>&lt;1</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>C</td>
<td>8.2</td>
<td>13.7</td>
<td>12.3</td>
<td>32.9</td>
<td>32.8</td>
<td>73</td>
</tr>
<tr>
<td>13</td>
<td>C</td>
<td>3.7</td>
<td>11.0</td>
<td>23.7</td>
<td>33.0</td>
<td>28.4</td>
<td>455</td>
</tr>
<tr>
<td>14</td>
<td>C</td>
<td>3.2</td>
<td>11.1</td>
<td>18.7</td>
<td>36.2</td>
<td>30.8</td>
<td>315</td>
</tr>
<tr>
<td>15</td>
<td>C</td>
<td>3.1</td>
<td>9.4</td>
<td>17.8</td>
<td>37.8</td>
<td>31.9</td>
<td>540</td>
</tr>
<tr>
<td>16</td>
<td>B</td>
<td>6.0</td>
<td>17.0</td>
<td>30.4</td>
<td>32.0</td>
<td>14.6</td>
<td>1445</td>
</tr>
<tr>
<td>17</td>
<td>B</td>
<td>5.4</td>
<td>15.4</td>
<td>29.2</td>
<td>34.2</td>
<td>15.8</td>
<td>1549</td>
</tr>
<tr>
<td>18</td>
<td>B</td>
<td>7.8</td>
<td>16.6</td>
<td>33.3</td>
<td>31.4</td>
<td>10.8</td>
<td>830</td>
</tr>
<tr>
<td>19</td>
<td>B</td>
<td>7.0</td>
<td>16.1</td>
<td>26.3</td>
<td>39.2</td>
<td>11.0</td>
<td>528</td>
</tr>
<tr>
<td>20</td>
<td>A</td>
<td>15.4</td>
<td>19.8</td>
<td>38.5</td>
<td>21.6</td>
<td>4.7</td>
<td>338</td>
</tr>
<tr>
<td>21</td>
<td>A</td>
<td>13.2</td>
<td>22.8</td>
<td>34.4</td>
<td>24.2</td>
<td>5.1</td>
<td>372</td>
</tr>
<tr>
<td>22</td>
<td>B</td>
<td>6.6</td>
<td>18.6</td>
<td>26.9</td>
<td>38.3</td>
<td>9.6</td>
<td>167</td>
</tr>
<tr>
<td>23/4</td>
<td>A</td>
<td>14.8</td>
<td>37.0</td>
<td>27.8</td>
<td>18.5</td>
<td>1.9</td>
<td>54</td>
</tr>
</tbody>
</table>
Discussion of the non-flake debitage in section 4.5e showed that the mean mass of quartzite flakes had decreased through time from 7.8gms in spit 23/4 to 3.3gms in spit 12 (see esp. figure 4.27). The size increase below spit 19 is not even, with a sharp decline to 3.6gms in spit 22, followed by a the second sharp rise to 7.8 in 23/4. The figures for chert show a weaker version of this pattern.

Figures 4.30 and 4.31 break this trend down into the various flake size categories. The quartzite sample exhibits a clear increase in the proportion of flakes <1cm² with the 1-2cm² category exhibiting more consistency through time. This is balanced by decreases in the 2-4, 4-8 and the >8cm² categories. In the chert flakes the trend is carried primarily by the <1cm² category with the 1-2cm² remaining at relatively constant proportions. Like the quartzite, the 2-4, 4-8 and >8cm² classes show a series of individually less dramatic declines.

The trends in the size classes, especially in the quartzite sample, are not uniform. They appear to be composed of periods of proportional stability followed by rapid changes. This is evident in the <1cm² class with a substantial jump between spits 16 and 15 and in the 1-2cm² with its sharp rise after spit 19, preceded by a second rise in spit 22 and a second decline in spit 23/4. What the graphs do not show effectively is that these represent points at which there are substantial changes in the overall proportions of all flake classes. This may be seen more easily in table 4.30.
Figure 4.30: Quartzite flake size distributions - percentage number of flakes in each size class per spit.
Figure 4.31: Chert flake size distributions - percentage number of flakes in each size class per spit.
A hierarchical cluster analysis (Wards MVC), as described by Romesburg (1984), shows these data to be composed of three distinct proportional groups (A, B and C). The resulting dendrogram (figure 4.32) plots the degree of dissimilarity, expressed as the square root of E, which is an index of the variance between the proportional groups. Group A, spits 20, 21 and 23/4 is distinguished by high proportions of large flakes (>8 and 4-8cm²); group B (spits 16, 17, 18, 19 and 22) retains the highest proportions of flakes from 2-4cm² and group C (spits 12, 13, 14 and 15) exhibits the highest proportions of flakes in the <1cm² class.

While the ordering of the clusters confirms the general trend towards smaller flake deposition through time, the close relationship between spits 16-19 and spit 22, combined with the separation between the three groups, indicates that what appears superficially to be the product of a constant process is composed of a series of distinct modal clusters which suggest a progression from a cyclic pattern in the lower levels [A-B-A-A-B] to a linear sequence in the upper [B-B-B-C-C-C-C]. A one sample runs test on the entire sequence (incorporating B and C as a single class BC) shows, however, that the patterning does not differ significantly from that expected from a random combination. This is despite the combination of B and C which would tend to increase the probability of non-randomness. This does not argue that cyclic or linear trends do not underlie the patterning, simply that their
Figure 4.32: Dendrogram of spit combinations grouped according to difference in flake proportions - Quartzite.

Figure 4.33: Dendrogram of spit combinations grouped according to difference in flake proportions - Chert.
presence is not demonstrated on the size of sample available.

Figure 4.33 plots the dendrogram for the chert flakes which exhibit a similar tripartite clustering (A, B and C) with a similar ordering of classes through time. Compared to the quartzite, however, the chert groups show less overall differentiation and differing spit combination. Group A, again associated with relatively high frequencies of large flakes (>8 and 4-8cm²), is more clearly associated with the lower third of the assemblage including spits 20-23/4. The character of group B is less clearly defined, showing a weak tendency towards medium to small size categories (2-4 and 1-2cm²) and incorporates spits 19-16 and 12. The dendrogram shows moderate dissimilarity between the central spits and 12 which has been affected by an anomalously high percentage of flakes in the 4-8cm² class. The group C is also weakly defined by a rise in small flakes (<1cm²) and includes spits 13-15.

Although the chert groups show less dissimilarity compared to the quartzite a one sample runs test on the sequence (again combining B and C) show the sequence to be non-random, suggesting the presence of some form of ordering process through time.

The hypothesis forwarded to explain the group clusters in both chert and quartzite samples is that they represent periods of relative stability in what are distinctive behavioural modes. The term 'mode' is used to
define a set of events in which one class of events or behaviours is more strongly represented than others, i.e., is a modal or most common event. The hypothesis derives from Binford and Binford's (1966, 1969) argument that archaeological assemblages reflect differences in "human activities" and that it was in practice possible to distinguish the 'tool kits' which constituted the assemblage (see also Ammerman and Feldman 1974). Mode A is not, for instance, seen as composed of 'a' type behaviour exclusively, but would, if it could be examined in detail show a recursive pattern of events in which the 'a' type most commonly occurred (e.g., a,b,a,a,a,c,b,a,a,....). As the underlying behaviour sets (i.e., a,b,c....n) can not in this case be observed directly because they are, as Clarke (1978:162) describes them "...the thinnest recognizable slice of an artifact or assemblage time trajectory", their character must be inferred from the modal attributes of the archaeological unit used in this analysis (i.e., the spits). It should be remembered, as Frankel (1988:41) points out, that these large temporal units are "averages" and conflations of separate events. The 'mode' is not, therefore, meant to imply a static industrial structure in which the relation between events is in some fashion formalized. Further, the modes may only have significance in relation to the Ingaladdi assemblage.

Although an interpretation of the modal shifts will be presented in more detail in Chapter Six, they raise a second set of questions as to whether the modes, as
defined above, represent the stages in a single reduction process differentially represented through time, the variable presence of a set of distinct reduction processes (i.e., primary core or secondary flake reduction) or an improvement in the control of reduction. These are closely related to the primary problem of shifts in the core to flake ratio and will also be examined in the following analyses.

4.6b: Decortication

As the degree of cortical retention can be seen as inversely related to the extent of reduction all flakes were divided into three cortical categories according to the amount of dorsal cortex: primary (retaining total dorsal cortex), secondary (retaining some but not complete cortex) and tertiary flakes with no dorsal cortex. Table 4.31 shows the percentage of primary and secondary classes in the quartzite and chert to be low and comparable in each material type.

Table 4.32 also shows there to be a progressive decline in the proportion of secondary decortication in the smaller flake classes; a pattern weakly reflected in the primary decortication flakes. As the analysis of off-site core reduction showed there to be no evidence of a systematic decortication of core blanks, the decline in cortex in the smaller flake sizes may simply reflect the reduced probability of small flakes removing cortical
| TABLE 4.31: Percentage of Primary and Secondary Decortication Flakes |
|-------------------------|-------------------------|
|                        | primary | secondary |
| Quartzite              | 2.3%    | 12.3%     |
| Chert                  | 0.8%    | 8.5%      |

<table>
<thead>
<tr>
<th>TABLE 4.32: Percentage of Primary and Secondary Decortication Flakes by Size Classes and Material Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary (%)</td>
</tr>
<tr>
<td>Quartzite</td>
</tr>
<tr>
<td>&lt;1</td>
</tr>
<tr>
<td>1.6</td>
</tr>
<tr>
<td>Chert</td>
</tr>
<tr>
<td>&lt;1</td>
</tr>
<tr>
<td>0.4</td>
</tr>
<tr>
<td>Secondary</td>
</tr>
<tr>
<td>Quartzite</td>
</tr>
<tr>
<td>&lt;1</td>
</tr>
<tr>
<td>3.6</td>
</tr>
<tr>
<td>Chert</td>
</tr>
<tr>
<td>&lt;1</td>
</tr>
<tr>
<td>4.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 4.33: Percentage of Secondary Decortication Flakes in the three Proportional Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
</tr>
<tr>
<td>Quartzite</td>
</tr>
<tr>
<td>A 2.8</td>
</tr>
<tr>
<td>B 2.9</td>
</tr>
<tr>
<td>C 4.5</td>
</tr>
<tr>
<td>Chert</td>
</tr>
<tr>
<td>A 7.3</td>
</tr>
<tr>
<td>B 3.4</td>
</tr>
<tr>
<td>C 5.2</td>
</tr>
</tbody>
</table>
surfaces on already partly decorticated cores.

Table 4.33 compares the secondary decortication flakes for the three proportional modes A, B and C in each material type. The quartzite and chert modes each show similar proportions of secondary flakes in each of the five size classes, except for Mode C in the quartzite and chert which exhibits increased percentages in the larger flake classes. A chi² test for change in the proportions of secondary decortication to tertiary flakes in the three proportional Modes showed no significant difference in the chert (chi²=1.6, df=2, p>.4) but significant variation between the quartzite modes (chi²=10.1, df=2, p<.01). Table 4.34 shows, however, that these differences are not great and possibly of little technological significance. The low strength of association (Cramer’s V=.04) confirms this limited significance.

The overall percentage of cortical platforms was consistently low in both quartzite (7.9%) and chert (1.7%); the chert again exhibiting a lower rate of occurrence and a weak trend towards reduced frequencies in the smaller size classes in the quartzite flakes (table 4.35). The differences between non-cortical and cortical platforms in the five size classes in the quartzite are, however, statistically significant (chi²=34.5, df=4, p<.01) but of little associative strength (Cramer’s V=.07).

In the proportional modes there is again a statistically significant difference (chi²=12.7, df=2,
### TABLE 4.34: Percentage of Secondary and Primary Decortication Flakes in each Mode

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartzite</td>
<td>3.1%</td>
<td>2.3%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Chert</td>
<td>.7%</td>
<td>.6%</td>
<td>.4%</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartzite</td>
<td>15.2%</td>
<td>11.3%</td>
<td>12.5%</td>
</tr>
<tr>
<td>Chert</td>
<td>6.8%</td>
<td>8.1%</td>
<td>8.6%</td>
</tr>
</tbody>
</table>

### TABLE 4.35: Percentage of Cortical Platforms by Flake Size

<table>
<thead>
<tr>
<th></th>
<th>&lt;1</th>
<th>1-2</th>
<th>2-4</th>
<th>4-8</th>
<th>&gt;8</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quartzite</strong></td>
<td>4%</td>
<td>6.9%</td>
<td>7%</td>
<td>12.6%</td>
<td>11.6%</td>
<td>512</td>
</tr>
<tr>
<td><strong>Chert</strong></td>
<td>1.1%</td>
<td>1.7%</td>
<td>1.6%</td>
<td>3.3%</td>
<td>-</td>
<td>56</td>
</tr>
</tbody>
</table>

### TABLE 4.36: Percentage of Cortical Platforms in Proportional Modes

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quartzite</strong></td>
<td>9.7%(74)</td>
<td>8.1%(365)</td>
<td>5.9%(82)</td>
</tr>
<tr>
<td><strong>Chert</strong></td>
<td>2.0%(11)</td>
<td>1.6%(30)</td>
<td>1.2%(12)</td>
</tr>
</tbody>
</table>
p<.01) in the frequencies of cortical to non-cortical platforms between the A, B and C modes in the quartzite flakes. The differences in the percentages of cortical platforms in each mode are, however, not large and probably reflect the relative proportion of flake sizes in each (table 4.36). The strength of association is also predictably low (Cramer's V=.04).

A closer examination of the cortical to non-cortical (ie., flaked and plain) platform proportions in the five size classes across the quartzite modes shows a statistically significant difference only in the 1-2cm² category (chi²=14.88, df=2, p<.001) produced by an anomalously high (14.5%) percentage of cortical platforms in that size class in mode A. The other size classes show there to be no significant difference in the proportion of cortical/non-cortical platforms between the size classes of the three modes (<1/chi²=1.05; 2-4/chi²=2.12; 4-8/chi²=4.9; >8/chi²=.15, df=2, p>.05). The chert modes also show no significant difference in the proportions of cortical platforms.

These results are consistent with the observation from the core analysis that the production of primary and secondary decortication flakes are a persistent feature of core reduction. The analysis has shown that there is no evidence, based on the proportions of cortex, to indicate that the proportional modes are derived from primary or secondary reduction with markedly different cortical proportions. The comparability of platform cortex frequency across the modes, especially in the smaller
flake classes, is also inconsistent with a decline in cortical platforms which might be expected if the modal differences represented a shift from primary core to secondary flake reduction. If this were the case, the consistent removal of flakes from the plain ventral surfaces of primary flakes would be expected to reduce the proportion of cortical platforms in the smaller size categories, in Mode C particularly.

4.6c: Breakage

In their discussion of debitage analysis Sullivan and Rozen (1985) suggested that the intactness of a flake's margins be utilized as a defining attribute for the creation of a debitage category of "broken flakes". This procedure was not followed in this analysis because of the difficulty of relating broken flakes as a class to the reduction process. While Sullivan and Rozen (1985) assume breakage to have some technological significance ie., to be associated with secondary reduction (tool manufacture), Hiscock (1985) has argued that it may also be a product of post depositional transformations, principally treadage. This may also include intentional breakage, discussed by Bergman et. al. (1987), and use breakage.

The problem of distinguishing flakes broken by these factors is complicated by the similarity of fracture mechanism in each case. As Cotterell and Kamminga's
(1987:691, fig. 15) discussion illustrates, the bending loads which are principally responsible for the formation of hinge and step termination during the production of a flake produce similar finial patterns to those which occur through treadage, producing similar breakage patterns. Breakages formed in compression fields where an impact is applied directly above the surface supporting the flake (see Cotterell and Kamminga 1987:691, fig 15) produces features which Bergman et. al. (1987) have associated with deliberate breakage. They report, however, that approximately 25% of their experimental breaks produced in this way did not form these features and concluded that flakes in this class would be difficult to assign to intentional breakage.

To avoid these problems the analysis of breakage has been carried out using the presence of sheared cones alone. A sheared cone is defined by the cleavage of the hertzian cone which fractures the flake into two near equal sections. Although this clearly defined break appears to be a form of combined conchoidal and compression fracture its mechanism has not been extensively discussed. It is suggested that with further analysis it will prove to be indicative of high input force. Where it is associated with small cores it may, (because of the high inertia expected) indicate the supporting of the core but not the presence of full bipolar reduction.
As breakages were not noted in the preliminary analysis of the total flake collection the feature was recorded on a sample composed of all flakes drawn from squares A9 and B9. The proportions of total breakages, including sheared cones, was high in both chert and quartzite samples with approximately 40% of the quartzite and 20% of the chert retaining some form of breakage (table 4.37).

The broken category as a whole (including transverse and marginal snaps and hinge and step fractures) is more frequently represented in the smaller flake classes, especially on quartzite, but shows no significant changes between the proportional modes in the two major material types. Sheared cones, however, appear to be almost exclusively associated with quartzite flakes. The number of sheared cones as a percentage of total quartzite flake numbers by size class for the proportional modes is given in table 4.38 below.

The proportion of quartzite sheared cones to other flakes in the five size classes shows significant differences ($\chi^2=14.71$, df=4, $p<.01$) with a tendency towards higher percentages in the central sizes. This, as will be seen in section 4.7b, is consistent with the appearance of inertia threshold responses in flakes from class 4-8cm$^2$ and below. The proportion of sheared cones to other flakes in each size class between the modes is, however, not statistically significant despite what appears to be a substantial rise in frequency in the >8 class in mode C ($<1/\chi^2=1.45$, $p>.5$; $1-2/\chi^2=1.3$, $p>.5$);
### TABLE 4.37: Percentage of Break Types

<table>
<thead>
<tr>
<th></th>
<th>shears</th>
<th>other</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartzite</td>
<td>10%</td>
<td>31%</td>
<td>2420</td>
</tr>
<tr>
<td>Chert</td>
<td>.5%</td>
<td>20%</td>
<td>1146</td>
</tr>
</tbody>
</table>

### TABLE 4.38: Percentage of Sheared Cones in Quartzite Flakes by Size Classes and Modes

<table>
<thead>
<tr>
<th></th>
<th>&lt;1</th>
<th>1-2</th>
<th>2-4</th>
<th>4-8</th>
<th>&gt;8</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sample</td>
<td>6%</td>
<td>10%</td>
<td>13%</td>
<td>11%</td>
<td>9%</td>
<td>2420</td>
</tr>
<tr>
<td>Mode A</td>
<td>0%</td>
<td>9%</td>
<td>6%</td>
<td>9%</td>
<td>10%</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>8%</td>
<td>9%</td>
<td>14%</td>
<td>13%</td>
<td>7%</td>
<td>1459</td>
</tr>
<tr>
<td>C</td>
<td>5%</td>
<td>12%</td>
<td>14%</td>
<td>7%</td>
<td>22%</td>
<td>544</td>
</tr>
<tr>
<td>total</td>
<td>432</td>
<td>822</td>
<td>637</td>
<td>379</td>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>
2-4/chi^2=4, p>.1; 4-8/chi^2=2.4, p>.3; >8/chi^2=4.2, p>.1; df=2).

The significance of the variation in the size category proportions suggests that the probability of cone shear was, to some degree related to flake size. The relationship is not great, however, indicating that sheared cones had a near constant probability of occurring with any quartzite flake removal. The consistent proportions throughout the modes also argues against the hypothesis that the variation in flake proportions is associated with major shifts in the reduction process. The possibility that shearing may be symptomatic of some interaction with core inertia and flake input forces also supports the suggestion that the high proportion of small flakes in Mode C is still derived from primary core reduction rather than the reduced proportions that would be expected if they represented a significant increase in hand held secondary flake reduction.

4.6d: Platform Modification

To allow a more detailed metrical analysis to be carried out on the flakes from A and B9 a 10% random sample stratified by size class for each spit was created. The sample consisted of 217 quartzite and 104 chert flakes representing 9% of the total A/B9 population (the loss of
1% in both is due to the effect of selection via mechanical randomization on size classes with less than 10 artifacts).

All flakes in the sample were examined for two platform modification traits: overhang removal and platform flaking. The former was characterized by the detachment of small scalar or step flakes from the striking platform which run onto the dorsal surface of the flake. The feature could vary from the single flake removing the initial section of a dorsal ridge to a series of heavy step fractures running across the width of the platform consistent with edge battering. The trait may represent both the removal of overhang, with the result of more effective positioning the PFA, the reduction of platform thickness required to remove flakes at high platform angles or the effect of overstabilized platforms and poor PFA location accidentally removing platform edge. While the trait may represent both greater concern for core geometry and flake formation it also points to the approach of threshold conditions where the conventional flake formation relationships break down. The trait's ambiguity limits its interpretation. However, no attempt was made to differentiate between the two possibilities as this would assume some understanding of the knapper's intent. Similarly the term "overhang removal" is used for simplicity to denote a set of traits and does not necessarily imply the original presence of overhang which was intentionally removed.
Platform flaking is more simply indicated by the presence of small scalar or step flakes removed from the dorsal surface running on to the striking platform. The trait has the effect of modifying the platform surface and the platform angle and is seen as also exhibiting concern for core geometry.

The percentage of flakes with overhang removal is higher in the chert sample (63%) than in the quartzite (54%). The difference in the proportion of overhang removal to non-overhang removals between the two material types is, however, not statistically significant (chi=1.9, df=1 p>.1) and can not be seen as a more consistent feature of the reduction process in either case. In relation to flake size there also appears no tendency in either sample for overhang removal to be associated with any size class (quartzite- chi²=2.8, p=.5; chert- chi²=2.3, p=.69, df=4).

Table 4.39 shows there to be a rise in the frequency of overhang removal in Mode C in both material types. Although the significance of the rise is statistically marginal when comparing the proportion of overhang removals to other flakes in the quartzite and chert samples (quartzite- chi²=6.3, chert- chi²=7.0, df=2, .05>p>.02) the consistent rise in both samples does suggest that the trend may be a real feature of both Mode C groups. There is, however, no significant indication that there is any tendency for overhang removal to be confined to the smaller flake size classes.
### TABLE 4.39: Percentage of Overhang Removals in the Proportional Modes

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartzite</td>
<td>52%</td>
<td>50%</td>
<td>71%</td>
</tr>
<tr>
<td>Chert</td>
<td>47%</td>
<td>55%</td>
<td>78%</td>
</tr>
</tbody>
</table>

### TABLE 4.40: The Percentage of Flaked Platforms in the Proportional Modes

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartzite</td>
<td>14%</td>
<td>9%</td>
<td>7%</td>
</tr>
<tr>
<td>sample no.</td>
<td>21</td>
<td>151</td>
<td>42</td>
</tr>
<tr>
<td>Chert</td>
<td>33%</td>
<td>11%</td>
<td>7%</td>
</tr>
<tr>
<td>sample no.</td>
<td>15</td>
<td>47</td>
<td>41</td>
</tr>
</tbody>
</table>
Platform flaking is substantially less frequent than overhang removal with only 13% of the chert and 9% of the quartzite flakes retaining the feature. Again the proportional difference between the samples is not significant ($\chi^2 = .5$, df=2, $p > .3$) and there appears to be no tendency for the flaking to be associated with any size class in either material type, although testing for a relationship was restricted by the small numbers in each size class. (quartzite: $\chi^2 = .39$, df=2, $p > .8$; chert: $\chi^2 = .045$, df=1, $p > .8$).

In relation to the proportional modes only the chert sample retained sufficiently high frequencies in each mode to allow for testing. This showed a marginally significant rise in the frequency of flaked platforms in Mode A relative to B and C ($\chi^2 = 7.0$, df=2, $0.05 > p > 0.02$) (see table 4.40). The table shows there to be little probability, given the chert results, of there being any significant difference in the quartzite proportions.

There is no tendency in either the chert or the quartzite sample for platform flaking and overhang removal to be strongly associated. As traits they principally appear independently as the above analysis would suggest (quartzite: $\chi^2 = 2.5$, df=2, $p > .1$; chert: $\chi^2 = 1.1$, df=2, $p > .7$).

The lack of association is also retained in the proportional modes with Fisher's exact probabilities in the chert sample of: A ($p = .18$), B($p = .78$) and C($p = .88$). In the quartzite the Mode B sample alone shows some tendency
towards a higher than expected association ($\chi^2 = 3.75$, df=1, $0.05 > p > 0.02$) but the relationship is not strong (Cramer's $V = 0.16$) - A ($\chi^2 = 2.5$, $p > 0.1$) and C (Fisher's exact probability $p = 0.81$).

The independence of overhang removal and platform flaking does not argue against the original suggestion that both may represent a concern for core geometry as they may derive from different problems of core geometry. The analysis has also shown there to be no difference between the proportional modes in terms of platform traits indicating no major change in the manner of platform modification through time.

4.6e: Flake Shape

As flake shape is largely dependent on core morphology its variation may be seen as an indicator of changes in modes of core preparation and reduction control. Table 4.41 gives the means and coefficients of variation of four shape indices for the quartzite and chert samples. The first two indices, flake length (measured perpendicular to the striking platform along the ventral surface through the hertzian cone) divided by width (maximum width normal to the length axis), and thickness (maximum thickness normal to length axis) divided by width provide standard measures of flake elongation and sectional robustness. The ratio of platform thickness (maximum dimension normal to width
### TABLE 4.41: Shape Indices for Quartzite and Chert Flakes

<table>
<thead>
<tr>
<th></th>
<th>l/w</th>
<th>t/w</th>
<th>Pt/Pw</th>
<th>w/Pw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartzite</td>
<td>( \bar{x} )</td>
<td>1.3</td>
<td>.31</td>
<td>.39</td>
</tr>
<tr>
<td></td>
<td>Cv</td>
<td>44%</td>
<td>45%</td>
<td>49%</td>
</tr>
<tr>
<td>Chert</td>
<td>( \bar{x} )</td>
<td>1.2</td>
<td>.32</td>
<td>.44</td>
</tr>
<tr>
<td></td>
<td>Cv</td>
<td>39%</td>
<td>60%</td>
<td>43%</td>
</tr>
</tbody>
</table>

### TABLE 4.42: Shape Indices by Size Class - Chert Flakes

<table>
<thead>
<tr>
<th>Size Class</th>
<th>l/w</th>
<th>t/w</th>
<th>Pt/Pw</th>
<th>w/Pw</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>( \bar{x} )</td>
<td>1.0</td>
<td>.26</td>
<td>.37</td>
</tr>
<tr>
<td></td>
<td>Cv</td>
<td>36%</td>
<td>44%</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>no.</td>
<td>21</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>1-2</td>
<td>( \bar{x} )</td>
<td>1.3</td>
<td>.37</td>
<td>.42</td>
</tr>
<tr>
<td></td>
<td>Cv</td>
<td>42%</td>
<td>70%</td>
<td>44%</td>
</tr>
<tr>
<td></td>
<td>no.</td>
<td>39</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>2-4</td>
<td>( \bar{x} )</td>
<td>1.3</td>
<td>.31</td>
<td>.51</td>
</tr>
<tr>
<td></td>
<td>Cv</td>
<td>29%</td>
<td>37%</td>
<td>43%</td>
</tr>
<tr>
<td></td>
<td>no.</td>
<td>21</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>&gt;4</td>
<td>( \bar{x} )</td>
<td>1.1</td>
<td>.31</td>
<td>.52</td>
</tr>
<tr>
<td></td>
<td>Cv</td>
<td>43%</td>
<td>26%</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>no.</td>
<td>7</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

MW-U: u = 72, z = -0.08, p = 0.47

\( u \) test: u = 72, z = -0.08, p = 0.47

MW-U: u = 72, z = -0.08, p = 0.47

\( z \) test: u = 72, z = -0.08, p = 0.47

\( p \) test: u = 72, z = -0.08, p = 0.47
axis) and platform width (Pt/Pw), as a measure of platform shape is included because its correlation (in section 4.7b) with section shape (t/w) provides an index of the relation of platform and free face geometry. Marginal flare (or parallel index [Hiscock 1986]), width divided by platform width (w/Pw), is defined by the relation of the arc of the free face of the core to that of the platform, and provides a fourth index of core morphology.

The following analysis is based on the 10% random sample of flakes from AB 9 used in the platform analysis above. The variation in sample numbers seen in subsequent tables stems from the exclusion of broken flakes from the calculation of specific shape indices.

In overall shape, both chert and quartzite flakes are comparable, showing a tendency to be marginally over square with moderate to thin sections and moderate to high marginal flaring. The variability in each indicating medium to poor variable control. A series of Kolmogorov-Smirnov (two tailed) tests (see Appendix B - note [2]) shows there to be no significant differences in the size of the indices between the to samples (KS - two tailed; l/w D=.09<.22, p=.4; t/w D=.038<.21, p=.8; Pt/Pw D=.137<.2, p=.08; w/Pw D=.122<.206, p=.14).

To test if there were any progressive change in flake shape through the size range a series of Mann-Whitney U tests compared the the distributions of the <1cm² and the largest flake class in each sample (4-8 and >8cm² were
### TABLE 4.43: Shape Indices by Size Class - Quartzite Flakes

<table>
<thead>
<tr>
<th>Size Class</th>
<th>l/w</th>
<th>t/w</th>
<th>Pt/Pw</th>
<th>w/Pw</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>1.4</td>
<td>.27</td>
<td>.39</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>62%</td>
<td>55%</td>
<td>60%</td>
<td>68%</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>1-2</td>
<td>1.2</td>
<td>.30</td>
<td>.35</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>43%</td>
<td>50%</td>
<td>42%</td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>65</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>2-4</td>
<td>1.3</td>
<td>.31</td>
<td>.38</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>41%</td>
<td>36%</td>
<td>37%</td>
<td>78%</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>53</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td>4-8</td>
<td>1.4</td>
<td>.35</td>
<td>.45</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>36%</td>
<td>49%</td>
<td>55%</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>&gt;8</td>
<td>1.5</td>
<td>.35</td>
<td>.41</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>36%</td>
<td>22%</td>
<td>53%</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>MW-U</td>
<td>u</td>
<td>134</td>
<td>123</td>
<td>233</td>
</tr>
<tr>
<td></td>
<td>z</td>
<td>.96</td>
<td>-2.7</td>
<td>-.16</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>.17</td>
<td>.004</td>
<td>.44</td>
</tr>
</tbody>
</table>

### TABLE 4.44: Shape Indices by the Proportional Modes - Chert Flakes

<table>
<thead>
<tr>
<th>Mode</th>
<th>l/w</th>
<th>t/w</th>
<th>Pt/Pw</th>
<th>w/Pw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode A</td>
<td>1.3</td>
<td>.36</td>
<td>.5</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>32%</td>
<td>50%</td>
<td>43%</td>
<td>107%</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Mode B</td>
<td>1.2</td>
<td>.34</td>
<td>.44</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>42%</td>
<td>73%</td>
<td>45%</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>38</td>
<td>47</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>Mode C</td>
<td>1.2</td>
<td>.29</td>
<td>.41</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>39%</td>
<td>38%</td>
<td>40%</td>
<td>114%</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>
combined in the chert to form a $>4\text{cm}^2$ class). The results showed there to be a significant rise in the platform ratio in the chert sample with platforms becoming proportionally narrower as flake size increased (Table 4.42). In the quartzite sample there is a significant decline in the t/w ratio, with smaller flakes becoming proportionally thinner relative to maximum width (table 4.43). The tests between the largest and smallest size classes in both the chert and quartzite samples showed, however, no further significant difference in the shape indices between the two material types in those size classes.

To examine the variation in shape and control between the proportional modes the shape indices for chert and quartzite Modes A, B and C are presented in tables 4.44 and 4.45. The tables show there to be little difference between the modes except for a slight tendency for flakes in both chert and quartzite Mode A groups towards squarer platforms and higher sectional ratios (t/w). Both KS and MW-U tests again show there to be no significant difference between the modes of each material type in the size of the various indices. In both the chert and the quartzite, Mode B and C comparisons samples were of sufficient size to allow two-tailed tests on overall distributional similarity. In each case there was no significant differences found. As the chert and quartzite modes are not composed of the same spit groups, inter material comparison is not possible.
These data show that, in terms of both distribution and central tendency, the shape indices of quartzite and chert flakes appear to be comparable, and that this similarity is consistent throughout the size classes and modes. Overall, the flake analysis has shown there to be little evidence for any change in the mode of flake production in the underlying assemblage based on cortical removal, platform preparation and core geometry (as measured by the shape indices). This argues against the improvement in reduction procedures suggested as a possible explanation for the increasing core to flake ratio noted in section 4.5c. The uniformity of product within the size classes and modes also suggests that there is no shift towards the reduction of cores of radically different morphology, as might be expected with a change to the increased secondary retouching of flakes through time. It does suggest that we are seeing in the mode's proportional shifts, the differential representation of the reduction stages of a single process. However, as will be shown in the following analysis of the internal structure of flake form, this similarity hides a complex set of factors which point to chert and quartzite flakes being produced under different reduction conditions.
### TABLE 4.45: Shape Indices by Proportional Modes - Quartzite Flakes

<table>
<thead>
<tr>
<th>Mode</th>
<th>1/w</th>
<th>t/w</th>
<th>Pt/Pw</th>
<th>w/Pw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode A</td>
<td>1.4</td>
<td>.34</td>
<td>.44</td>
<td>1.9</td>
</tr>
<tr>
<td>Cv</td>
<td>36%</td>
<td>38%</td>
<td>45%</td>
<td>50%</td>
</tr>
<tr>
<td>no.</td>
<td>15</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Mode B</td>
<td>1.3</td>
<td>.30</td>
<td>.38</td>
<td>1.8</td>
</tr>
<tr>
<td>Cv</td>
<td>47%</td>
<td>46%</td>
<td>49%</td>
<td>64%</td>
</tr>
<tr>
<td>no.</td>
<td>99</td>
<td>135</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>Mode C</td>
<td>1.4</td>
<td>.31</td>
<td>.40</td>
<td>2.1</td>
</tr>
<tr>
<td>Cv</td>
<td>40%</td>
<td>46%</td>
<td>50%</td>
<td>80%</td>
</tr>
<tr>
<td>no.</td>
<td>32</td>
<td>42</td>
<td>42</td>
<td>42</td>
</tr>
</tbody>
</table>

### TABLE 4.46: Pearson's r Correlation Matrix

<table>
<thead>
<tr>
<th></th>
<th>l</th>
<th>w</th>
<th>t</th>
<th>Pw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartzite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w</td>
<td>.61</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>.74</td>
<td>.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pw</td>
<td>.35</td>
<td>.62</td>
<td>.56</td>
<td></td>
</tr>
<tr>
<td>Pt</td>
<td>.43</td>
<td>.48</td>
<td>.70</td>
<td>.76</td>
</tr>
<tr>
<td>Chert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w</td>
<td>.59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>.58</td>
<td>.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pw</td>
<td>.29</td>
<td>.35</td>
<td>.55</td>
<td></td>
</tr>
<tr>
<td>Pt</td>
<td>.33</td>
<td>.44</td>
<td>.65</td>
<td>.85</td>
</tr>
</tbody>
</table>

*n=146* critical value .19 (p=.01)

*n=86* critical value .24 (p=.01)
4.7: Internal Relations of Flake Production

4.7a: Path Analysis

The above analysis showed there to be a general consistency not only in the platform traits, cortex and breakage patterns but also in the form of both quartzite and chert flakes. The comparison of measures of central tendency and variability do not, however, deal with the relationship between variables which comprise the shape indices. The internal relations between the platform and dimensional variables (flake length, width and thickness) may be used as a method of examining the factors which structure the internal relations of flake formation. These allow comparison with those identified in the core analysis.

Table 4.46 shows there to be a high proportion of significant correlations between and within the platform and dimensional variables of both chert and quartzite samples with the quartzite showing generally higher coefficients. While these tables remain an adequate first approximation the bivariate model disguises the effects of prior correlations i.e., the relation between Pw and t may derive from Pw's high correlation with Pt and its correlation with t. To examine the relationship between platform and dimensional variables in a more structured manner a simple path analysis model was constructed.

Path analysis has been used in the biological and social sciences to investigate multivariate problems via
the assumption that there is some definable causal relationship between correlated variables and that the relationship between variables can be defined as causally closed (ie., that each dependent variable should be 'completely' determined by the variables in the system) (see Blalock 1981:468-482, Duncan 1966, Dwyer 1983:13-22, Kim and Kohout 1970, Walters 1968:176-201, Wright 1954, 1960). The causal ordering is derived from a model of the structure of causal dependence and need not account for all of the variation of the dependent variable.

The fundamental assumption of the model to be used for the path analysis is that the platform variables of platform angle (Pa), thickness (Pt) and width (Pw) are causally related to flake length (l), width (w) and thickness (t) and that platform thickness is causally prior to platform width because it is directly related to PFA location.

For their experimental series Dibble and Whittaker (1981) identified and controlled for material, core morphology, force input, PFA and platform angle, using the latter three as independent predictors of flake length and thickness. Their analysis showed increased force to positively affect flake length and that both platform angle and thickness were also important in the determination of flake length ($R^2 = .64$) and thickness ($R^2 = .83$) where the effects of both variables were combined via a multiple regression to give the following predictive equations:

$$l = .08Pa + 2.3Pt - 2.01$$
$$t = .02Pa + .8Pt - 1.1.$$
Applying Dibble and Whittaker's (1981) experimental assumptions that Pa and Pt are independent variables, the relationship between Pa, Pt and l and t could be modelled as two sets of trivariate relationships as shown below:

However, the experimental results also showed that where force was held constant the strength of the relationship between Pt and flake length was affected by Pa such that as the platform angle increased the resulting increase in flake length became less dependent on platform thickness and the median platform thickness which would result in a flake also decreased. Dibble (1981:98) found these relationships to hold in a sample of flakes from Tabun Cave where force and core geometry could not be as tightly controlled. The flakes also showed a decline in the relation of Pw and w as platform angle increased (Dibble 1981:97).

These results suggest that Dibble and Whittaker's (1981) treatment of Pa and Pt as independent experimental variables cannot be applied to the real reduction process where the knapper may adjust to the increasing threshold conditions, which high platform angles have already been shown to constitute. Force input will also be related to platform angle as flake size may be further increased at high Pa by increasing force input. Where this option is restricted by the limitations of core inertia a move towards the decrease of platform thickness is the only
alternative to reduced flake size. This evidence suggests a modified model of the type illustrated below where Pa and Pt are causally related. Pw is also added as causally dependent on Pt:

\[ \tan \alpha(P_t) = P_{12} \]

The problem with the imposition of this path lies in the complexity of the Pa>Pt relationship which proved to be curvilinear and to vary between zero and strongly negative correlations at critical threshold points in the reduction process. To avoid this problem the effect of Pa and Pt on length was combined in the single trigonometric expression, \( \tan Pa(Pt) \), which estimates flake length and simplifies the second causal path to Pt>t unaffected by Pa which is removed as a separate variable from the revised path model below:

\[ \tan \alpha(P_t) = P_{12} \]

Under the conventions of path analysis l, w and t are correlated via unanalysed relationships and e represents the error or disturbance i.e., the degree to which the standard deviation of the dependent variable has not been
explained by the independent (see Blalock 1981:409). The error terms are assumed to be unrelated to the predictor variable. In this model there are strong geometrical reasons for assuming the error of Pw is independent of Pt and that Pt and Pw can be the only direct causes of t and w respectively.

Figure 4.34 compares the path models from both the chert and quartzite samples. The model uses unstandardized path regression coefficients \( b_{xy} \) (see Wright 1960) which measures the absolute contribution of the independent variable to the dependent, i.e., \( b_{pt,t} \) equals the degree to which a one unit increase in Pt changes flake thickness (t). Regression coefficients are more useful for comparison between populations than the standardized beta values often used in these models (Kim and Kohout 1970:394-397). The paths between l, w and t on the right side of the model are presented as unanalysed correlations. The unanalysed coefficients are Pearson’s r correlation values which were also used to calculate the causal path regression coefficients. All correlations were significant at \( p<.01 \). The disturbance factors in the brackets represent the percentage of the variance not explained by the causal path.

An examination of the disturbance factors shows that platform variables explain from 50 to 9% of the variance in the flake variables in either sample, with length being poorly predicted by tan Pa(Pt) in both. This is consistent with Dibble and Whittaker’s (1981) finding that
Figure 4.34: Path analysis models for Quartzite and Chert: $P_{12}$ - tan [Platform angle] platform thickness; $P_t$ - platform thickness; $P_w$ - platform width; $l$ - flake length; $w$ - flake width; $t$ - flake thickness.
the relation of platform thickness to flake length becomes weak at high platform angles (i.e., above 70°). Only the high contribution of Pw to w in the quartzite sample derives from a significant difference in the respective correlation coefficients between the materials (quartzite r=.62 and chert r=.35, p=.009) with the difference in the strengths of 1-t showing a marginally significant difference between the two samples (p=.04). In both samples, Pt is a good predictor of flake thickness accounting for approximately 42-50% of the variation of the latter. A second order partial correlation coefficient between w and t also showed that little of the relation between the two flake dimensional variables was due to any underlying association with the correlation of Pt and Pw which accounted for only 10.7% (quartzite) and 12.5% (chert) of the w-t variation.

While the path analysis has shown that there is generally little relation between the platform and flake variables in both samples, the closer relation between Pw and w in the quartzite sample does suggest some greater degree of consistency in the production of these flakes. Some indication of this is seen in the comparison of w/Pw indices in table 4.42. These data are also supported by the correlations seen in table 4.46, however, their relation to the reduction process remains unclear.

Although a direct comparison between the platform and the flake variables does not show platform variables having a great effect on the form of the flake, a bivariate comparison of the relation between platform
shape (Pt/Pw) and flake sectional shape (t/w) shows there to be a highly significant (p<.001) difference between the quartzite (r=.64) and chert (r=.15) samples in the degree to which platform shape is reflected in flake cross-section.

This difference was generally maintained throughout the size classes in each material type except for the <1cm² class in the chert exhibiting a correlation of comparable significance to the quartzite and the >8cm² flakes in the quartzite retaining a non-significant correlation comparable to those of the larger chert flakes (table 4.47). Although the reasons for this are not, at present, clearly understood it will be shown that these differences appear to be associated with the variable effect of inertia threshold conditions on flake formation. It is suggested that they principally reflect the relative flaking qualities of the two materials and the size of cores. This will be discussed further below.

4.7b: Threshold Reactions

The core analysis has suggested that a proportion of the quartzite and all of the chert cores exhibited traits of shape, mass and platform angle consistent with the effect of powerful threshold conditions which limited reduction. By extending Dibble and Whittaker's (1981) experimental findings to the problem of threshold
### TABLE 4.47: Platform (Pt/Pw) and Sectional (t/w) Shape Correlation (r) by Flake Size

<table>
<thead>
<tr>
<th></th>
<th>Quartzite</th>
<th>Chert</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>p</td>
</tr>
<tr>
<td>&lt;1</td>
<td>.84</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>1-2</td>
<td>.68</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>2-4</td>
<td>.45</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>4-8,&gt;8</td>
<td>.61</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>&gt;8</td>
<td>.49</td>
<td>&gt;.05</td>
</tr>
</tbody>
</table>

### TABLE 4.48: Predicted Reduction in Pt holding Fa Constant (20mm)

<table>
<thead>
<tr>
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<th>Quartzite</th>
<th>Chert</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pa°</td>
<td>Pt</td>
</tr>
<tr>
<td>60</td>
<td>5.4</td>
<td>4.6</td>
</tr>
<tr>
<td>70</td>
<td>4.7</td>
<td>4.1</td>
</tr>
<tr>
<td>80</td>
<td>4.0</td>
<td>3.7</td>
</tr>
<tr>
<td>89</td>
<td>3.5</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Chert: Pt = -6.6 log[Pa] + .18Fa + 12.7

Quartzite: Pt = -11.3 log[Pa] + .22Fa + 21.1

### TABLE 4.49: Correlation of log[Pa] and Pt by Size Classes

<table>
<thead>
<tr>
<th></th>
<th>Quartzite</th>
<th>Chert</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fa</td>
<td>r</td>
</tr>
<tr>
<td>&gt;8</td>
<td>&gt;28</td>
<td>-.16</td>
</tr>
<tr>
<td>4-8</td>
<td>&lt;28-20</td>
<td>-.65</td>
</tr>
<tr>
<td>2-4</td>
<td>&lt;20-14</td>
<td>-.40</td>
</tr>
<tr>
<td>1-2</td>
<td>&lt;14-10</td>
<td>-.15</td>
</tr>
<tr>
<td>&lt;1</td>
<td>&lt;10</td>
<td>.05</td>
</tr>
</tbody>
</table>
In the elaboration of the discussion of threshold conditions in the core analysis it was pointed out that under conditions of increasing platform angle and constant platform thickness (i.e., PFA location) the knapper must increase the force necessary for the production of flakes. Where the core is of sufficiently high mass to accommodate this, large flakes may be removed at angles increasingly close to 90° without modification of PFA location. Where platform angle is increased on cores of reduced mass, an increasing proportion of the force applied to the core results in core motion and is unavailable for flake generation. The resulting inertia threshold conditions set a limit on the amount of force available for flake formation which is proportional to the inertia of the core. Under these conditions a knapper's attempts to increase force will simply be converted into increased core motion with a progressively reduced increment available for fracture.

Because Dibble and Whittaker's (1981) experimental core was mounted on a bench, it had a mass equivalent to that of the table and vice. Their experiment, therefore, simulated the effect of the inertia threshold by the holding of force as a constant. They discovered that as platform angle increased the PFA had to be moved closer to the platform edge and the platform thickness which would result in flake formation was reduced. Figure 4.35
Figure 4.35: Low inertia reaction model: $F_i$ - force imparted; $m$ - core mass; $F_a$ - force available for flake formation; $F_r$ - force required for given $Pa$ and $Pt$ values; $Pt$ - platform thickness; $Pa$ - platform angle.
illustrates the relationships among force and platform variables under conditions of high and low core inertia. The model differentiates between the force required for flake formation \( (F_r) \), that available \( (F_a) \) and force imparted to the core \( (F_i) \). Where core mass is high and the force required \( (F_r) \) is equal to, or less than, the force available a flake is formed with increased force compensating for high platform angles or increased platform thickness. As the model shows, both these platform variables are directly causally related to the force required for flake formation \( (A) \). Under inertial conditions increased force results in core motion, the force available approaches a constant and increased \( P_a \) or \( P_t \) results in no flake being formed \( (B) \). To mitigate this a negative relation between platform angle and platform thickness is formed and flakes are again produced \( (C) \).

To test this model on the flake samples the force available \( (F_a) \) was measured by the square root of ventral area \( (l \times w) \) which may be taken as directly proportional to the force used in the flake's formation (Phagan 1976). The test was divided into halves. In the first, the relation between \( P_a \), \( P_t \) and \( F_r \) should take the form \( P_a > F_r < P_t \) where increases in both \( P_a \) and \( P_t \) would result in the higher force requirements, and there should be no significant \( P_a > P_t \) relationship. This tests for the presence of high inertia conditions. The second half tests for low inertia conditions by using the degree to which \( F_a \) and \( P_a \) affect \( P_t \) (ie., \( F_a > P_t < P_a \)). An examination of the bivariate relationship between \( P_a \) and \( P_t \) in the
flake size class which proved to be most affected by inertial conditions showed the relationship to be a negatively sloped curvilinear function. To afford a closer fit to the regression assumption of a linear relationship a log transformation was used on Pa. The results of applying the model to the chert and quartzite sample are shown in figure 4.36. The two halves of the test are joined by an (=) sign.

Comparing the left side of the model first it can be seen that both Pa and Pt make stronger contributions to force requirement in the quartzite than in the chert sample and account for more of the variation (the path coefficients are all significant at p<.001). As would be expected there is no significant correlation between Pa and Pt on that side of the model and the standard errors of the coefficients are accordingly low. At this point, the model's features are consistent with the earlier path analysis which showed a tendency for a weaker relationship between platform and flake variables in the chert sample.

Turning to the right hand section of the model, the presence of inertia reactions is confirmed by the negative regression weight between log[Pa] and Pt when Fa is held constant. Again, the absolute effect in the quartzite sample is stronger than in the chert and the quartzite regression accounts for more of the variation (33% compared with 24%). The regression coefficients are again significant at p<.01 and the proportion of the variation (R^2) of the dependent variable explained by the two independents in each material is also highly significant.
Figure 4.36: Test for inertia threshold reaction for Quartzite and Chert flakes.
Table 4.48 shows the predicted reduction of platform thickness in both quartzite and chert samples for a flake of 4cm². The predicted decline of 35% in the quartzite is comparable to the 38% Dibble (1981:98) encountered in the Tabun Cave sample and higher than the 19% seen in the experimental results (Dibble and Whittaker 1981:293).

The utility of this model is, however, affected by the presence of a positive correlation between \( F_a \) and \( \log([Pa]) \). Although represented as noncausally related in the model because \( F_a \) is dependent only on the strength of the low inertia threshold, the weak collinearity of the variables has produced large standard errors for the estimated coefficients (or weights). While we can be 99% confident that the effect is negative in both materials and that there is an inertia reaction in the samples the relative strengths of the coefficients between the quartzite and the chert can not be uncritically accepted. The right hand side of the model would only work effectively if the assumption that all force inputs and subsequent force availability were under threshold conditions applied to all flake removals. Taken over all values of \( F_a \) the negative relationship between \( \log([Pa]) \) and \( Pt \) is averaged across the sample. The specific points in the reduction process where inertia conditions may be the most critical can, however, be gauged by comparing the strength of the negative correlation for each of the flake size classes (table 4.49).
Table 4.49 shows that threshold conditions, or more correctly the predicted response to threshold conditions, are most marked in the quartzite flakes in the 4-8cm² size class and tend to become progressively less evident as the flakes become smaller. In the chert samples the condition is not well marked and appears weakly only in the smaller flake classes. The decline in the strength in the correlation in the quartzite may reflect two factors. Firstly, the most expedient behaviour in the face of inertia conditions is to move the PFA closer, reduce $F_i$ and produce smaller flakes thus restoring the $F_a > F_r$ relationship of normal flake formation. A proportion of the flakes in the smaller size categories could, therefore, be expected to derive from this response to conditions higher up the $F_a/F_r$ scale, but show little of the $P_a>P_t$ relationship expected at that level. The second factor is that cores will arrive at threshold conditions at different stages of their reduction and the point where constant force availability becomes a problem can be expected across a range of core and resulting flake sizes. Having noted this, however, it is evident, particularly for the quartzite, that inertia threshold responses are concentrated in particular size ranges.

A comparison of the mean lengths of flakes in quartzite size class 4-8cm² ($\bar{x}=33\text{mm}$), the class to exhibit the most pronounced threshold response, with the mean face lengths of the single and rotated cores ($\bar{x}=36\text{mm}$ for both) shows there to be no significant difference between the size of the lengths (KS-one tailed test- $H_1$ - flake
lengths are shorter: 4-8cm²/Rn: D=.27, chi²=4.8, p=.09; 4-8cm²/Ro: D=.21, chi²=3.3, p=.19). The addition of the next most affected size class (2-4cm²) to the comparison also had no effect on the significance of the relationship with the single platform cores [Ro] (KS- D=.18, chi²=4.14, p=.13) but shows a significant effect on the multiplatform cores [Rn] (D=.34, chi²=11.7, p=.003). An examination of this result shows the distribution of the rotated cores to be bimodal with the larger peak derived from the inclusion of the R2 cores. With the removal of those 18 cores from the sample the comparison of 2-8cm² flakes showed a marginally significant difference to the remaining R1 cores (KS- D=.26, chi²=5.9, p=.05). The flakes are, however, within the range of flakes produced on the core faces seen in the comparison of the free face length to the scar lengths (x=16mm).

The lengths of the chert flakes most affected by threshold conditions tend to be smaller than the face lengths of both the chert multi and single platform cores (flakes: \( \bar{x}=14\) mm; Rn: \( \bar{x}=21\); Ro: \( \bar{x}=22\)). Although the differences are statistically significant the flakes fall within the range produced on the face again determined by the difference between the face and the scar lengths (which were from 9-12 mm). Comparison of the total chert flake sample with the distribution of the core face lengths shows the range of both to also be similar (flakes: \( R=5-36\); Rn: \( R=9-46\); Ro: \( R=13-48\)).
These data show that the presence of inertia threshold responses in the medium to large flakes in the quartzite range is coincident with the appearance of platform and, more directly, shape thresholds in the quartzite core sample and add further to the evidence that both artifact types may be derived from the same reduction process. The connection is possible because approaching high platform angles and poor free face geometry are both resolvable via increased force input. Where core inertia is limited so is the degree of increased force which may be applied, hence while threshold conditions on the core will be manifest in problems of overstability, they will be mirrored in flakes exhibiting inertia threshold responses. Although core and flake threshold conditions have been described as separate phenomena they are, as noted in the core discussion, highly related conditions.

While the chert flakes retain less evidence of inertia response there appears little reason to argue against the probability that they and the chert cores were also derived from a single reduction process, although the relation between them is not as clearly defined as in the quartzite. The reduced presence of inertia response in the chert flakes and the extremely reduced state of the cores is also consistent with the impression, that as a material, chert is generally easier to flake the quartzite.

The presence of inertia conditions in different flake size classes is averaged across the three proportional modes and it remained possible that different inertial
response were also present in each of the three modes. The testing of this procedure is limited in Mode A by the small size of some of the flake sub-samples, but the results that can be obtained for Modes B and C suggest that an inertial shift is present and that the higher correlations between platform and flake variables are associated with sub-threshold flake production.

Table 4.50 compares the log[Pa]>Pt and Pt/Pw>t/w correlations for quartzite flakes in modes B and C in size classes numbers >8cm², 2-8cm² and <1-2cm². The table shows that while the Mode B sample retained the distribution of correlation coefficients of log[Pa]-Pt consistent with that shown in the flake size analysis above, the Mode C sample exhibits a highly significant switch (z=3.05, p=.001) from a marginally significant positive correlation in the 2-8cm² sample to a highly significant negative correlation in the <1-2cm² size class. This is consistent with a shift between the modes in the point at which threshold conditions were affecting flake production. The positive pre-threshold conditions in Mode C, compared with the non-significant weak negatives in the Mode B sample, along with the substantially reduced threshold level, also suggest a more controlled reduction in the Mode C material. Using the Pt/Pw>t/w correlation as a general expression for the consistency of platform and flake relationships, it can also be seen, that a shift to highly significant correlations is associated with the onset of inertial conditions in the Mode B sample. This shift is also more
### TABLE 4.50: Test for Inertial Response in Quartzite Flake Modes

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<td></td>
<td>B</td>
<td>p</td>
</tr>
<tr>
<td>&gt;8</td>
<td>-.22</td>
<td>-</td>
</tr>
<tr>
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<td>-.53</td>
<td>&lt;.0005</td>
</tr>
<tr>
<td>&lt;2</td>
<td>-.02</td>
<td>-</td>
</tr>
<tr>
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</tbody>
</table>

### TABLE 4.51: Test for Inertia Response in Chert Flake Modes

<table>
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<tr>
<th>size</th>
<th>log[Pa]-Pt</th>
<th>Pt/Pw-t/w</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>p</td>
</tr>
<tr>
<td>&gt;8-2</td>
<td>.08</td>
<td>-</td>
</tr>
<tr>
<td>&lt;2</td>
<td>-.09</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>size</th>
<th>Pt/Pw-t/w</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;8-2</td>
<td>-.09</td>
</tr>
<tr>
<td>&lt;2</td>
<td>-.03</td>
</tr>
</tbody>
</table>
weakly represented in the Mode C.

The association of platform and sectional shape correlation with the onset of inertia threshold reactions can be equated with the general decline in core viability. In the quartzite the correlation between platform and sectional shapes is brought about principally by the higher $Pw/w$ relationship which indicates a greater consistency between platform and free face curvature. This may indicate a further response to low core inertia where the knapper maintains platform thickness but reduces the size of the flake by increasing the curvature of the platform and free face. There is some indication of this in the lower mean marginal flare of the quartzite flakes (see table 4.41).

The utilization of curved platforms could derive from one of the primary features of quartzite core reduction which is that the cores' free face lengths ($Fl$) are small relative to their mass (the regression equation being $Fl = .11m_q + 25.6$). In comparison, the chert cores achieve progressively longer face lengths per unit mass above 40gms ($Fl = .36mc + 16$). The difference in the regression coefficients is significant ($t=2.62$, $p<.01$) and indicates that knappers were more restricted in the quartzite in the degree to which they could utilize the size of the core for flake production. This is probably related to the relatively poor flaking qualities of the material (compared to chert) and the resulting need to retain high core mass to avoid inertia threshold conditions. Under
these restrictions, we may expect there to be a tendency to work around the core face to maintain free face length rather than into the body of the core, increasing the flake size and requiring force inputs which more rapidly approached inertia limits. As threshold conditions became more pronounced the procedure of curving the platform and free face appears to have been increased, producing the platform and sectional shape correlations seen in the sub-threshold quartzite flakes.

In the chert samples (table 4.51) the onset of inertia threshold response appears to occur only in the small flakes of Mode C.

These data suggest that core reduction in both the chert and quartzite flake samples was more complex than the previous analyses have shown. In the quartzite Mode B inertial responses occur early in the reduction process which appears relatively poorly controlled up to that point. At the onset of threshold conditions platform thickness was reduced as platform angle increased for a given available force and there is an increased uniformity in platform and flake variables. In the Mode C sample this change occurs for smaller applied forces which suggest either that: (a) the total reduction process was more carefully controlled (enabling platform angle to remain lower over an increased reduction length), (b) that smaller flakes were removed from relatively larger cores or (c) both the size of the input force and the core were generally reduced.
If the former (a) were in operation in the quartzite Mode C sample its flakes should exhibit lower mean platform angles and a more restricted variance about the mean. As the distributions of both Mode B and C platform angles exhibited no difference from that of normally distributed populations (at p=.01) a parametric F test showed, however, there to be no significant difference between the sample variances (F=1.37, df=98/31, critical F value at .01=2.11) and with means of 73° and 71° respectively there is no indication of the expected decline in the Mode C angles (t=.88, p>.2). Except for a marginal rise in the numbers of flakes with overhang removal there is also no substantial evidence of greater care in flaking in the Mode C material.

The second alternative (b), of removing small flakes from a relatively larger core, appears a simple process. It is made more complex, however, by the problem that removing flakes consistently smaller than the free face of the core allows, accelerates the increase in platform angle (see Kamminga 1982:90) and rapidly produces over stabilized platforms and free faces. As noted above, the solution to this is to elongate the flake such that it travels the length of the free face while reducing the width to maintain the reduced force required. The development of 'blade' production may, for example, be derived from the use of this procedure as a solution to the problem of removing small flakes from relatively large cores, as a means of core conservation. It will be
recalled that there is no evidence in the shape analysis of any elongation of Mode C flakes. As the process of producing such flakes would have to be maintained throughout the reduction sequence, it would also be expected to be associated with increases in flaking control which, as noted above, is not clearly evident.

This leaves the third possibility (c), that Mode C flakes were generally produced under conditions where the average core size was small (i.e., near to Mode I quartzite and average chert cores). These conditions are comparable to those seen in the chert material where evidence for the inertia response is restricted to the smaller flakes in Mode C.

The argument underlying this third suggestion is that the difference between the appearance of inertia responses between Mode B and C is entirely related to core size. As the appearance of inertia threshold conditions will reoccur throughout the process of reduction, what we are seeing is a variation in the point at which knappers respond to threshold conditions in an active manner. It is not behaviourally realistic to see the response as an act of referring to a core's place in some abstract scheme of overall reduction and reacting when a core reaches this fixed point. Such a point occurs at the limits of hand held reduction, which the Mode I quartzite and chert cores approach. In all other cases the response must be dependent on the degree of individual core reduction and may, therefore, occur differently on large and small cores relative to the extent of their
individual reduction. If the core is originally large the response will occur when the appearance of threshold conditions threatens to reduce the size and form of flakes which the knapper habitually produces from that size of core, even though the core is still relatively large. Conversely, if a subsequent reduction sequence is begun with the core when it is in a more reduced state, the active response will be later, when threshold conditions restrict the flake size expected from the smaller core. In other words, the expectation of flake size is directly related to the core size as it is encountered at the beginning of each sequence of reduction and the active inertia response initiated when the flake formation process (i.e., the expectation) is restricted. The term 'expectation' does not simply mean some clearly defined goal or template but, at a more fundamental level, a pattern of motor 'habits' (like PFA location and force input) which are reset at the beginning of each reduction sequence. The knapper's response may be simply a product of the restriction of these motor 'habits'.

In summary, although the investigation of the inertia threshold and its effects on flake forms are only at a preliminary stage, they point to the possibility of identifying critical points in the reduction process using the flake assemblage alone. The analysis of the internal relations of flake production has shown that quartzite flakes generally exhibit a greater relationship between the platform and flake dimensional variables, especially in relation to width and sectional shape, and that this
may be derived from the operation of threshold conditions. Both materials were affected by the presence of these conditions which varied between the flake modes of each material: Mode B in the quartzite retained reaction relationships consistent with threshold conditions relatively early in the reduction process in contrast to the Mode C which exhibited these reactions only in the smaller flake sizes. The chert Mode C material also showed the presence of inertial conditions over the same small flake sizes. This, it is suggested, is related to the tendency to react, in an absolute sense, to inertia thresholds later when reducing smaller cores. The reactions' association with small flakes in Mode C material is also consistent with the extended reduction of small cores which have reached the limit of hand held percussion. This differs from the chert Modes A and B material which retained no evidence of inertial reactions. This may be a product of the relatively low flaking forces required for the chert combined with a less extended reduction of chert cores in these modes.

The analysis has also suggested that threshold conditions will also influence the relationship between shape variables in an unexpectedly complex manner. As the inertia threshold restricts the conditions of flake formation, they appear to also produce a unexpected consistency in the internal relations of flake and platform variables. The increased consistency of these relationships seen in the quartzite material do not, as might be conventionally interpreted, represent the
increased control of the reduction process by the knapper aiming to produce flakes of a particular form, but their response to inertia conditions which restricted the formation of flakes.

4.8: Retouched Flakes

Retouched flakes were defined by the presence of sequential scalar removals along the flake margins. This class includes flakes with substantial edge modification and does not include removals assumed to reflect edge damage. While this, it may be argued, should restrict the numbers of modified flakes it is consistent with the aim of confining flake removal to the process of knapping; the analysis is not concerned with the damage incurred as part of the flake's function in manufacturing processes beyond that of lithic reduction. As will be argued in Chapter Six, it also does not require some assessment of secondary modification as a means of producing tools of a particular type preformed in some prior mental template i.e., the assumption that lithic reduction was primarily understood as a process which produced tools. A second reason for not pursuing this approach is that it has already been applied to the Ingaladdi assemblage by Sanders (1975).
Secondarily modified flakes are poorly represented in the underlying assemblage, comprising less than 1% of the total quartzite (0.95%) and chert (0.85%) flake numbers. As the numbers in each material type are low, the effect of random sampling variation had to be discounted before any comparison of the distribution of modified flake discard through time could be made with those of the artifacts types used in the preceding analyses. A one sample chi² test on the actual and expected distribution in each material type showed the quartzite flakes retaining a highly significant divergence from the expected (chi² = 42.23, df = 11, p < .001), while the chert showed no significant change (chi² = 18.9, df = 11, p > .05) and could not be assumed to demonstrate any variation in deposition through time.

Figure 4.37 shows the distribution of the secondarily modified quartzite flakes to be comparable to that of the unmodified flakes with which it retains the strongest correlation (tauP = .62). They correlate less well with the redirecting flakes (tauP = .55) and like each of the latter show little accord with the distribution of rotated (tauP = -.17) and unrotated cores (tauP = .12).

The correlation between the modified and unmodified flakes is reduced by the sharp decline in modified flakes below spit 16 and a trend towards higher proportions in the upper spits. A series of chi² tests shows that while there is no difference in the proportion of modified to unmodified flakes in Modes A and B (chi² = .56, df = 1, p > .5) there is a highly significant difference between modes A/B.
Figure 4.37: Quartzite modified flake percentage numbers by spit.
combined and Mode C ($\chi^2=11.3$, $df=1$, $p<.001$) which sees the proportional rate of discard more than double from 0.75% to 1.8%. Although the strength of the association is, in this case, extremely low (Cramer's $V=.04$), and Wright (1974) warns against over interpreting the $\chi^2$ test in such instances, it will be suggested that this rise is compatible with a change in the on-site organization of the reduction process which the Mode C material represents.

In relation to size (measured by length) both chert and quartzite modified flakes are larger than the average unmodified flake (KS-one tail- $H$ that retouched flakes are larger; quartzite: $\chi^2=34.25$, $df=2$, $p=3.6E-8$; chert: $\chi^2=20.6$, $df=2$, $p=3.3E-5$). A comparison of the distributions of the larger size classes in the quartzite ($4->8cm^2$) and the chert ($2->8cm^2$) with that of the modified, showed there to be no difference between the distributions (KS-one tailed- quartzite: $\chi^2=1.6$, $df=2$, $p=.44$; chert: $\chi^2=1.7$, $df=2$, $p=.42$). This indicates that the secondary modification of flakes occurred selectively on larger flakes which can be assumed to have been derived from a section of the unmodified population.

In terms of flake shape, the modified quartzite flakes tend to be squarer than the comparable class of unmodified ($1/w$: $\bar{x}=1.1$; KS- $D=.39>.33$, $p<.01$). This can not be seen to be a product of a predominance of distal modification as approximately 67% of the modified flakes retain flaking on the side margins alone. This suggests
the favouring of large squarish flakes for secondary modification. The modified chert shows no significant difference in elongation from the unmodified chert flake sample \((l/w: \bar{X}=1.05)\). Marginal flaring was also consistent in both material types.

To test for any change in the length of the modified edge as a proportion of the total available margin in the proportional modes the length of the modified edge was expressed as a fraction of its parallel flake dimension (i.e., length if the modification was along the side margins and width if it was distally located). The modified length averaged between 83 and 76% of the dividing dimension in quartzite and 101 and 67% in the chert (although the chert range is wider the difference is not significant and is strongly affected by small sample size). Neither the modified quartzite and the chert shows any significant tendency for the proportion of the flaked edge to change between the modal groups. While the quartzite Mode C material exhibits an increased disposition to discard modified flakes this was not apparently accompanied by any increase in the degree of retouch.

While it has been assumed in the flake analysis that the bulk of the debitage derived from primary core reduction, it remained possible that some proportion of the smaller flakes derived from the secondary modification of flakes. To test for this possibility the maximum length of the flake scars on the retouched edges was measured and compared with the two smallest flake size classes(<1cm²)
and 1-2cm²). In both the quartzite and chert the mean scar length proved to be on average smaller than the means of the two smallest flake size classes (Table 4.52).

The difference between the size of the scar lengths and the <1cm² flakes proved to be not significant (KS - quartzite: D=.31<.41, p>.05; chert: D=.34<.39, p>.05) in either the quartzite and chert material. When the <1 and the 1-2cm² classes are combined, however, the difference between flake scar and flake lengths becomes highly significant (KS - quartzite: D=.60>.32, p<.01; chert: D=.43>.39, p<.01). A comparison of the distributions also shows that from 35% of the quartzite and 23% of the chert scar lengths are below the 5mm lower limit of the flakes in the assemblage, indicating that a high proportion of these flakes would have been lost through the sieves employed on the site.

In terms of mean size, it is evident that flakes from secondary modification are statistically similar to the smallest sized flake class. Although from one third to one quarter would have been lost through the sieves, flake retouch could have contributed to the <1cm² size class. While the increase in secondary modification in the quartzite Mode C material is consistent with the rise in the proportion of the smallest flake class in the Mode, the flake analysis has shown that they have not significantly altered the shape, breakage and decortication patterns.
<table>
<thead>
<tr>
<th></th>
<th>scar length (mm)</th>
<th>flake length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;1</td>
<td>1-2</td>
</tr>
<tr>
<td>Quartzite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>8.3</td>
<td>12.6</td>
</tr>
<tr>
<td>Cv</td>
<td>62%</td>
<td>34%</td>
</tr>
<tr>
<td>Chert</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>7.5</td>
<td>10.2</td>
</tr>
<tr>
<td>Cv</td>
<td>64%</td>
<td>23%</td>
</tr>
</tbody>
</table>

TABLE 4.52: Mean Scar and Flake Length - Size Classes <1 and 1-2 cm²
4.9: Summary of Main Findings

1) The sources of quartzite and chert material which constitute the bulk of the assemblage are geographically strongly separated - the cherts are located at distances of $>30$ kms and quartzites from $>2$ kms. The quartzite cores appear mainly to be drawn from locally available material in the form of pebbles and large flakes. The difference between the proportions of cortex on the chert and quartzite cores suggests that the former had been more heavily reduced.

2) All cores exhibit high proportions of platforms with the threshold conditions of high platform angle and poor free face geometry consistent with the termination of reduction.

3) Chert cores also approach the boundary of hand held percussion flaking with low mean and tightly restricted mass distribution.

4) Both the rotated and unrotated quartzite core mass distributions exhibit bimodalities. These bimodalities are most evident in the lower half of the assemblage in both core types. In the upper half the modalities shift to smaller values in the R1 cores and became a single modality in the Ro's. While the distribution of the smaller Mode I cores is comparable to that of the chert sample the Mode II cores are significantly larger.
5) In both material types the rotated cores retain shapes consistent with high mass concentration and morphological stability which appears to have been instrumental in restricting further rotation. The unrotated cores in comparison show less tendency to overstabilized forms.

6) The mean masses of the quartzite Ro, R1 and R2 cores, although inconsistent with the predictions of a simple reduction model, are consistent with the operation of variable reduction trajectories and a variable disposition to reduce cores of higher than average mass.

7) While the deposition of unrotated and rotated chert and unrotated quartzite cores peak in spit 20 (tau=.72, tau_p=.70), rotated quartzite cores appear to predominate up to spit 17.

8) Although measures of the on-site rotation of cores (ie., redirecting flakes and non-flake debitage) showed a strong correlation with the discard flake numbers in the quartzite and chert material, only the discard of quartzite rotated cores show any significant correlation with flake discard and rotation measures. The overall correlation of core and flake discard remains weak.

9) The flake analysis showed the decline in flake size, from the lower to the upper spits, comprised three distinct proportional Modes A, B and C which are generally comparable in both material types.
10) While the proportions of secondary decortication flakes are comparable in both chert and quartzite, there is a tendency towards high proportions of primary decortication flakes and cortical platforms in the quartzite. Comparison of the cortical platforms in the three modal classes also showed there to be no significant difference between them and no major variation in cortical platforms between the modal size classes.

11) Quartzite flakes showed significantly higher proportions of sheared cones with some indication that it was more common in the central size classes.

12) The percentage of overhang removal was high in both material types and there was some indication of higher frequencies in both chert and quartzite Mode C.

13) Although flake shape showed no major shifts between the two major raw materials, size classes or modes, the path analysis showed a tendency for quartzite flakes to retain a more consistent relationship between platform and flake width and for accompanying stronger correlations between platform and sectional shape. While this may be seen as some indication of greater control the analysis of inertial reactions showed this consistency to be related to inertia conditions which were much more strongly apparent in the quartzite sample.

14) Inertial reactions appear higher in the quartzite Mode B flake sizes and substantially lower in the Mode C sample. The chert Mode C material shows comparable reaction levels to that of the quartzite. It is argued
that this reflects differences in the knapper's response to inertia threshold conditions on cores of differing size.

15) The retouched flakes form a small percentage of the assemblage and tend to be larger and squarer than the assemblage mean. There appears to be a higher proportion discarded in the Mode C material but these show no significant differences in form or length of retouch compared to the previous modes.

16) Although the maximum retouch scar length is an average smaller than the <1cm² flake class, secondary retouch could still have contributed to this class. The consistency in the proportions of cortical platforms in all modes suggests, however, that its contribution was not large.

A detailed interpretation of these findings and their implications for Australian prehistory will be presented in Chapter Six. The main point to be made here is that the analysis has revealed a complex reduction organization in an assemblage type which has generally been seen as behaviourally amorphous. This complexity is centred on the shifts in on-site core reduction and discard. As there is no evidence that the retouching of flakes contributed greatly to flake numbers, we can be confident that the bulk of the debitage derives from on-site core reduction. However, this reduction is not strongly correlated with core discard. The analysis has
examined three alternative hypotheses (section 4.5c) which might explain this discrepancy. As the strongest remaining, it is suggested that there is an increased disposition to transport reduced cores off-site and that this is accompanied in the final phases of the assemblage by a shift to the working of smaller material. The flake analysis has shown that these changes occurred in a series of definite modal steps. In the interpretation of the Modes, it will be argued that these should be viewed as recursive components of a single system, rather than the products of progressive and irreversible technological change.
CHAPTER FIVE

ANALYSIS OF THE OVERLYING ASSEMBLAGE

In Chapter Five the structure of the overlying assemblage is examined. This follows a similar analytical approach to that of Chapter Four in considering artifacts as products of reduction processes, and in its testing of the reduction model presented for the later assemblages in Chapter Two.

Two problems are examined in this chapter. Firstly, an examination of the production of lancet flakes is necessary, as these constitute the primary artifact type found in the overlying assemblage. As the production of these flakes occurred off-site, it required the separate examination of the lithic material on one of the local stone sources. Analysis of the internal relations of the flakes from this site and the Ingaladdi lancets allowed direct comparison with the underlying flake production. This procedure revealed a structural unity between the early and later flake production processes not previously seen. The second problem centres on whether we can separate, in terms of their respective reduction...
sequences, the retouch of pointed flakes and the production of invasively worked points, and whether the production of the latter follows a two stage unifacial, or the bifacial sequence seen in the production of Kimberley points.

5.1: Introduction to the Overlying Assemblage

The overlying assemblage is defined by stratigraphic unit I which incorporates spits 1-11. The material is drawn from the same six squares (A,B/8-10) used for the underlying assemblage. All material from A8 is included as spit 11 appears to be above any of the disturbance suspected in the square's lower spits. The effect of missing spits (encountered in B8/6, A9/9, B9/3/4/10 and B10/10) on the time series correlations has been corrected as for the underlying assemblage (see section 4.1).

A breakdown of the basic artifact types and materials is provided in Appendix A. The assemblage comprises 11,947 artifacts which includes all flake and non-flakedebitage, modified and unmodified material. Like the underlying assemblage, chert and quartzite predominate (99.2% of all artifacts), with other materials contributing 0.8% of the total. Of these 81% are volcanics (mainly local basalt), with declining proportions of quartz, silcrete and mudstone.
Table 5.1 shows the total numbers of quartzite and chert artifacts and the percentage of chert. Compared to the underlying assemblage (table 4.1), the chert percentage is consistently low, except for spits 10 and 11 where similar values are retained. These are larger than might be expected by chance deviation from the combined overlying average (zI: z>5.4, p<.003 [see Langley 1970:245]) and appear to be related to the final phases of the underlying assemblage.

The percentage numbers of total flaked artifacts, including cores, redirecting flakes, core fragments, retouched flakes and non-flake pieces for each material are given in table 5.2. The table shows the overall percentage to be comparable in both materials, with the quartzite proportion exhibiting a significant rise above the 4% average seen in the underlying assemblage (table 4.2) (proportion of flaked to unflaked - chi²=17.71, df=1, p<.001). The proportion of flaked to unflaked in the chert also shows a significant increase to that of the underlying assemblage (chi²=6.68, df=1, p<.01). Significant departures from the remaining combined average occur in spits 5, 6, 7 and 9 (zI, z>2.58, p<.01) in the quartzite sample, with no major variation in the chert.

Both the rise in the total of modified quartzite and chert artifacts, compared to that of the underlying assemblage, is due largely to a substantial increase in the levels of retouched flakes (table 5.3). These percentages, substantially higher than the less than 1%...
### TABLE 5.1: Total Numbers of Quartzite and Chert Artifacts

<table>
<thead>
<tr>
<th>spit</th>
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<th>chert</th>
<th>chert%</th>
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<tbody>
<tr>
<td>1</td>
<td>630</td>
<td>233</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>545</td>
<td>235</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>429</td>
<td>181</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>682</td>
<td>307</td>
<td>31</td>
</tr>
<tr>
<td>5</td>
<td>871</td>
<td>379</td>
<td>29</td>
</tr>
<tr>
<td>6</td>
<td>1376</td>
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<td>30</td>
</tr>
<tr>
<td>7</td>
<td>1196</td>
<td>319</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>1892</td>
<td>366</td>
<td>16</td>
</tr>
<tr>
<td>9</td>
<td>617</td>
<td>216</td>
<td>26</td>
</tr>
<tr>
<td>10</td>
<td>205</td>
<td>149</td>
<td>42*</td>
</tr>
<tr>
<td>11</td>
<td>264</td>
<td>234</td>
<td>47*</td>
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</tbody>
</table>

### TABLE 5.2: Percentage Flaked by Spit

<table>
<thead>
<tr>
<th>spit</th>
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<th>chert</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>2</td>
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</tr>
<tr>
<td>3</td>
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<tr>
<td>6</td>
<td>12*</td>
<td>8</td>
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<tr>
<td>7</td>
<td>10*</td>
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<td>8</td>
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<td>5</td>
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<tr>
<td>9</td>
<td>13*</td>
<td>7</td>
</tr>
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<td>10</td>
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<td>13</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

\[ \bar{X} = 9.4\% \quad 8.6\% \]
level which predominated in the underlying assemblage, mark the most fundamental difference between the two assemblage structures. It is also evident from the difference between the quartzite and chert percentages that the structural change is most clearly exhibited in the quartzite material.

The retouched quartzite flakes are dominated by modified lancet flakes which constitute over 93% of the retouched quartzite material. This contrasts with the chert in which lancet retouch accounts for only 37%. The retouched quartzite lancets also exhibit some temporal separation in formal type with the peak discard of bifacially worked lancets occurring in spit 8, before the unifacially flaked in spit 6 (figure 5.1). The definition of uni and bifacial lancets is arbitrarily based on the presence and absence of ventral and dorsal flake removals and does not, at this stage of the analysis, relate directly to the separation of bifacial and unifacial 'point' reduction processes distinguished in Chapter Two. The diachronic separation does, however, suggest some variation in reduction mode.

As the samples of both bifacially and unifacially worked lancets is low in the chert, it is not possible to assess confidently their association with the quartzite lancet discard. The distribution of the total retouched chert flakes appears, however, to be more strongly associated with the quartzite plain and unifacial lancet discard (figure 5.2).
### TABLE 5.3: Percentage Retouched Flakes

<table>
<thead>
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<th>chert</th>
</tr>
</thead>
<tbody>
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<td>1</td>
</tr>
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<td>2</td>
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<tr>
<td>11</td>
<td>2</td>
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</tbody>
</table>

$\bar{x}$ 7.2% 2.9%

### TABLE 5.4: Ratio of Flake (a) to Non-Flake Debitage (b)-a/b

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<tr>
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<td>1.4</td>
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<td>1.4</td>
<td>1.9</td>
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</tr>
<tr>
<td>11</td>
<td>1.7</td>
<td>1.4</td>
</tr>
</tbody>
</table>

$\bar{x}$ 1.7 1.5
Figure 5.1: Distributions of the plain (unretouched) quartzite lancet (above) and the unifacially and bifacially worked quartzite lancet flake percentage numbers by spit.
Figure 5.2: Chert retouched flake and flaked piece percentage numbers by spit.
Turning to the bulk of the assemblage, the flake to non-flake debitage ratio (table 5.4) is comparable in both materials with mean values of 1:1.5 and 1:1.7 for chert and quartzite respectively. The overall quartzite ratio shows some decline compared to that of the underlying assemblage (table 4.3) which is statistically significant ($\chi^2=21.3$, df=1, $p<.001$), but technically dubious. The quartzite ratios also appear to exhibit some ordering in time, with higher values in the upper spits (1-4) and in spit 11 and some tendency to lower values in the middle. A one sample runs test shows, however, that there is no statistical basis for this suggestion. The mean chert ratio is comparable to that of the underlying assemblage with no evidence for any time dependent ordering.

Both the quartzite flake and non-flake debitage retain high time series correlations at $\tau=.85$ with negligible time dependence ($\tau_p=.86$). Both the quartzite distributions (figure 5.3) exhibit similar patterns of declining modalities in spits 8 and 6, corresponding with the variation in lancet retouch discard. In contrast, the chert distributions show a weaker correlation through time ($\tau=.47$, $\tau_p=.53$) despite their overall similarity (figure 5.4). This decline in correlation strength appears to be due to the statistic's sensitivity to low level variation in the relatively featureless distributions. Although the chert distributions exhibit a substantial peak in spit 6 alone, the flake debitage's correlation with the quartzite flake debitage remains moderately high ($\tau=.6$, $\tau_p=.65$),
Figure 5.3: Quartzite flake and non-flake debitage percentage numbers by spit.

Figure 5.4: Chert flake and non-flake debitage percentage numbers by spit.
along with that of the retouched chert flakes (tau=.57, tau_p=.55) (figure 5.4).

The trend towards lower debitage mass, seen in the underlying assemblage, is continued in the overlying with mean flake masses of 0.75gms for the quartzite and 0.64gms for the chert; substantially smaller than the means of 3.1 and 1.7gms seen in the lower assemblage. Using table 4.4 and 5.5 it can be seen that the flake means drop rapidly from spit 12, reaching consistently lower values from spits 9 and 8 on. The quartzite non-flake values are comparable to those of the underlying assemblage until a rapid decline again between spits 9 and 8. The chert exhibits a similar but less distinct trend.

The decline in mean flake sizes can also be seen in the shift towards higher proportions of flakes in the <1cm² class at the expense, primarily, of flakes >4cm². The proportional shift mirrors the data above, with the quartzite showing no consistent trends after large flake (>8cm²) proportions decline in spit 8 (table 5.6). The chert flakes also exhibit a similar pattern after spit 9. Beyond the small rise in the larger size classes in spits 9-11 there appears to be no extended sequence of modal clusterings comparable to those seen in the underlying material (see table 4.30).

To illustrate this a series of Ward’s cluster analyses were carried out on the flake proportions in both chert and quartzite. To aid calculation and to provide comparable stratigraphic groupings to those used in the
### TABLE 5.5: Mean Non-Flake and Flake Debitage Mass (gms) by Spit

<table>
<thead>
<tr>
<th>Spit</th>
<th>Non-flake</th>
<th></th>
<th>Flake</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quartzite</td>
<td>Chert</td>
<td>Quartzite</td>
<td>Chert</td>
</tr>
<tr>
<td>1</td>
<td>1.3</td>
<td>.8</td>
<td>.9</td>
<td>.7</td>
</tr>
<tr>
<td>2</td>
<td>.9</td>
<td>.4</td>
<td>.7</td>
<td>.6</td>
</tr>
<tr>
<td>3</td>
<td>.7</td>
<td>.6</td>
<td>.9</td>
<td>.5</td>
</tr>
<tr>
<td>4</td>
<td>.5</td>
<td>.6</td>
<td>.5</td>
<td>.5</td>
</tr>
<tr>
<td>5</td>
<td>.5</td>
<td>.8</td>
<td>.7</td>
<td>.5</td>
</tr>
<tr>
<td>6</td>
<td>.6</td>
<td>.5</td>
<td>.7</td>
<td>.7</td>
</tr>
<tr>
<td>7</td>
<td>.8</td>
<td>1.3</td>
<td>.6</td>
<td>.5</td>
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<td>8</td>
<td>.5</td>
<td>.5</td>
<td>.6</td>
<td>.4</td>
</tr>
<tr>
<td>9</td>
<td>1.1</td>
<td>1.4</td>
<td>1.0</td>
<td>.7</td>
</tr>
<tr>
<td>10</td>
<td>2.5</td>
<td>.7</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>11</td>
<td>2.6</td>
<td>4.1</td>
<td>1.4</td>
<td>1.2</td>
</tr>
<tr>
<td>X</td>
<td>.8</td>
<td>1.0</td>
<td>.8</td>
<td>.6</td>
</tr>
</tbody>
</table>

### TABLE 5.6: Quartzite Flake Size Proportions (%) by Spit

<table>
<thead>
<tr>
<th>Spit</th>
<th>&gt;8</th>
<th>4-8</th>
<th>2-4</th>
<th>1-2</th>
<th>&lt;1</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1</td>
<td>5.2</td>
<td>13.5</td>
<td>41.4</td>
<td>38.8</td>
<td>348</td>
</tr>
<tr>
<td>2</td>
<td>.6</td>
<td>4.5</td>
<td>10.7</td>
<td>32.4</td>
<td>51.8</td>
<td>309</td>
</tr>
<tr>
<td>3</td>
<td>1.2</td>
<td>1.6</td>
<td>11.9</td>
<td>42.6</td>
<td>42.6</td>
<td>244</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>1.3</td>
<td>8.1</td>
<td>30.4</td>
<td>60.2</td>
<td>397</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>4.2</td>
<td>13.0</td>
<td>37.9</td>
<td>44.6</td>
<td>377</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>2.3</td>
<td>7.9</td>
<td>34.4</td>
<td>55.1</td>
<td>619</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2.6</td>
<td>10.8</td>
<td>41.2</td>
<td>45.2</td>
<td>573</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>3.5</td>
<td>14.4</td>
<td>39.1</td>
<td>42.8</td>
<td>919</td>
</tr>
<tr>
<td>9</td>
<td>2.1</td>
<td>4.9</td>
<td>10.5</td>
<td>29.0</td>
<td>53.5</td>
<td>286</td>
</tr>
<tr>
<td>10</td>
<td>2.7</td>
<td>6.3</td>
<td>9.9</td>
<td>36.0</td>
<td>45.1</td>
<td>111</td>
</tr>
<tr>
<td>11</td>
<td>3.2</td>
<td>5.1</td>
<td>17.3</td>
<td>29.5</td>
<td>44.9</td>
<td>156</td>
</tr>
</tbody>
</table>
Figure 5.5: Dendrograms of spit combinations grouped according to difference in flake proportions - quartzite and chert.
underlying analysis adjoining spits were combined to produce two sets of groupings for each material. The resulting dendrograms (figure 5.5) show the clustering in each material to be substantially tighter than for the underlying assemblage, with no evidence for the degree of modal separation seen especially in the underlying quartzite flake sample. With final $E^{1/2}$ values of less than 20 for each of the overlying assemblage groupings the overall level of clustering is comparable to that of some of the individual underlying modal groups. This suggests that the overlying assemblage may, in terms of the earlier assemblage's variation, be comparable to a single behavioural mode representing a period of extended uniformity in reduction behaviour.

In summary, the overlying assemblage may be characterized by three primary features:

1) The appearance and dominance of the lancet flake in the quartzite artifacts and the temporal separation of the plain lancet discard and the bifacial and unifacial lancet reduction.

2) The weak development of the lancet component in the chert assemblage.

3) A relatively high percentage of retouched flakes associated with small sized debitage of uniform size proportion through time.
As they are the dominant component, the following analysis will concentrate on the examination of the quartzite lancet flakes in the assemblage. This will include a detailed examination of the production of lancet flakes and the relation of these flakes to those of the underlying assemblage, using both the unretouched lancets in the Ingaladdi assemblage and the cores and flakes from a stone source (SS/1) which features a lancet production process. The analysis will also test lancet reduction models presented in Chapter Two by utilizing the distinction between scalar, invasive, bifacial and unifacial reduction modes to separate the A-1-1 from the C-1-1 and D-1 reduction processes (see figure 2.10).

5.2: Lancet Flake Production

5.2a Historical accounts of lancet production

The earliest account of lancet flake production comes from Baines (1865/7) who recounted a process of manufacture as it was described to him by A.C. Gregory:

The native operator squatting down before a block, large and solid enough to be used as an anvil, selects a pebble of convenient form and size, as nearly oval as possible, and five or six inches in length; one end of this he strikes on the larger block so as to detach a fragment which leaves a flattened base, then, taking it vertically in the hands, he strikes the edge of the base upon the anvil, detaching in
succession two ovate chips, as nearly equal in form and size as possible, and this if cleverly done, leaves a sharp and well-defined central rib, with a slightly hollows facet on either side; the next blow, if successful, should spit off another portion, small in the base, spreading slightly as it goes upwards, and finally tapering to a keen point, with the rib previously formed running truly along the centre. Baines (1865/7:260-1)

Baines goes on to note that the process requires the production of three flakes in order to produce the final 'blade', and that there would have been many failures before the desired flake was produced.

Although Baines' account contains the essential geometrical elements of lancet production confirmed by later accounts, the description of an anvil technique remains a unique and problematic element. While the technique may have been used to establish the striking platform, it would appear to lack the fine control of force and PFA location which is necessary for the production of lancet flakes (see Ackerman's account below). There is also no mention of platform overhang removal which the following analysis shows to be important in establishing the correct relationship between platform and flake dimensional variables. A further practical problem is that if knappers adopted the position illustrated by Baines (1865/7: fig. 1) their faces and chests would have been showered by the detached flakes.

These inconsistencies suggest that the Baines/Gregory description is not based on an observation of an actual sequence, but on artifact study and intelligent surmise.
The limited reference to Aboriginal activities in Gregory's journal also argues against the probability that this remarkable account derived from direct observation. Despite this limitation, the account is generally comparable to the two major ethnographic descriptions supplied by Roth (1904:17) and Spencer and Gillen (1904:641-643).

As noted in Chapter Two, the term 'lancet', derived from Roth's (1904) description of the flake and its production, is used here to refer to a class of elongated primary flakes distinguished by the presence of a strongly developed dorsal ridging, often terminating in a strong point (see figure 2.9). The production process, as described by Roth, is essentially similar to that of Baines', except that the core was held in the palm of the hand and struck with a hammerstone. The core is prepared by the removal of flakes which set up guiding ridges:

"...two must at least be removed before one suitable for a proper knife blade can possibly be obtained..." (Roth 1904:17). These initial removals establish the correct core geometry for lancet formation:

The straighter and longer the lines of junction of the facets [...] the straighter and longer will be the flake, which may possibly next be procured. Here, however, the special skill of the artificer comes into play: namely, to strike with such nicety just on the lower margin of the surface-slope between the angle of junction of any two facets that a lancet is produced with the ridge preserved to its very tip. Roth (1904:17)
The guiding ridge may be multiple or singular depending on the number of previous removals. Spencer and Gillen's (1904:641-3) description is similar to that of Roth's, emphasizing the geometric relationships of flake removals within the sequence.

Ackerman (1976) has replicated the production of lancet flakes following these ethnographic accounts. His description of the process includes the use of overhang removal as a step; strengthening platforms and thinning the flake butt before removal. The mean platform angle of the resulting flakes was 73° (ranging from 64° to 84°) which is consistent with normal percussion flaking. Core rejuvenation was carried out by repeating the preliminary preparation. Once a core had been properly set-up, with careful reduction it was possible to produce a range of lancet sizes as the core was reduced.

While Spencer and Gillen (1904:641-3) noted the skill required to produce 'knives' they state that the production of "really good knives is more or less a matter of chance" (1904:643). Spencer (1928:503) later noted that only one in twenty flakes were considered suitable. Roth (1904:16) also observed 300 flakes being produced before a suitable knife was selected, and Thomson (1949a:55) stated that, "...out of the hundreds of flints struck off, all but a dozen or so would be rejected".

Ackerman (1976:122) has argued that this gives a distorted view of what is in his experience a "precise and controlled process" which can regularly produce suitable...
flakes. He goes on to suggest that this distortion may be due to a number of factors, including informants unfamiliar with the process and the utilization of poor material (which Roth's example seems to imply). The demonstration of the process by old men, no longer able to control the reduction in the Roth (1904) and Thomson (1949a) accounts can also, Ackerman suggests, have distorted the picture. Spencer's ratio may include all preparation flakes and is conditioned by the high aesthetic selection criteria associated with the prestige of the Renner Spring Quarry where the observation was made (see Harney and Elkin 1949:163). This may also apply to Thomson's observations at the Ngilipitji Quarry.

While these are valid objections, Ackerman's craftsman-like approach to lithic replication cannot be seen as a completely neutral factor in his assessment of the effectiveness of the process of lancet production. The high numbers of lancets in north-western sites and their complex reduction noted in Chapter Two does, however, suggest a more effective procedure than the major ethnographic accounts, where lancet flakes are highly valued exchange goods with little local archaeological visibility beyond the quarries where they were produced.
5.2b: Lancet Production and its relation to the Underlying Assemblage

As the types of cores discarded in the overlying assemblage appear unrelated (see section 5.9 below) to lancet production, an examination of the stages of core reduction associated with lancet flake formation on one of the local quartzite sources is a necessary first step in the lancet analysis. The most concentrated of these, with densities from 9-32 artifacts/m², SS/1, is located approximately 7kms ESE of the Ingaladdi shelter (site number [2] figure 3.1). The source is derived from one of the pebble pavements which form on the thin alluvium bands between the low rocky ridges of the Napier land system (see Appendix C). Although erosion along the side of the track which runs by the site shows an underlying stratum of vein quartzite, there appears to have been no sustained attempt to excavate this material (plates 5.1 and 5.2).

The site is primarily related to the production of lancet flakes with the presence of the large characteristic prismatic cores, a high percentage of lancet flakes (28%) and a high core to flake ratio (1:10.6), which is comparable to that found on the extensive Pine Creek quarries - noted by Eylmann (1908:331) to be associated with the production of lancet flakes. (Baker [1983] and writer's unpublished research produced ranges of 1:3-25 cores/flakes for these quarries.)
Plate 5.1: View of SS/1 looking north-west. The track to Ingaladdi is on the middle right.

Plate 5.2: Detail of SS/1. Typical lancet cores can be seen in the middle and bottom right.
Because of the difficulty of sampling and transporting the large sized material on source sites, much of the artifact recording was carried out on-site, restricting the information which could be collected. The sample examined was derived from seven 3m² sample areas, selected to cover the range of artifact densities and core and flake combinations over a total distribution measuring approximately 80*40m. The total recorded material included 35 cores, 104 typologically standard lancet and 267 non-standard flakes. Due to the need to maximize the information obtained in a restricted time, two working assumptions were used:

1) That the reduction mode on the site was representative of the core reduction associated with the production of lancet flakes. As noted above there is substantial support for this assumption.

2) That the lancet flakes in the Ingaladdi assemblage derived from a similar (if not identical) reduction process and could be considered representative of its production.

As the relation between the discarded cores and flakes in the Ingaladdi assemblage was not as clear as that on the stone source, it was decided that the primary comparison between the reduction processes of the underlying and later assemblage would be initially between the flake products in the shelter and those on the stone source, SS/1. Working on the assumption that the Ingaladdi lancet flakes and those of SS/1 represented the products of a
single reduction process allowed the stone source to be used to produce more information on the parts of the process which were missing in the main assemblage ie., the cores and non-lancet flake debitage.

With an average mass of 755gms and a range of 80–4620gms the cores on SS/1 are substantially larger than those found in the underlying Ingaladdi assemblage (see table 4.13). The frequency of rotation is also reduced to 26%, approximately half that seen in the underlying assemblage. This is consistent with the correlate of rotation and low situational availability, and will be used in Chapter Six to explain the change in frequency of rotation through time in the underlying assemblage. A further feature of behavioural similarity is the comparable mass of the rotated (Rn) and unrotated cores (Ro) on the stone source. With means of 1004gms and 840gms respectively (MW-U z=-.45, p=.32) they again suggest that the disposition to rotate individual cores is dependent on core size at the termination of the initial platform.

While comparison of the lancet component of SS/1 will be made with the Ingaladdi sample in section 5.3, the remainder of this discussion will focus on the 'non-standard' flake component. These are flakes associated with lancet reduction which do not retain all of the defining lancet traits. To facilitate this analysis a grab sample of 90 non-standard flakes was obtained from areas 6 and 7. These areas represent middle to lower densities and were considered the most representative of the site
generally. The sample of non-standard flakes will be termed 'flakes' in the discussion, as opposed to the lancets or lancet flakes.

The mean size of the flakes on the stone source is substantially larger than that seen in the Ingaladdi assemblage. Using the five size classes, only 4% of the original sample of SS/1 flakes are in the four <8cm² categories with the remaining 96% in the >8cm²; the average ventral areas of the lancet and non-standard components being 30 and 37cm² respectively. While the mean length of the underlying quartzite flakes falls between 21-25mm the mean of the SS/1 debitage lies within 68-86mm (at 95% confidence limits). Even allowing for the loss of very small flakes in the surface collection comparable coefficients of variance (51 and 44% respectively) show the clear separation of both populations.

The percentage of primary and secondary decortication flakes is given in table 5.7. Compared to the underlying quartzite percentages provided in table 4.31, there is a significant difference (\( \chi^2 = 38.2, \ df=2, \ p<.001 \)) between the proportions of primary, secondary and tertiary flakes in the two assemblages, with a substantial rise in secondary decortication flakes in the SS/1 assemblage. As both samples are derived from primary core reduction of identical material the difference in proportions appears to correlate with a greater degree of core reduction in the underlying assemblage.
**TABLE 5.7: The Percentage of Decortication Flakes in the Second SS/1 Non-Standard Sample**

<table>
<thead>
<tr>
<th></th>
<th>primary</th>
<th>secondary</th>
<th>total no.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3%</td>
<td>30%</td>
<td>90</td>
</tr>
</tbody>
</table>

**TABLE 5.8: Flake Shape in SS/1 Non-Standard and the Underlying Quartzite Flakes**

<table>
<thead>
<tr>
<th></th>
<th>1/w</th>
<th>t/w</th>
<th>Pt/Pw</th>
<th>w/Pw</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS/1</td>
<td>1.9</td>
<td>.42</td>
<td>.52</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>29%</td>
<td>41%</td>
<td>51%</td>
</tr>
<tr>
<td>Underlying</td>
<td>1.3</td>
<td>.31</td>
<td>.39</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>44%</td>
<td>45%</td>
<td>49%</td>
</tr>
</tbody>
</table>
At 39%, there is also a significant rise in the percentage of cortical platforms in the SS/1 sample compared to that of the underlying ($\chi^2 = 116, \ df = 1, \ p < .001$) in which the overall average is 8% (see table 4.35). This can again be related to the degree of reduction - specifically core rotation.

Comparison of platform modification, defined by the presence of platform flaking and overhang removal, present a more compatible picture. The frequency of flaking at 5% is comparable to the 9% exhibited in the underlying quartzite flakes and shows no significant difference in proportion ($\chi^2 = 1.3, \ df = 1, \ p > .05$). While at 69% the frequency of overhang removal in the SS/1 material is higher than the average in the underlying of 54%, it will be remembered that there was a marginally significant difference between the Modes A/B and C in the overhang removal frequency. Comparison of the 50% average in the quartzite Modes A and B with the proportions in the SS/1 sample shows a significant difference ($\chi^2 = 7.8, \ df = 1, \ p < .01$). This is not present in the later Mode C material which retains a frequency of 71%, directly comparable to that of SS/1 ($\chi^2 = .009, \ df = 1, \ p > .9$). Both the lancet and the Mode C quartzite reduction exhibit an increased concern for platform geometry which, it will be argued below, forms an important link between the underlying and later lancet reduction processes.

There appears in the SS/1 sample to be no relationship between overhang removal, platform flaking
and cortical platforms, and none between platform modification and the degree of dorsal cortex. This is again similar to the underlying assemblage.

Table 5.8 compares the underlying quartzite and the SS/1 non-standard flake samples in terms of the four shape indices used in the analysis of the former. The table shows the SS/1 flakes to be more elongated and thinner relative to width. The platform shape in contrast tends to be thicker relative to the platform width and there appears to be little change in the degree of marginal flare. These are confirmed by a series of two tailed Kolmogrov-Smirnov tests which produce highly significant differences between the l/w, t/w and Pt/Pw distributions but not between the marginal flare (w/Pw): (l/w: D=.37>.28; t/w: D=.3>.23; Pt/Pw: D=.36>.23, p<.01 and w/Pw: D=.07<.18, p>.05). As the sample sizes are large the test on w/Pw also shows the marginal flare distributions to be comparable in dispersion as well as central tendency.

There is also no significant difference between the mean platform angles of 73° for the underlying and 76° for the SS/1 flakes. The pattern of breakage also appears comparable with the overall percentage of broken flakes in the SS/1 sample at 47% and 40% in the underlying. The percentage of sheared cones at 11 and 10% respectively, with equally comparable snap proportions suggest that the bulk of the breakage of flakes, in both assemblages, is primarily attributable to the process of quartzite reduction and not to post depositional factors which are
assumed to have varied between the two sites. For instance, extensive post depositional treadage would be expected to have significantly different effects on assemblages with flakes of substantially different modal size.

5.2c: The comparison of the internal structure of lancet reduction

The path analysis of the relation of the platform to flake dimensional variables was introduced in Chapter Four to facilitate the comparison of the variables which structured chert and quartzite flake form in the underlying assemblage. In this analysis the same causal model will be used to compare the SS/1 non-standard flake sample to that of the quartzite flakes from the underlying assemblage.

The underlying flakes will be considered as a unit for two reasons. Firstly, although it was demonstrated that shifts in inertia threshold reactions between the modal groups had affected platform and flake variables, these threshold responses are confined principally to individual size classes within the Modes and should be considered as a feature of the core reduction process which dominated the underlying assemblage. Secondly, while it would appear logical to compare the lancet reduction with the later Mode C material alone, as it
directly precedes the appearance of the later overlying assemblage, it will be remembered that the diachronic relationship between the reduction modes was not clearly established. There is no evidence that the modal sequence is historically inevitable, such that, Mode B precluded A, C precluded B and that Mode C was the immediate precursor to lancet reduction. The selection of individual modal groups can not, therefore, be made without the implicit assumption that lancet production, as a whole, derived from some facies of underlying core reduction (ie., Mode C) which may only be site specific.

Table 5.9 presents the correlation coefficients for the SS/1 and underlying flake platform and dimensional variables. While the SS/1 sample exhibits higher coefficients overall the central correlations for the path analysis, Pt>l, Pw>w, Pt>t and Pt>Pw, show no significant difference between the two samples.

The presence of a weak negative correlation of marginal significance between platform angle and platform thickness (r=-.25, .05>p>.01) also suggests the presence of a inertia threshold reaction in the SS/1 sample. With the large size of the cores involved and the flakes produced, (some greater than 150mm in length) it is equally likely, that this correlation relates to the approach of the upper limits of the knapper's ability to generate the force required to remove large flakes. The correlation between the platform and the flake sectional indices, which was associated with inertia threshold conditions in the underlying flakes, also shows only a
<table>
<thead>
<tr>
<th>TABLE 5.9: Pearson's r Correlation Coefficients for Platform and Dimensional Variables - Quartzite Flakes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SS/1</strong></td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>w</td>
</tr>
<tr>
<td>t</td>
</tr>
<tr>
<td>Pw</td>
</tr>
<tr>
<td>Pt</td>
</tr>
</tbody>
</table>

N=75, critical value .3 (p=.01)  
*N=42, critical value .39 (p=.01)  

<table>
<thead>
<tr>
<th>TABLE 5.10: F Values for Analysis of Covariance Test for Slope Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>df</strong></td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>P12 l</td>
</tr>
<tr>
<td>Pt t</td>
</tr>
<tr>
<td>Pw t</td>
</tr>
<tr>
<td>Pt Pw</td>
</tr>
</tbody>
</table>
weak relation in the SS/1 sample at $r = .29$ compared to $r = .64$ in the latter.

Figure 5.6 illustrates the path models of the SS/1 and the underlying quartzite flakes samples. The first thing to note is that the error terms (the percentages in the brackets referring to the percentage unexplained by the independent variable) which are dependent on the correlation coefficients are generally comparable between the two structures. The difference between the two processes is not, therefore, one of increasing bivariate control. The second order partial correlation between flake thickness and width, factoring out the effect of platform width and thickness $r_{t\leftrightarrow w,Pt,Pw}$ shows, however, some degree of decline in the independence of the $t\leftrightarrow w$ correlation in the SS/1 sample. This indicates some increase in the influence of platform variables, which account for 34% of the variation in $t\leftrightarrow w$ in the SS/1, compared with 13% in the underlying.

The most immediate difference between the two models lies in the change in the regression weights (or the rate of change which the independent variable effects on the dependent). In the relation of platform to flake variables the SS/1 sample retains higher coefficients, indicating an increased effect on the flake form by changes in the platform variables, such that an increase in $Pa$ and $Pt$ (in $\tan Pa[Pt]$ or $P_{12}$) will tend to produce a longer flake than the equivalent values in the underlying model. This increase is, however, not great on the
Figure 5.6: Path analysis models for the non-standard lancets from SS/1 and the underlying quartzite flake sample.
marginal flaring between the two samples (table 5.8) and of probably little significant affect on the profile flare \((t/Pt)\).

A series of covariance tests for slope interaction (see Blalock 1981:519-525) between the causal paths of the SS/1 and underlying samples for each bivariate combination produced significant differences between the slopes of the \(Pw>Pt\) and \(Pt>t\), and a marginally significant difference between the regression weights of \(Pw>Pt\) (table 5.10).

Of most comparative interest, however, is the non-significant difference between the weights of the \(Pt>Pw\) regressions. This may be more easily seen in the similarity of their regression equations:

\[
\begin{align*}
\text{SS/1:} & \quad Pw = 1.3Pt + 8.5 \\
\text{Underlying:} & \quad Pw = 1.6Pt + 4.7
\end{align*}
\]

The estimate of the common slope is \(bw=1.4\).

As the slope is greater than unity the index of platform shape will shift from lower to higher values as platform thickness increases.

Despite the results of the shape analysis, which showed that in terms of the platform shape indices both the SS/1 and the underlying quartzite flakes could be considered to originate from separate populations, the former can be directly derived from the latter via its comparable rate change of Pt on Pw. This is of importance because, as the causal model shows, the relation between platform thickness and width is the central causal path underlying the relation between platform and flake width.
The Pt>Pw>w relationship may also affect the flake length by determining the ratio of lateral to vertical force components available for flake formation. The regressions indicate that the higher platform index exhibited by the SS/1 sample can be seen as an expected consequence of increasing the platform thickness in the basic underlying flake production process. This raises the possibility that lancet production may be directly derivable from the underlying core reduction via a shift to the production of larger flakes on larger cores.

An explanation of how this transformation could have been brought about depends on the concept briefly forwarded in Chapter Four (see also Chapter Seven) that knappers do not fundamentally understand reduction as a series of intellectualized instructions or mental templates, but as a series of actions which may be equated in this case with motor 'habits'. If a set of familiar or habitualized reduction behaviours, derived from the reduction of one core form is transferred to another of differing geometry, its interaction with the new geometry may be sufficient to markedly change flake proportions. In extending this principle to the derivation of the SS/1 sample, it is argued, that the reduction habits which reduced the small cores in the underlying assemblage resulted in a different flake form when transferred to the larger cores associated with lancet production.

A possible mechanism by which this may have occurred is suggested by the progressive change in the platform shape ratios produced by a single function in both
samples. Axiomatically, the shape of a flake's platform is determined by the depth of the PFA location and the curvature of the platform edge. If the curvature is low the applied force will tend to spread laterally and produce a relatively wide and narrow platform. As the curvature increases the lateral spread is confined and the ratio of Pt/Pw approaches unity (or greater). In reality the value probably approaches some fractional constant less than unity - this is yet to be determined. While the platform curvature is primarily a function of core geometry, it is also possible to locally reduce or increase it via "overhang removal". Although this has been seen as a passive removal of brittle overhang (see Ackerman 1976:120) it can also positively affect local platform curvature. In the understanding of overhang removal as a passive flaking procedure the action restores local core geometry and is therefore reflective of that geometry. This is, however, only an interpretation of a particular flake trait and need not reflect its actual relationship to the core geometry. If the overhang removal process is not simply a passive restoration but a form of standardizing behaviour which the knapper applies to cores as part of the core reduction procedure it becomes an an effective modifier of platform geometry.

In the examination of inertia reactions in Chapter Four, it was suggested that the poor face length to mass relationship seen in the quartzite cores would have forced knappers to work around the core and as inertia threshold conditions become more evident, to increase the curvature
of both the platform and free face to restrict flake size. If this procedure is transferred as an unconscious motor habit to cores with larger platform diameter it will progressively increase the local platform curvature as core size increases. The size difference between the mean underlying and SS/1 cores is consistent with a doubling of the mean radius of platform curvature - sufficient to cause local platform restriction on the larger cores.

As Dibble and Whittaker (1981) and the path analysis have shown there to be a causal relationship between platform and flake dimensional variables, it may be further argued that the restriction of platform curvature, combined with an increased depth of PFA location is enough to alter the form of the flakes produced. When this process is combined with greater concern for PFA location over ridges on the free face of the core the formation of lancet flakes occurs.

5.3: Lancet Flakes in the Ingaladdi Assemblage

Having demonstrated a relationship between lancet flake production on SS/1 and that of the underlying assemblage flakes, an examination of the relationship between the process and the lancet flakes which constitute its products in the overlying assemblage will be carried out below. This will involve the testing of the assumption that these lancet flakes are derived from a
similar process to that examined above, and the degree to which their presence in the Ingaladdi assemblage is a product of selection. As in the analysis of the underlying flakes, this examination will utilize flake size and shape, cortex and platform modification, breakage patterns, and the internal structure of flake formation.

5.3a: Size and Shape

Before comparing the Ingaladdi lancets with those from the stone source it is firstly important to test for any shift in either size or shape of the former through time. The mean length, width and thickness of the lancet flakes from the overlying assemblage are compared by spit in table 5.11. Because of the high percentage of lateral tip breakages mean length could be calculated on only 94 of the 199 flakes classes as 'whole'. This combined with the small sample sizes in the lower and upper spits forced the combination of some adjacent spits to ensure adequate sample sizes.

The table exhibits no major trend toward size change through time. This is confirmed by a series of tests showing no significant difference between the upper (spits 1-4) and lower (8-9) spit groupings in all three dimensions (MW-U test - two tailed - length; U=65.5>42, p>.1; KS - two tailed - width: D=.09<.43; thickness: D=.08<.43, p>.05).
### TABLE 5.11: Mean Length, Width and Thickness of Ingaladdi Lancet Flakes by Spit (mm)

<table>
<thead>
<tr>
<th>spits</th>
<th>( \bar{x} )</th>
<th>no.</th>
<th>( \bar{x} )</th>
<th>( \bar{x} )</th>
<th>no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>50.2</td>
<td>9</td>
<td>25.5</td>
<td>9.2</td>
<td>14</td>
</tr>
<tr>
<td>3-4</td>
<td>42.8</td>
<td>23</td>
<td>19.6</td>
<td>7.3</td>
<td>11</td>
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<tr>
<td>5</td>
<td>41.4</td>
<td>33</td>
<td>20.7</td>
<td>8.5</td>
<td>43</td>
</tr>
<tr>
<td>6</td>
<td>45.1</td>
<td>12</td>
<td>21.8</td>
<td>8.2</td>
<td>66</td>
</tr>
<tr>
<td>7</td>
<td>45.7</td>
<td>16</td>
<td>21.9</td>
<td>8.2</td>
<td>26</td>
</tr>
<tr>
<td>8</td>
<td>24.5</td>
<td>94</td>
<td>20.3</td>
<td>8.1</td>
<td>26</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td>9.2</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>43.7</td>
<td>94</td>
<td>21.7</td>
<td>8.3</td>
<td>199</td>
</tr>
</tbody>
</table>

### TABLE 5.12: Shape Index Means by Spit - Ingaladdi Quartzite Lancet Flakes

<table>
<thead>
<tr>
<th>spits</th>
<th>l/w</th>
<th>t/w</th>
<th>w/Pw</th>
<th>Pt/Pw</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>2.1</td>
<td>.38</td>
<td>1.3</td>
<td>.48</td>
</tr>
<tr>
<td>5</td>
<td>2.2</td>
<td>.38</td>
<td>1.3</td>
<td>.50</td>
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<tr>
<td>6</td>
<td>2.1</td>
<td>.42</td>
<td>1.3</td>
<td>.48</td>
</tr>
<tr>
<td>7</td>
<td>1.9</td>
<td>.40</td>
<td>1.3</td>
<td>.42</td>
</tr>
<tr>
<td>8-9</td>
<td>2.2</td>
<td>.39</td>
<td>1.3</td>
<td>.43</td>
</tr>
<tr>
<td>total</td>
<td>2.1</td>
<td>.41</td>
<td>1.2</td>
<td>.44</td>
</tr>
<tr>
<td>sample</td>
<td></td>
<td>.37</td>
<td>1.2</td>
<td>.43</td>
</tr>
<tr>
<td>total</td>
<td>.40</td>
<td>1.3</td>
<td></td>
<td>.45</td>
</tr>
<tr>
<td>sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As there appears to be no change in the flake dimensions, it is also unlikely that basic shape has changed as well. A comparison of the means of the three primary shape indices in table 5.12 shows this to be the case. The Pt/Pw index, as a predictor of flake proportions, also shows no significant change through time (KS- two tailed test- Pt/Pw: D=.27<.44, p>.05).

In comparison with the lancet flakes recorded on the stone source the Ingaladdi lancets are substantially smaller (table 5.13). Direct statistical comparison is not, however, possible because it can not be assumed that the Ingaladdi lancets represent a random sample drawn from a population similar to that of the SS/1 flakes (ie., the assumption underlying the null hypothesis). The contrary hypothesis, that Ingaladdi flakes represent a highly selected sample is supported by the forms of their respective length distributions. In the stone source sample the distribution is typically skewed to the left (figure 5.7) with a decreasing tail of larger examples. In comparison, the length distribution of the Ingaladdi lancets (figure 5.8) is essentially normally distributed about the mean 43.7mm (test for normal distribution - chi²=8.5, df=5, p=.13) which suggests some consistency in selection behaviour. The Ingaladdi lancets do not appear, therefore, to represent a naturally derived population but one selected from the smaller flakes produced off-site on lancet production sites.

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### TABLE 5.13: Ingaladdi and SS/1 Lancet Flake Dimensional Means (mm)

<table>
<thead>
<tr>
<th></th>
<th>Ingaladdi</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>width</td>
<td>thickness</td>
<td></td>
</tr>
<tr>
<td>length</td>
<td>43.7</td>
<td>21.7</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cv</td>
<td>27%</td>
<td>31%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>24-84</td>
<td>4-46</td>
<td>3-18</td>
</tr>
<tr>
<td>no.</td>
<td>94</td>
<td>199</td>
<td>199</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SS/1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>84.3</td>
<td>36.6</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td>Cv</td>
<td>35%</td>
<td>27%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>37-172</td>
<td>23-65</td>
<td>4-30</td>
</tr>
<tr>
<td>no.</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 5.14: Shape Indices - Ingaladdi and SS/1 Lancets

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<thead>
<tr>
<th></th>
<th>Ingaladdi</th>
<th></th>
<th>SS/1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>l/w</td>
<td>t/w</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>2.1</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cv</td>
<td>36%</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>t/w</td>
<td>.4</td>
<td>.39</td>
<td></td>
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<td></td>
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<td></td>
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</tbody>
</table>
Figure 5.7: Distribution of SS/1 lancet lengths.

Figure 5.8: Distribution of Ingaladdi lancet lengths.
Because of the limited infield measurement, only elongation (1/w) and sectional shape (t/w) can be compared between the SS/1 and Ingaladdi lancet samples. Table 5.14 shows there to be little difference between the respective means.

The slight decline in elongation in the Ingaladdi sample is consistent with a tendency in the larger SS/1 lancets towards an increase in elongation as flake size increased. The regression coefficients for the width by length relationships of both samples (SS/1 b=2.2; Ingaladdi b=1.14) show, however, there to be a considerable difference between the slopes; b<2 indicates that as the width increases the length becomes relatively shorter and the flake becomes increasingly squarer, while b>2 shows a tendency for elongation to increase as width increases. Although both samples retain high correlation coefficients for width↔length, r=.73 (SS/1) and r=.70 (Ingaladdi), the relationship between length and elongation confirms that there is no significant tendency for elongation to accompany increased length in the Ingaladdi sample (r=.17) compared to the SS/1 (r=.60, p<.001). The scatterplot of elongation by length for both samples does, however, show that the Ingaladdi sample occupies a confined area at the extreme lower range of the SS/1 scatter.

As the Ingaladdi lancets can not be assumed to represent a random sample it is again not possible to compare directly the regression coefficients for length on width, however, it is possible to assess the likelihood
of their being derived from a larger lancet population represented by the SS/1 lancets. By splitting the latter sample into randomly selected halves and combining the Ingaladdi sample with one the effect of the latter's presence on the larger sample's regression coefficient can be assessed. As an analysis of covariance test for slope interaction shows there to be no significant difference between the slopes of the combined and SS/1 half sample (bw=2.1; F1,175=.87, critical value 6.6 at p=.01) it is possible, despite the primary slope differences, that the Ingaladdi lancets could, in terms of elongation, be derived from the larger population.

The decline in elongation is also accompanied by a reduction in the platform shape index for the Ingaladdi lancets to a value (Pt/Pw=.45) intermediate to that of the non-standard flakes from SS/1 (Pt/Pw=.52) and the flakes from the underlying assemblage (Pt/Pw=.39). The non-standard flakes have to be used in this comparison because platform measurements were not taken on the SS/1 lancets. Given the hypothesized relationship between the platform index (Pt/Pw) and flake forms derived from cores of various sizes this decline is consistent with the character of lancet flakes which would be produced as core size declines - as platform restriction reduces and PFA moves towards the platform edge the value of the platform ratio (Pt/Pw) decreases and the elongation of the flake declines. This will be discussed further in the path analysis (section 5.4).
5.3b: Cortex and Platform Modification

Consistent with the late phases of reduction only 2.5% of the Ingaladdi lancets retain dorsal cortex, substantially less than the 33% seen in the SS/1 non-standard flakes and the 14% in the underlying assemblage. At 50%, cortical platforms are, however, more numerous than the 39% seen in the SS/1 and substantially higher than the average of 8% in the underlying assemblage. The difference between the Ingaladdi and SS/1 samples probably reflects local pebble shape at stone sources, while the difference from the underlying assemblage is reflective of the latter's high levels of core rotation.

At 9% platform flaking is comparable with the SS/1 and underlying proportions. The frequency of overhang removal at 85% is, however, higher than those of the latter two samples. This is understandable given the hypothesized selectivity of the sample and the increased care in production. There is again no relation between platform flaking and overhang removal, although both represent a level of concern for core geometry. The frequency of dorsal cortex is too low for any meaningful test of its relation to either platform type or overhang removal.
In her discussion of the later stone assemblages of Northern Australia Schrire (1982:246), drawing on her own and Flood's Yarar material, noted that the broken butts of worked points were more frequent in sites than their associated tips. By assuming that tips had not been lost in sieving, she and Flood (1970:48), were able to suggest that this represents a pattern of off-site breakage where broken butts were brought to the sites in their hafts and discarded as part of refurnishing. Schrire (1982:246) also argued that as broken butts "could always be reworked". This would tend to result in higher tip proportions than that produced primarily by on-site manufacture.

Although Schrire and Flood have suggested that breakage patterns in points reflected manufacture and use, there has been little further evidence to support some of their fundamental assumptions. This makes it necessary to give a more detailed analysis of lancet breakage in the Ingaladdi assemblage.

Firstly, the proportion of lancet flake breakages is substantially higher at 73% than that of the underlying (40%) and the SS/1 (47%) flakes. The lancet flake sample's percentage includes only the proportion of proximal (or butt) segments to whole pieces. There are also no sheared cones in the lancets which is again consistent with the presumed selectivity of lancet sample.
As noted above, a high proportion (53%) of the lancet flakes, considered as sufficiently whole to be used in the primary analysis, suffered a lateral snapping of the last few millimetres of the flake's distal tip. Snap fractures also occurred along the length of the flake resulting in four classes of broken flake: the "tip-off" described above; the butt - lateral snap judged at, or under, two-thirds of the length, producing a proximal segment; a section - retained central ridges but no proximal or distal ends; and the tip - a distal segment. The numbers of each class are presented in table 5.15, which presents a pattern of some complexity given that, of the distal segments, sections relate to butts but tips (of which there are significantly less) may be derived from the tip-off, butt and section categories.

Table 5.16 shows there to be no significant change in the lengths of the broken segments through time, allowing the overall means to be taken as an accurate estimate of the population means. Although the overall length distributions of the tip-off and butt categories are significantly different (KS- two tail - D=.64>.22, p>.01) their combination into a single break category results in a unimodal distribution peaking between 20-30mm. This suggests that the initial distinction between the two is not a reflection of the presence of any distinctive modality in the breakage pattern itself and, as such, the categories can be combined into a single group of proximal segments. Significant differences also occur between butt and section distributions (KS- two tailed -
<table>
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<tr>
<th>TABLE 5.15: Lancet Breakage Pattern</th>
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</thead>
<tbody>
<tr>
<td>whole</td>
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<tr>
<td>number</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 5.16: Mean Length (mm) of Lancet Segments by Spit</th>
</tr>
</thead>
<tbody>
<tr>
<td>tip-off</td>
</tr>
<tr>
<td>$\bar{x}$ no.</td>
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<tr>
<td>5</td>
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<tr>
<td>6</td>
</tr>
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<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>total</td>
</tr>
<tr>
<td>sample</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 5.17: Frequency Distributions of Width at Break</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width Class (mm)</td>
</tr>
<tr>
<td>0-5</td>
</tr>
<tr>
<td>&gt;5-10</td>
</tr>
<tr>
<td>&gt;10-15</td>
</tr>
<tr>
<td>&gt;15-20</td>
</tr>
<tr>
<td>&gt;20-25</td>
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<tr>
<td>&gt;25-30</td>
</tr>
<tr>
<td>&gt;30-35</td>
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<tr>
<td>&gt;35-40</td>
</tr>
<tr>
<td>&gt;40-45</td>
</tr>
<tr>
<td>&gt;45-50</td>
</tr>
</tbody>
</table>
D = .32 > .21, p < .001) despite the similarity of the means—both categories retaining only marginal or less significant differences to the tip length (KS - two tailed - butt/tip: D = .18 > .25, p > .05; section/tip: d = .21 < .26, p = .02).

A feature of the mean lengths of the butts, tips and sections is that where an addition of any two produces a length comparable to the mean length of whole lancets, a combination of all three is approximately two standard deviations larger. This does not, however, indicate that larger flakes were broken more frequently.

Although a KS test shows the sections to retain higher widths at the proximal break (W1) than the tips (KS - one tail- H1: proximal section width > tip - D = .27, chi^2 = 12.7, df = 2, p < .01) the means of both at 18.2 and 15.7 mm respectively, are sufficiently similar to suggest that both sections and tips represent comparable breaks, remembering that they also retain similar mean lengths. If the frequency distribution of the breakage widths of the combined butts and tip-offs (i.e., the proximal segments) are compared with the combined tips and sections (or distal segments), it can be seen that the frequencies are consistent from the >10-15 mm class up but markedly different for the two smaller classes, >5-10 and 0-5 mm (table 5.17). This shows distal segments with widths at the proximal break (W1) of <10 mm to be largely unrepresented in the breakage sample. The distribution of the distal break width (W2) on the distal segments where present (i.e., on sections) retain, however, higher
frequencies in these size classes. In the proximal segments 28% of the sample is less than 10mm wide at the break and in the distal sections 45% of the second or more distal break (W2) are within the <10mm class, while only 4% of the proximal breaks (W1) on the distal segments are in this class.

Given the continuous distribution of the widths at the break for the proximal segments there appears to be no behavioural or post-depositional process in operation on breakage which would produce such a marked cut-off in the size of distal segments, i.e., that the proximal segments of points broken in hunting were returned to the site as part of armature repair. If this were the case, a much more consistent discrepancy between proximal and all distal segments could be expected. The comparable number of distal and proximal segments in the larger size classes also suggest that there is no substantial degree of off-site breakage of the type which the armature hypothesis requires. An explanation for the under-representation of small distal sections is that they have been lost through the sieves during the excavation.

From table 5.17 it can be estimated that approximately 30% of the distal segments are missing from the sample and that judging from their low numbers in table 5.15 the majority of these are tips. Correcting for this produces a proximal to distal ratio of 1: .82 which is an improvement on the 1: .73 of the uncorrected data. A second component to the explanation for the remaining
portion is that some of the missing tips were retouched and have been incorporated into the modified category.

The proportion of proximal to distal lancet segments does not vary significantly within the spits (chi² = 10.7, df = 7, p = .17), except for an anomalous ratio of 1:0.2 in spit 8. As the lengths of the broken segments are comparable to those in other spits, there appears to be no change in the pattern of breakage in spit 8, although the decline in distal segments is statistically significant (z1, z = 3.02, p < .01).

It is not possible at this stage of the analysis to suggest any specific cause for the high on-site breakage rate seen in the lancet flakes. Compared with the underlying flakes they are longer and more elongated with more definite triangular sections which are relatively weak in terms of areal moment (see Beer and Johnston 1962:319) making them more susceptible to bending loads of the type illustrated by Cotterell and Kamminga (1987:fig. 15a). As noted above, these bending loads may be derived from various sources, including treadage and both deliberate and accidental breakage.

5.4: Comparison of the Internal Structure of Lancet Reduction

Table 5.18 presents the correlation coefficients for the primary platform and flake variables in the Ingaladdi lancets. Comparison with the SS/1 non-standard and
<table>
<thead>
<tr>
<th></th>
<th>w</th>
<th>t</th>
<th>Pw</th>
<th>Pt</th>
</tr>
</thead>
<tbody>
<tr>
<td>w</td>
<td>.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>.51</td>
<td>.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pw</td>
<td>.48</td>
<td>.76</td>
<td>.64</td>
<td></td>
</tr>
<tr>
<td>Pt</td>
<td>.29</td>
<td>.58</td>
<td>.74</td>
<td>.68</td>
</tr>
</tbody>
</table>

*n=91  critical value .27 (p=.01)

n=193  critical value .26 (p=.01)
underlying coefficients (table 5.9) shows there to no major divergences between the degree of bivariate correlation in the three samples. Although there is a tendency for the lancet coefficients to be lower than those of the SS/1 sample, the differences appear not to be significant. For example, the decline in the Pt>1 relationship from .43 to .29 retains a probability of it representing a lower correlation of only 0.4.

The Ingaladdi lancet sample, like the non-standard SS/1, retains a comparably weak relationship between Pt and Pa (r=-0.14, .05>p>.01) supporting the argument that inertia relation was not a significant factor in the formation of these flakes. This is further indicated by the weak relationship (r=.29, p<.01) between the platform and section indices in the lancets; identical to the value for the SS/1 flakes but substantially less than that of the underlying assemblage (r=.64) (the difference is significant at p<.001).

Figure 5.9 shows the path diagrams for the Ingaladdi lancets and those of the SS/1 and underlying assemblages. As might be expected from the results of the previous comparison, the error terms are similar in all three structures, again emphasizing the point, that variation in flake shape is not simply a product of increased bivariate correlation.

The second-order partial correlation between w↔t controlling for the influence of Pt>Pw at rtw.rtpw=.29 shows there to be a continuation of the decline in the
Figure 5.9: Path analysis models for the Ingaladdi lancets, SS/1 non-standard lancets and the underlying quartzite flake sample.
independence of flake width and thickness already noted in the SS/1 sample. This may seem paradoxical in the face of the decline in the relation of platform shape and flake section indices, however, it must be remembered that correlation is not necessarily indicative of direct causal relationships. While the correlation of platform and section shape indices appears to be related to threshold conditions the variable interactions underlying the relationship have yet to be examined in detail. The decline in second-order partial correlation coefficient between the underlying and the SS/1 and lancet samples suggests that while the strengths of the underlying bivariate correlations may have changed little, the causal relations between platform and flake variables have increased in the lancet flake and SS/1 samples. In the underlying assemblage the relation of platform and flake variables is probably due to some underlying uniformity of platform and freeface geometry brought on by the small core size and their tendency towards an overstabilized shape.

In terms of the regression weights the lancet path structure exhibits a variable relationship to both the underlying and SS/1. Similar to the latter two samples, the lancets retain a poor relationship between the platform variable $P_{12}$ and flake length, with a regression weight of $0.07$ and a correlation coefficient of $r = 0.14$ which is not significantly different from the underlying and SS/1 coefficients ($p = 0.18$). Analysis of covariance also show the lancet regression weight for $P_{12}$ to be not
significantly different from either of the above, although both the underlying and the SS/1 samples are significantly different from each other (lancet and underlying: $bw=.113$, $F_{1.231}=.79 < 6.64$, $p>.01$; lancet and SS/1: $bw=.25$, $F_{1.133}=4.07 < 6.64$, $p>.01$; lancet, SS/1 and underlying: $bw=.2$, $F_{2.275}=6.149 > 4.7$, $p<.01$). This agreement with two different weights derives from the extremely weak correlation in the lancet sample which explains little of its variation.

With a regression weight of .73 for $Pt>t$ the lancet sample is comparable to the underlying value of .71 ($bw=.73$, $F_{1.336}=.26 < 6.64$, $p>.01$). There is, however, a significant interaction when all three samples are analysed together ($bw=.93$, $F_{2.379}=10.59 > 4.6$, $p<.01$) which is due to the influence of the SS/1 flakes. The association is reversed in the case of $Pw>w$ with the lancet coefficient of 1.03 being more directly comparable to the 1.15 of the SS/1 sample ($bw=1.11$, $F_{1.265}=.77 < 6.64$, $p<.01$). The difference between the lancet, SS/1 and underlying when analysed together is, however, significant ($bw=1.0$, $F_{2.409}=4.65 > 4.6$, $p<.01$).

Of greater importance for the hypothesis of how the production of lancet flakes could be derived from a reduction process like that of the underlying assemblage, the lancet flake's retention of a regression weight of 1.35 for $Pt>Pw$ is directly comparable to those of the lancet and SS/1 samples. An analysis of covariance incorporating all three samples shows no significant
interaction between the slopes \(bw=1.39, F_{2.409}=1.51 < 4.7, p>.01\) and the regression equation for the lancet flakes:

\[Pw = 1.35Pt + 7\]

is similar to those presented above for the SS/1 and underlying samples. As noted above, this is also reflected in the mean value of the platform shape index on the lancet sample of .45 intermediate between the larger SS/1 (.52) and that of the underlying flakes, (.39). These relations are illustrated in figure 5.10 which shows the mean \(Pt>Pw\) values of all three samples to be on the common regression slope.

These data for the lancet sample support the hypothesis that lancet production is an extension of the core reduction process seen in the underlying assemblage. Although the lancets in the Ingaladdi assemblage retain the external morphology of the large lancet and non-standard flakes left on SS/1, those which make up the unmodified Ingaladdi sample are, in terms of the internal relations of their platform and flake variables, intermediate between the SS/1 and underlying flake structures. The comparability of the \(Pt>Pw\) slopes shows that as core size reduced and the size of the resulting lancets decreased, there was no special platform modification used to continue the relationship which constricted platform width and produced the high \(Pt/Pw\) figures seen in the larger flakes of the SS/1 sample. The increasing ratio between \(Pt\) and \(Pw\) which the slope
Figure 5.10: The linear relationship between the platform ratio of the underlying quartzite flakes, the Ingaladdi lancets and the SS/1 non-standard lancets.

\[ R_w = 14P_t + 6.7 \]
produces as Pt becomes smaller tended to reduce the elongation of the lancets as the cores were reduced and Pt declined. The ability of this process to restrict the elongation of the lancet with declining size has already been demonstrated to be present in the lancet sample from the stone source (SS/1), and is supported by the intermediate status of the Ingaladdi lancets. If the core reduction were continued, the process would produce flakes very similar, in terms of their internal structure, to those of the underlying assemblage.

In summary, the analysis has shown that the Ingaladdi lancet flakes can be considered to be a sub-set of the wider population of lancet flakes found on the stone sources where the flakes were produced. Although the lancet appears to be very different morphologically from the smaller 'amorphous' flakes of the underlying assemblage, the analysis has also shown that both forms can be derived from the same reduction process. The formal differences, it is argued, are derived from the transference of motor 'habits' suitable for the small cores of the underlying assemblage to the larger cores on the local stone sources. This shift is a product of a major behavioural switch from on-site to off-site core reduction.
5.5: Lancet Modification

5.5a: Flake Modification Model Re-examined

In Chapter Two the model of the flake reduction presented for the overlying north-west assemblages was based on the presence of a series of parallel reduction processes deriving from the variable combination of six basic components. These were defined by the opposition of lancet and and non-lancet flake forms which were seen as emerging from two separate production processes and their ensuing unifacial and bifacial reduction. It was argued that the structure of north-western assemblages could be seen as largely determined by the interrelation between these components on each site. Separation of the processes allowed a series of hypothetical sequences to be developed which, when tested against the data, have the potential to clarify the typological complexity which has developed around, for example, in the point forms.

The initial component of the reduction model is the separation of the processes of primary flake production from the various assumed end products of secondary reduction. The principal separation between lancet and a generalized non-lancet flake formation is consistent with the ethnography of the former, but differs in assumption that in the north-western assemblages lancet production does not represent a specialized point or point blank, but a standardized flake which is pointed by virtue of its production process. This has been supported by the above
analysis, which has shown that the internal structure of the Ingaladdi lancets can be derived from the flakes of the underlying assemblage. The analysis also suggests that the initial assumption of a clear distinction between a lancet and non-lancet production may have been too simple. In the Ingaladdi material the difference may exist only at the level of flake size.

The second component, sees the modification of lancet flakes as a part of a wide flake utilization which encompasses point manufacture; not simply reflecting point production as implied in Jones and White (1988). The possibility of wider utilization is suggested by McCarthy's (1951) classification of modified lancet flakes in the Tandandjal assemblage as 'scrapers', Davidson's (1935) discussion of 'adze points' and Dortch (1977a) and Bradshaw's (1986) description of point modification in the Kimberley assemblages (ie., A-1-2, figure 2.10). Conversely, Flood's (1966, 1970) suggestion that the majority of the point forms in Yarar are made on flakes (as opposed to pointed flakes) may represent the production of 'points' from a less standardized flake form.

The model divides the secondary reduction of both lancet and non-lancet flakes into unifacial and bifacial processes. This separation is, however, arbitrarily determined by the level at which reduction processes are to be examined. At that of individual flake removals, all single platform reduction is unifacial. What distinguishes the bifacial is the spacing of the core rotations between individual removals. If there is no rotation the sequence
is unifacial up to the last removal where, with rotation, a bifacial sequence is produced. In the model presented in Chapter Two a further distinction was made between what are technically two bifacial sequences. The first of these follows Flenniken and White's (1985:148) general point reduction sequence in which a single face is unifacially retouched before the flake is rotated and the second face is completed (see C-1-1/2, figure 2.10). Although technically a bifacial process it is probably of greater use to view this as a series of two opposed unifacial sequences. The sequence allows unifacially and bifacially flaked 'points' to be seen as products of a single reduction process, with the former representing an early stage of a potentially longer bifacial sequence.

The second bifacial process (D-1, figure 2.10), derived from the ethnography, exhibits much higher frequencies of rotation with both faces being retouched together (see Flenniken and White 1985:149), complying more closely with standard definitions of bifacial reduction.

If the model is to be more than a ranking of retouched flakes it must retain some capacity to separate 'point' from other reduction modes. As the sequences have been presented there is no basis for the latter distinction, except for the appearance of bifacial working, and even this may be problematic in the early stages of both the double unifacial (C-1) and standard bifacial modes (D-1).
In the Flenniken and White (1985) model the process of manufacturing points progresses from scalar to predominantly invasive retouch. The former, characterized by its confinement to edge modification with little effect on flake thickness, can be equated with a general retouch mode (i.e., A-1-2). Invasive flaking is denoted by a flake removal extending up to and into the central portion of the flaked surface. If properly achieved this mode brings the rate of width and thickness reduction into closer alignment, maintaining platform angles as reduction continues. In the Flenniken and White model scalar flaking of the edge is the initial stage of manufacture with invasive flaking occurring in the final phases of 'pirri' and fully bifacial reduction.

If this model accurately represents the relation between the two flaking modes in point production, there is no possibility of differentiating between the preliminary phases of a point reduction process (C-1 and D-1) and the effect of more general retouch (A-1-2) on lancet and non-lancet flakes, as they will both be characterized by an undifferentiable scalar flaking.

The scalar>invasive sequence can, however, be questioned on the basis of whether scalar flaking could be a preliminary for invasive retouch. As noted above, scalar flaking has the effect of reducing flake width while leaving flake thickness unaffected. Not only does this decrease the thickness to width ratio, resulting in an increasingly stable section shape, but the scalar
flaking also increases the platform angle at the flake's edge. This moves the flake's margins away from the central plane towards the unflaked surface. This is opposite to the requirements of invasive retouch which as, Flenniken and White (1985:148, fig. 30) point out in their discussion of bifacial working, requires the platform to be moved as far as possible towards the face to be flaked. This may be achieved by retouching the opposite face to that which will be invasively flaked. This opposite retouch also has the effect of strengthening the platform for the more difficult invasive removals.

This suggests that far from providing some preliminary base for invasive flaking, scalar retouch can preclude the possibility of further invasive removals unless modification of the opposite face is used to force the platform back to a more central position. While this recovery is possible on wide flakes it would appear to be limited on elongated flakes like the lancet.

As invasive flaking may not be neatly nested within a scalar process, it allows a potentially more useful model of secondary flake reduction to be defined. It is suggested that invasive removals require a separate sequence in which invasive reduction must be established from the beginning of the process. This is based on the hypothesis that the process of producing invasive removals is inherently unstable, as the formation of scalar flakes can terminate the sequence if recovery is limited. Using this model, the role of scalar modification in an invasive sequences is as a preliminary platform modifier when used
to force a platform towards the opposite face. Scalar flaking may also terminate a sequence where scalar flakes force the platform away from the worked face, precluding subsequent invasive removals.

In summary, the reduction model rests on two basic propositions:

1) That lancet flakes as products were not necessarily predetermined by the desire to produce a specialized form (i.e., a point or blade) and were not necessarily modified in a uniform manner consistent with a single desired end. Reduction followed a range of modes producing a range of forms.

2) That secondary flake reduction was governed by two principal reduction modes, bifacial and unifacial, and two flaking modes, scalar and invasive. These modes combine to produce a series of reduction sequences:

(a) The first of these is a unifacial scalar sequence (A-1-2) which is seen as related to the functions of lancet and non-lancet flakes as artifacts in wider production activities. It is expected that retouch in this sequence will exhibit little systematic reduction with equal probability of retouch being located within any area of the flake margins.
(b) The second set of sequences can be characterized by a more systematic reduction process and the presence of invasive flaking. These are assumed to be associated with the formation of point forms. The model predicts two possible invasive sequences:

(i) an essentially a unifacial sequence in which the process may be terminated after the completion of one face or continued by reducing the second face producing a bifacial product (C-1-1/2).

(ii) a standard bifacial sequence in which both faces are flaked together (D-1). As noted above, scalar flaking can be associated with these sequence as a platform modifier and as a sequence terminator.

5.5b: Analytic Categorization

Before applying the reduction model to the Ingaladdi assemblage some discussion of its form and the analytic units used is necessary. At its simplest the model is based on the distinction of six reduction components at three levels. The first distinguishes between lancet and non-lancet flake formation. As the former appears to be a direct transformation from the latter, in the Ingaladdi assemblage the definition of a clearly separate non-lancet mode of flake production from the analysis is not possible. This will have to await comparative studies with assemblages like that of Yarar and the Kakadu sites.
which appear to be less dominated by lancet flakes.

For this reason the non-lancet component of the model will not be used in the following analysis, which will examine only the reduction of lancet flakes. As table A-3 (Appendix A) shows, these represent 90% of the retouched quartzite flakes in the assemblage.

The second component of the model, the distinction between unifacial and bifacial sequences, will for the first part of the analysis be taken literally, i.e., flakes with retouch on one face will be classified as unifacial and on both as bifacial. This classification is principally an analytic device which will be used to test for the variable relation between dorsal and ventral retouch suggested by the model.

The third distinction between scalar and invasive retouch is not as simply defined as an analytic category. As outlined above, the distinction is based on an assessment of whether any flake removals from the edge reached the central section of the flaked surface. As there are no intervening degrees of scalar or invasive flaking it may be argued that there is an element of arbitrariness in the assessment. The assignment of flaking form to either category should not, however, be seen as a simple 'is' or 'is not' statement describing some essential quality of scalar or invasive, but a tendency for flake removals to exhibit a given configuration. The category of scalar retouch is made up of flakes whose retouch tends to be confined to the edges of the flake,
while the invasive group's tends towards the central portion of the flakes surface. The problem of arbitrariness in the assignment of retouch to either class is a limitation only if it is claimed that all items in the class retain an essential character in equal proportions, or that we need to be sure of this claim. Although the model makes an assumption that the essential classes of scalar and invasive retouch can, in principle, be defined as entities, this is not required of the analytic categories devised to test the model because the procedure is not concerned with distinction of an ideal category, only the ability to separate reduction processes. The same can be said for the unifacial and bifacial categories discussed above. The approach is pragmatic in its reliance on the categorization to effectively test this separation, not its claim to rest on universalities.

A second difficulty with the model lies in the possible objection that while it may be accepted that invasive removals represent intentional reduction, we can be less sure of scalar, which may derive from use-wear and post depositional edge damage. The term 'retouch' to denote both invasive and scalar removals is used to show that some judgement has been made in the assignment of flake modification to categories which show substantial sequential flaking above what was assumed to be the isolated flake removal associated with minor edge damage. Although the predominant form of use-wear\(^1\) found on the Ingaladdi flakes, in both the underlying and overlying
assemblages, is a form of edge rounding (see Kamminga 1978) which appears not to produce flake removals, a substantial investigation of the effect of other forms of use-wear (if extant) on the scalar retouch category was seen as beyond the scope of this analysis. Leaving aside the question of whether a systematic use-wear study would produce a satisfactory answer to the problem, it is also arguable whether such a distinction would substantially affect the most significant aspect of the model - the distinction between an invasive reduction and that of a less systematic edge retouch. Before it could have a significant effect on the argument the objection would have to assume that: (1) use-wear and retouch were unrelated events, (2) that major use-wear damage was more common than retouch and (3) that it was highly structured in its location.

Testing the model also required some measure of the degree of retouch. This was achieved by dividing the surface of the lancet flake into 12 parts: six on the dorsal and six on the ventral. Each group of six was composed of four major quadrants and two minor. The major quadrants (Q1, Q2, Q3, Q4) divide the left and right margins of the dorsal surface into equal quarters as shown in figure 5.11a; of the minor, Q5 corresponds to the proximal lateral margin and Q6 to the distal if one is present (figure 5.11b). The ventral surface is divided in a similar fashion with Q7, 8, 9 and 10 as the major and Q11 and 12 as the minor quadrants. The dorsal and ventral correspondence is: 1/8, 2/7, 3/10, 4/9, 5/11 and 6/12.
The recording of retouch in the quadrants provides a degree of control over the location and degree of edge modification without resort to the complex measures of edge and retouch length required by interval scale measurement. Again, the location of retouch in a particular quadrant should be seen as classifying flakes which exhibit a tendency for retouch to be distributed in a particular manner, i.e., near the tip, or near the base rather than in some exact position along the margin. The model does not require that accuracy.

Because of the frequency of retouch in Q5, due to overhang removal, and its rarity in Q6, 11 and 12, the following analysis will be concerned with retouch in the major quadrants only.

The distribution and degree of retouch were also combined into a more complex ordinal scale by assignment of a value '20' to the presence of invasive flake removals in a quadrant and '1' for the presence of scalar. In this scheme invasive is given assignment priority in any quadrant over any scalar flaking if present. Hence, quadrant retouch can have a value of only '20' or '1'. Although this procedure produces some information loss, by excluding the possibility of examining the relation of invasive to scalar in an individual quadrant, it was considered acceptable in the light of the complexity of the resulting analysis.
Figure 5.11: Quadrant order for the modified Ingaladdi lancets.

Figure 5.12: Inertia threshold conditions for north-western 'points' - plots of the mean t/w ratio and mass - 95% confidence limits of the means.
Using this system a measure of the degree and composition of the retouch could be achieved for individual flakes by the addition of the numeral codes for the retouch in each quadrant. This produced a scale in which each flake could be assigned to one of 14 possible retouch categories (table 5.19). The table shows there to be two possible assignments if one quadrant is retouched '1' or '20', three if two (where '21' represents one invasive and one scalar quadrant) four if three and five if retouch extends around the margin with '4' representing complete scalar retouch and '80' for complete invasive. Besides ranking the flakes in terms of edge modification the scale also provides a minor ranking in the degree of face modification, i.e., '4' denotes less face modification than '23' which is less than '42', et cetera.

5.5c: Testing the Reduction Model

The assumption underlying the testing of reduction models is that artifacts can be grouped in a sequential manner, and that this represents artifacts which have been abandoned at different stages of a reduction process. One immediately testable consequence of the assumption is that as the sequence represents a reduction process there should be some change in the size and form of artifacts at various stages of the sequence. While this appears to be reasonable, attempts to apply the expectation to points in the north-western assemblages have not proved successful.
### TABLE 5.19: Retouch Scale

<table>
<thead>
<tr>
<th>Retouch</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scalar</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Invasive</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Combination</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>41</td>
</tr>
</tbody>
</table>

### TABLE 5.20: Mean mass and t/w Ratio of points from Ingaladdi, Yarar and Bradshaw's Data.

<table>
<thead>
<tr>
<th>Type</th>
<th>Mass</th>
<th>t/w</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{x}$</td>
<td>$s_x$</td>
</tr>
<tr>
<td>Ingaladdi</td>
<td>bifacial</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>unifacial</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>plain</td>
<td>7.7</td>
</tr>
<tr>
<td>Yarar</td>
<td>bifacial</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>intermediate</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>unifacial</td>
<td>7.1</td>
</tr>
<tr>
<td>Bradshaw</td>
<td>bifacial</td>
<td>10.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td>unifacial</td>
<td>2.0</td>
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<tr>
<td></td>
<td></td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.4</td>
</tr>
</tbody>
</table>
In her analysis Flood (1970:47) could not arrange the Yarar points into a continuous sequence "...from larger, more unifacially trimmed to smaller, more bifacially trimmed..." (see also section 2.4). Although the difference between the size of the bifacial and unifacial groups appears statistically significant, the variation in mean mass of only 1gm and less than 2mm in mean length is not sufficient to suggest a sequential relationship. The difficulty led Flood to propose that unifacial and bifacial points represented two distinct types with different functions.

Bradshaw (1986:161,286) found bifacial points to be larger than the unifacial in her sites. With mean masses of 4.0 and 2.5gms respectively and a probably of $p>0.05$ (provided by her own t test) this appears, however, both statistically and technically questionable. Similarly, Barton (1979:57) claims evidence for an increase in bifacially flaked points through time and corresponding increases in point size. Re-analysis of his data shows this increase to be statistically unproven ($KS$-one tail-$D=0.338$, $chi^2=5.7$, $df=2$, $p>0.05$).

The tendency for there to be a poor size differential between unifacial and bifacial points is also seen in the Ingaladdi assemblage with less than 3gms separating the means of plain, unifacial and bifacial lancets (table 5.20). Besides the uniformity of size in the assemblages there is also a general similarity in size between all point types. Table 5.20 shows a clustering of mean values
about 10-5gms in the Ingaladdi and Yarar material, with the Bradshaw data tending to more extreme but less certain values. In Barton’s (1979:100) Ngarradj sample both mode and median values lie within the comparable range of 3-7gms.

The clustering of these figures is similar to the problem of similar core sizes discussed in section 4.5a and suggests that point discard is governed by similar threshold conditions. It will be recalled from sections 4.4 and 5 that, as artifacts become smaller they approach the limits of hand held percussion flaking and that this threshold affected quartz cores depending on platform angle from 10-6gms. Although this may to some degree be material dependent, the point masses are well within the range in which inertia threshold conditions can be expected to apply. Although platform angles were not measured in any of the samples they may be approximated by the t/w ratio. The values given in table 5.20 for each point type are again consistently about .4 representing a range of nominal values from 45°-50° (the actual edge angles are assumed to have been larger).

Figure 5.12 illustrates the degree to which the point samples group within what appears to be a range of critical mass and angle values. Only Bradshaw's scalar flaked unifaces with their small size and low ratio appear to stand outside of the main cluster. Bradshaw (1986:131) reports that just under 50% of this sample were broken.

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The clustering seen in figure 5.12 suggests that 'point' reduction is governed by a set of mass and platform angle condition which have the capacity to restrict and ultimately terminate flaking regardless of the degree of an individual flakes reduction. If these conditions occur early in the sequence the point will be discarded with little modification, if encountered later the artifact will exhibit greater modification yet both will retain similar size and platform values. Under these conditions of discard it is not possible to simply test reduction models by size criterion in the manner which the basic reduction sequence model would suggest. Testing must, therefore, also be based on the form and location of flake removals, hence their importance in the general reduction model discussed above.

The retouched lancets were firstly classified on the basis of retouch mode and location into scalar unifaces, invasive unifaces and bifaces. Scalar and invasive bifaces are combined because of the small sample size of the former. The two uniface groups were then divided into four classes based on the number of major quadrants which exhibited retouch. Totalling from 1 to 4 these are taken as taken as stages in a reduction process (ie., 1>2>3>4) The testing for unifacial sequences is primarily one of comparing the observed quadrant combinations at each stage against those expected, given an equal probability of retouch occurring in any remaining quadrant, ie., a non-structured selection of retouch location. The approach is based on the hypothesis that a manufacturing process will
exhibit some order in retouch location, as opposed to more
generalized reduction which will show no discernable
preference for a specific retouch location at any stage of
the sequence. The invasive unifaces should exhibit a
structured sequence while the scalar a more random
process.

Due to the relatively small proportion of
incompletely worked flakes, the bifacial sequences tests
will be based on the strength of the correlation between
the degree of ventral and dorsal retouch predicted by the
bifacial reduction models discussed above.

5.5d: Scalar Unifaces

Scalar unifaces are characterized by their retention
of only scalar flaking on either the ventral or dorsal
surface. Numbering 154 artifacts they constitute 75% of
the dorsally worked unifaces. Twelve flakes retaining
retouch on the ventral surface only, were excluded from
the unifacial analysis because their presence would
require the addition of extra categories substantially
affecting the application of the statistics (see Appendix
B - statistical note [4]). Comparison of the dimensional
and shape index means for the scalar unifaces (table 5.21)
with those of the unmodified lancets (tables 5.11 and
5.12) show no statistically significant difference in
their respective distributions (KS- one tailed- H1:scalar

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### TABLE 5.21: Scalar Unifacial Lancet Size and Shape Index Means (mm)

<table>
<thead>
<tr>
<th></th>
<th>length</th>
<th>width</th>
<th>thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{x}$</td>
<td>45.1</td>
<td>23.0</td>
<td>9.5</td>
</tr>
<tr>
<td>$S_x$</td>
<td>14.6</td>
<td>8.0</td>
<td>3.8</td>
</tr>
<tr>
<td>$1/w$</td>
<td>2.0</td>
<td>.41</td>
<td>.46</td>
</tr>
<tr>
<td>$t/w$</td>
<td>.7</td>
<td>.14</td>
<td>.11</td>
</tr>
</tbody>
</table>

### TABLE 5.22: Quadrant Frequency - Stage One - Scalar Unifaces

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>O</th>
<th>E</th>
<th>$(O-E)^2/E$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28</td>
<td>13.5</td>
<td>15.6</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>13.5</td>
<td>.02</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>13.5</td>
<td>5.4</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>13.5</td>
<td>3.1</td>
</tr>
<tr>
<td>total</td>
<td>54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\text{chi}^2 = 24.1$, df=3, p<.001
unifaces are smaller; length: \( \chi^2 = 1.3 \); width: \( \chi^2 = 1.3 \); thickness; \( \chi^2 = 5.3, \text{ df} = 2, p > .05 \); KS - two tailed - 1/w: \( D = .02 < .96 \); t/w: \( D = .05 < .18 \); Pt/Pw: \( D = .06 < .18 \); w/Pw: \( D = .11 < .18 \); p > .05).

Table 5.22 shows the frequency distribution of retouch across the four quadrants for scalar unifaces with retouch in one quadrant only. The table also gives the expected frequencies given an equal probability of retouch occurring in any quadrant and the resulting \( \chi^2 \) value of a goodness of fit test between the observed and the expected frequencies. The value is highly significant, with a major departure from the expected values in Q1.

The observed and expected frequencies for the six possible quadrant combinations for stage 2 (ie., retouch in two quadrant only) are given in table 5.23. The expected frequencies were obtained by taking the observed frequencies from stage 1 and tabulating the values expected in each of the other quadrants if there were equal probability of any of the other three unretouched quadrants being worked. The frequencies in identical quadrant combinations (ie., [14] and [41]) were added and their proportion of the total used to calculate the expected frequencies for the more numerous stage 2 flakes.

The resulting goodness of fit test (1) again shows there to be a highly significant departure from the expected. Of particular interest are quadrant combinations [14] and [23] which are well below the expected and [13] and [12] which tend to be above. The
### TABLE 5.23: Quadrant Frequencies - Stage Two - Scalar Unifaces

<table>
<thead>
<tr>
<th>Quadrant Combinations</th>
<th>O</th>
<th>E</th>
<th>((O-E)^2/E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>25</td>
<td>16.6</td>
<td>4.3</td>
</tr>
<tr>
<td>13</td>
<td>23</td>
<td>12.9</td>
<td>7.7</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>13.8</td>
<td>11.8</td>
</tr>
<tr>
<td>23</td>
<td>1</td>
<td>7.6</td>
<td>5.6</td>
</tr>
<tr>
<td>24</td>
<td>7</td>
<td>8.3</td>
<td>.2</td>
</tr>
<tr>
<td>34</td>
<td>7</td>
<td>4.7</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>64</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) \(\chi^2 = 30.86\), df = 5, \(p < .001\)

<table>
<thead>
<tr>
<th>Quadrant Combinations</th>
<th>O</th>
<th>E</th>
<th>((O-E)^2/E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>25</td>
<td>24.1</td>
<td>.03</td>
</tr>
<tr>
<td>13</td>
<td>23</td>
<td>18.9</td>
<td>.9</td>
</tr>
<tr>
<td>24</td>
<td>7</td>
<td>12.1</td>
<td>2.1</td>
</tr>
<tr>
<td>34</td>
<td>7</td>
<td>6.9</td>
<td>.002</td>
</tr>
</tbody>
</table>

(2) \(\chi^2 = 3.0\), df = 3, \(p > .3\)

### TABLE 5.24: Quadrant Frequencies - Stage 3 - Scalar Unifaces

<table>
<thead>
<tr>
<th>Quadrant Combinations</th>
<th>O</th>
<th>E</th>
<th>((O-E)^2/E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>123</td>
<td>7</td>
<td>8.4</td>
<td>.24</td>
</tr>
<tr>
<td>124</td>
<td>8</td>
<td>5.7</td>
<td>.95</td>
</tr>
<tr>
<td>234</td>
<td>3</td>
<td>2.6</td>
<td>.07</td>
</tr>
<tr>
<td>134</td>
<td>4</td>
<td>5.3</td>
<td>.33</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>22</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(\chi^2 = 1.58\), df = 3, \(p > .5\)
combinations [14] and [23] are diagonally opposed - left tip/right base [14] and right tip/left base [23]. This indicates that the overall departure form expected may be largely a product, not of the selection of certain quadrant combinations, but of their non-selection. Excluding the two flakes with diagonal combinations from the analysis and recalculating the expected frequencies produced no significant difference from the assumption of equal probability (test 2).

As the test is to some degree contrived the O and E values are more use in assessing the overall fit than the chi². However, the test does support the hypothesis that the quadrant combination in the second stage of scalar unifaces reduction is structured not by a preference for any particular combination but by the non-selection of diagonal quadrants. Excluding these, there appears to be an equal probability of any two quadrants being retouched given the heavy weighting towards the left tip in stage one, hence the observed dominance of bilateral tip [12] and left margin [13] combinations.

The decomposition of the scalar retouch into an essentially random combination of quadrants is continued in stage 3 (table 5.24). Calculating the expected frequencies using the observed values from stage 2 (including [14] and [23]), the resulting goodness of fit test shows there to be no significant departure in the combination frequencies in stage 3 from those expected from an assumption of there being an equal probability of
any third quadrant being retouched. Given, for example, a [12] combination in stage 2 there is an equal probability that in stage 3 it will be [123] or [124], similarly an equal probability that [13] will become [132] or [134].

The basic structure of the scalar sequence is summarized in a tree diagram in figure 5.13. The fractions on the tree show the proportion of all flakes which are in the quadrant combination connected by the branches at a given stage. Where the categories are shared (ie., [12] on the left and [21] on the right in stage two) the total proportion (.39) is split according to that of the previous stage (ie., [12]= .39(.66)=.26 as .52 is 66% of the flakes with retouch in quadrant one or two). This is justified by there being no discernible preference for specific quadrants at stages 2 or 3. The percentages to the right indicate the proportion of the flakes at each stage which are accounted for in the summary. The percentage increase as the sequence becomes less and less structured.

In terms of artifact number per stage, it is important to note for later comparison that only 14 (9%) of the scalar unifaces reach stage four with a progressive decline in the frequency from stage two. Although the differences between the frequencies at each stage are highly significant (chi²=46.75, df=3, p<.001), the variation may indicate both a low disposition to continue reduction beyond stage two, and that off-site curation of flakes was related to the degree of reduction.
Figure 5.13: Tree diagram of quartzite unifacial scalar reduction.
The former possibility is consistent with a process of edge modification which is associated only with immediate activity; not part of a specialized and highly structured tool manufacturing process. What structure there is, can be largely explained by least effort reduction behaviour. When held by the base dorsal face up in the right hand, quadrant [1] (the left tip predominantly retouched in stage one) is the most usable working surface and the most easily retouched when held ventral face up in the left. The low selection of diagonal quadrants in stage two is consistent with the retouch being extended down or around any face not being covered by the knapper's hand - to retouch diagonal faces would require the flake to be moved during the retouching procedure. The low occurrence of diagonal working also suggests that the bulk of the stage two retouch occurred as a single event not as two successive stage one processes.

While the above method of building up sequences by examining quadrant combinations at each stage is useful, it requires high artifact numbers and does not provide a ready picture of the most probable sequences to have structured the reduction process. To this end, a second procedure was developed which is concerned with defining the quadrant sequence to which the highest proportion of the retouched flakes could belong.

The first step was to list all the three element permutations of the four element quadrant set \{1,2,3,4\}. Three elements are used because the inclusion of
Figure 5.14: Spanning tree diagram of quadrant combinations.
completely retouched flakes provide no sequential information. Each of the 24 permutations represents a sequence constructing the arms of a spanning tree (figure 5.14). To calculate the maximum number for which a sequence could account, the numbers of flakes which could be related to the sequence at the three stages were added. For example, the sequence [123] would contain flakes with retouch in [1] plus [12] and [123]. The end values which show the greatest departure from the expected are taken as representing retouch sequences. The significance of these departures can be tested by applying a goodness of fit test to all the observed and expected sequence values.

The expected frequencies used in the goodness of fit tests above were added to obtain the E values for this test. The results of this procedure are given in table 5.25. The goodness of fit test confirms the presence of a sequence structure. The table shows there to be extremely high positive (O-E) values for [123], [124], [134] and [132] with the next highest value for [214]. These sequences (see figure 5.15) follow the left hand side of the tree diagram in figure 5.13.

To reveal the most likely sequences the structure may be broken down into, what can be termed, the mirrored sequences. These contain the 'obverse' and 'reverse' of a sequence and can be used to reflect the more realistic assumption that reduction behaviour follows a disposition to retouch general areas of the flake (e.g., the tip then move to the proximal margins) rather than follow a strict
### TABLE 5.25: The Observed and Expected Numbers for all Reduction Permutations - Scalar Retouched Lancets

<table>
<thead>
<tr>
<th>Sequence</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
</tr>
</thead>
<tbody>
<tr>
<td>123</td>
<td>60</td>
<td>38.5</td>
<td>21.5*</td>
</tr>
<tr>
<td>124</td>
<td>61</td>
<td>35.8</td>
<td>25.2*</td>
</tr>
<tr>
<td>134</td>
<td>55</td>
<td>31.8</td>
<td>23.2*</td>
</tr>
<tr>
<td>132</td>
<td>58</td>
<td>34.9</td>
<td>23.1*</td>
</tr>
<tr>
<td>142</td>
<td>37</td>
<td>32.9</td>
<td>4.1</td>
</tr>
<tr>
<td>143</td>
<td>33</td>
<td>32.6</td>
<td>.4</td>
</tr>
<tr>
<td>213</td>
<td>46</td>
<td>38.5</td>
<td>7.5</td>
</tr>
<tr>
<td>214</td>
<td>47</td>
<td>35.8</td>
<td>11.2*</td>
</tr>
<tr>
<td>231</td>
<td>22</td>
<td>29.5</td>
<td>-7.5</td>
</tr>
<tr>
<td>234</td>
<td>18</td>
<td>23.7</td>
<td>-5.7</td>
</tr>
<tr>
<td>243</td>
<td>24</td>
<td>24.4</td>
<td>- .4</td>
</tr>
<tr>
<td>241</td>
<td>29</td>
<td>27.5</td>
<td>1.5</td>
</tr>
<tr>
<td>312</td>
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<td>314</td>
<td>32</td>
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<td>.2</td>
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<td>321</td>
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<td>-16.5</td>
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<td>324</td>
<td>9</td>
<td>23.7</td>
<td>-14.7</td>
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<td>341</td>
<td>16</td>
<td>23.6</td>
<td>-7.6</td>
</tr>
<tr>
<td>342</td>
<td>15</td>
<td>20.8</td>
<td>-5.8</td>
</tr>
<tr>
<td>413</td>
<td>12</td>
<td>32.6</td>
<td>-20.6</td>
</tr>
<tr>
<td>412</td>
<td>16</td>
<td>32.9</td>
<td>-16.9</td>
</tr>
<tr>
<td>421</td>
<td>22</td>
<td>27.5</td>
<td>-5.5</td>
</tr>
<tr>
<td>423</td>
<td>17</td>
<td>24.4</td>
<td>-7.4</td>
</tr>
<tr>
<td>431</td>
<td>18</td>
<td>23.6</td>
<td>-5.6</td>
</tr>
<tr>
<td>432</td>
<td>17</td>
<td>20.8</td>
<td>-3.8</td>
</tr>
</tbody>
</table>

\[ \chi^2 = 120.5, \text{ df}=23, \ p<.01 \]

### TABLE 5.26: Mirrored Sequences - Scalar Retouched Lancets

<table>
<thead>
<tr>
<th></th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>123-214</td>
<td>107</td>
<td>74.3</td>
<td>32.7</td>
</tr>
<tr>
<td>b)</td>
<td>124-213</td>
<td>107</td>
<td>74.3</td>
<td>32.7</td>
</tr>
<tr>
<td>c)</td>
<td>134-243</td>
<td>79</td>
<td>56.2</td>
<td>22.8</td>
</tr>
<tr>
<td>d)</td>
<td>132-241</td>
<td>87</td>
<td>62.4</td>
<td>24.6</td>
</tr>
<tr>
<td>e)</td>
<td>214-123</td>
<td>107</td>
<td>74.3</td>
<td>32.7</td>
</tr>
</tbody>
</table>
Figure 5.15: Tree diagram of the most probable scalar reduction sequences.

Figure 5.16: Most probable scalar reduction sequences.

Figure 5.17: Least probable (negative) scalar reduction sequences.
retouch by numbers routine. For example, the mirror of [123] is [214] as both show a process of retouching the tip of the flake before moving on the diagonal to the base. The inclusion of the mirror also allows for the possibility that the knapper may hold the artifact in the right hand or left hand but carry out essentially the same sequence of reduction. The ability of the joint sequences to account for the maximum number of flakes with scalar retouch is shown in table 5.26. The table shows there to be three sets which can account for over 75% of the scalar retouched lancets. As sets (a),(b) and (e) are identical in this regard, no single reduction set can be distinguished for the scalar retouch, which is largely consistent with the results of the previous analysis. The illustration of the possible reduction sets (figure 5.16) shows there to have been a strong disposition to retouch the distal margins of the flake before moving in an unsystematic manner to reduce the proximal.

This approach also allows the negative sequences to be examined. There are four (see table 5.25) which are substantially low in artifact numbers: [321],[324],[413] and [412]. These all contain a diagonal, from an initial basal retouch to a distal (figure 5.17), and are composed of two sets of mirrored sequences, [312-412] and [324-413]. This also coincides with the results of the first analysis which showed that the stage 2 quadrant combinations were largely a product of the negative disposition to retouch diagonally opposed quadrants.
5.5e: Invasive Unifaces

Lancet flakes with invasive retouch in any quadrant constitute a class totalling 51 artifacts. Compared with the scalar 24 (47%) are at stage 4 with 11 (22%) retaining full invasive retouch i.e., a typologically standard unifacial point (which Flenniken and White [1985:148] characterize as 'pirri'). This leaves only 27 incompletely flaked points to test for a reduction sequence.

Comparing the dimensional and shape means for the invasive unifaces (table 5.27) with those of the unmodified and scalar lancets show slight but statistically significant differences in width from the plain and scalar, in thickness with the scalar and a marginal difference in length with the scalar and plain lancets (KS - one tail- H1, invasives are smaller: length, plain - chi^2=9.05, df=2 .02>p>.01; scalar - chi^2=7.5, df=2, .02>p>.01; width: plain - chi^2=14.9; scalar - chi^2=19.7; thickness: scalar - chi^2=14.7, df=2, p<.01). Although the variation is consistent with an extended reduction of the invasively worked flakes, the differences may be minimized by the threshold effects discussed earlier.

In stage 1 the four examples all retained retouch only in quadrant [1]. If the sample is drawn from a population where there is an equal likelihood of retouch
### TABLE 5.27: Dimensional and Shape Index Means - Invasive Unifacial Lancets

<table>
<thead>
<tr>
<th></th>
<th>length</th>
<th>width</th>
<th>thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{x} )</td>
<td>37.5</td>
<td>18.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Sx</td>
<td>11.7</td>
<td>5.3</td>
<td>1.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>1/w</th>
<th>t/w</th>
<th>Pt/Pw</th>
<th>w/Pw</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{x} )</td>
<td>2.1</td>
<td>.43</td>
<td>.48</td>
<td>1.45</td>
</tr>
<tr>
<td>Sx</td>
<td>.29</td>
<td>.11</td>
<td>.17</td>
<td>.51</td>
</tr>
</tbody>
</table>

### TABLE 5.28: Observed and Expected Frequencies - Stages 2 and 3 - Invasive Unifacial Lancets

<table>
<thead>
<tr>
<th></th>
<th>Stage 2</th>
<th></th>
<th>Stage 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>combinations</td>
<td>O</td>
<td>E</td>
<td>combinations</td>
<td>O</td>
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<tr>
<td>12</td>
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<td>4.7</td>
<td>123</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>4.7</td>
<td>124</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>4.7</td>
<td>134</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>0</td>
<td>0</td>
<td>243</td>
<td>0</td>
</tr>
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<td>3</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
occurring in any quadrant at this stage the probability of this occurring by chance is $p<.01$ ($\chi^2=12$, $df=3$), which suggests a similar distribution of retouch to that of the stage 1 scalar unifaces.

Although the use of goodness of fit tests is restricted in the analysis of stages 2 and 3 by the small samples and the variable expected frequencies (as table 5.28 shows), the alternative method described in the scalar analysis can be applied.

Table 5.29 lists the 24 sequence permutations and the difference between the observed and expected frequencies for the invasive unifaces. The significant variance from the expected values confirms the presence of a sequence structure. The sequences with the four highest differences [124], [134], [132] and [241] form a sequence diagram (figure 5.18) similar to that of the scalar (figure 5.15). The most important feature of these sequences is that [132] and [241] are a mirror set, which suggests that their combination will account for the highest proportion of the invasively flaked lancets. This is confirmed by an examination of the mirror sequences in table 5.30 where [132-241] and [241-132] combine to each account for over 85% of the invasively retouched sample.

In comparison with the scalar, the invasive unifaces have a clearly defined reduction sequence which starts in a similar fashion on one distal quadrant but moves down to complete a single side before proceeding to the diagonally opposite distal quadrant and the completion of the second
### Table 5.29: Observed and Expected Numbers for all Reduction Permutations - Invasive Unifacial Lancets

<table>
<thead>
<tr>
<th>Sequence</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
</tr>
</thead>
<tbody>
<tr>
<td>123</td>
<td>10</td>
<td>9.2</td>
<td>0.8</td>
</tr>
<tr>
<td>124</td>
<td>12</td>
<td>7.6</td>
<td>4.4*</td>
</tr>
<tr>
<td>134</td>
<td>12</td>
<td>8.2</td>
<td>3.8*</td>
</tr>
<tr>
<td>132</td>
<td>15</td>
<td>9.2</td>
<td>5.8*</td>
</tr>
<tr>
<td>142</td>
<td>9</td>
<td>7.6</td>
<td>1.4</td>
</tr>
<tr>
<td>143</td>
<td>4</td>
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</tr>
<tr>
<td>231</td>
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<td>4.5</td>
<td>-1.5</td>
</tr>
<tr>
<td>234</td>
<td>1</td>
<td>2.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>243</td>
<td>4</td>
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</tr>
<tr>
<td>241</td>
<td>8</td>
<td>2.9</td>
<td>5.1*</td>
</tr>
<tr>
<td>312</td>
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<td>9.2</td>
<td>1.8</td>
</tr>
<tr>
<td>314</td>
<td>8</td>
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</tr>
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<td>341</td>
<td>0</td>
<td>3.6</td>
<td>-3.6</td>
</tr>
<tr>
<td>342</td>
<td>1</td>
<td>2.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>413</td>
<td>0</td>
<td>8.2</td>
<td>-8.2</td>
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<td>7.6</td>
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<td>421</td>
<td>6</td>
<td>2.9</td>
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<td>423</td>
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<td>-3.6</td>
</tr>
<tr>
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<td>1</td>
<td>2.0</td>
<td>-1.0</td>
</tr>
</tbody>
</table>

\( \chi^2 = 45.8 \), \( df = 23 \), \( p < 0.01 \)

### Table 5.30: Mirrored Sequences - Invasive Unifacial Lancets

<table>
<thead>
<tr>
<th></th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>124-213</td>
<td>18</td>
<td>16.8</td>
<td>1.2</td>
</tr>
<tr>
<td>b)</td>
<td>134-243</td>
<td>16</td>
<td>10.2</td>
<td>5.8</td>
</tr>
<tr>
<td>c)</td>
<td>132-241</td>
<td>23</td>
<td>12.1</td>
<td>10.9</td>
</tr>
<tr>
<td>d)</td>
<td>241-132</td>
<td>23</td>
<td>12.1</td>
<td>10.9</td>
</tr>
</tbody>
</table>
Figure 5.18: Tree diagram of the most probable invasive reduction sequences.

Figure 5.19: Most probable invasive reduction sequences.
side (figure 5.19). This is consistent with the need to establish an invasive form of retouch from the outset of reduction and to continue it in the most systematic manner. As the distance from the central ridge to the flake margins is the narrowest in the distal quadrants it appears to be the most favoured location for the commencement of the process.

The main negative sequences, [413], [143], [341] and [431] show that there is a low disposition to begin the sequence from the basal quadrants, especially [4], and to move diagonally up to quadrant one - similar in effect to the scalar, if less systematic.

It has been suggested that scalar flake formation could effectively terminate an invasive sequence. Of the 51 flakes classed as invasively flaked, 27 (53%) exhibited scalar flaking in at least one quadrant. In stage two, 2 flakes retained scalar modification in quadrant [4] consistent with a terminated [24] sequence, however, none of the [13] sequences had scalar terminations. Of the remaining stage two, 5 have scalar retouch in one of the distal quadrants (3 from sequence class [12] may be derived from the scalar reduction). In the stage three flakes, 7 (78%) retain scalar retouch in at least one quadrant. Of these, 4 (57%) are consistent with the termination of a [132] or [241] by scalar flake formation in quadrant [2] or [1], while the remaining 3 flakes show indeterminate combinations. Of the stage four flakes, 13 (54%) exhibit scalar retouch with 9 retaining it in the
basal quadrants. This is, however, not significantly different from the 50% expected by chance, and there are only 2 flakes with scalar locations which are consistent with a terminated [1324] sequence.

While scalar modification is consistently associated with the invasive, its relation to the termination of the sequence is not as clear as was initially expected. This may be due to a knapper continuing to attempt the re-establishment of invasive flaking in other quadrants in the hope of rejuvenating the scalar portion from an opposite direction, or to the incorporation of failed invasives into the less structured scalar reduction mode. This would have the effect of overlaying any direct relationship which may have existed in the invasive sequence. As 47% of the invasive class are not associated with scalar retouch it was evidently not the only reason for sequence termination.

In summary, the analysis of the invasive unifaces has shown that these artifacts exhibit a more systematic reduction procedure compared to that seen in the scalar unifaces. It is argued that the analysis has successfully separated the modes of reduction associated with the simple working of pointed flakes and the manufacture of points, which the invasive unifacial sequence represents.
5.5f: Bifacial

As described above, any lancet flake with retouch on both ventral and dorsal surfaces was classified as bifacially modified. As an analytic category the class may incorporate flakes from a series of possible reduction modes:

1) The utilization of both faces for the removal of scalar flakes. Given the weak structure of the scalar unifacial reduction it is not likely that incorporation of both ventral and dorsal surfaces into a sequence would result in any coherent patterning in the location of flaking between the faces. If this is the case, there may be some expectation of a general agreement in the degree of reduction between the faces - if there were no preference for one face above another. This is, however, unlikely given the extreme preference for retouching the dorsal surface exhibited in the unifacial analysis.

2) Bifacial retouching as part of the process of shifting platforms towards the central axis of the flake, facilitating invasive flake formation on the opposite face. In this case, there should be a clear association between the two flaking modes in opposed quadrants, with possibly the tendency to modify complete opposite margins. The latter is dependent on whether the platform shifting is a distinct sub-sequence or simply contingently applied. In this mode bifacial flaking is a sub-sequence of the unifacial invasive process.
3) Bifacial reduction deriving from the extension of the unifacial invasive mode to the opposite face. This is the first of the bifacial sequences distinguished in section 5.4a. If this is the case, a high proportion of opposite invasive modification can be expected to be associated with full invasive retouch on the opposed face.

4) A 'true' bifacial sequence where both faces are reduced at the same rate with the artifact passing through blank and preform stages.

Only 69 lancet flakes retained retouch on both faces. Of these, 20 (29%) were fully invasively flaked. The remainder retained varying combinations of scalar and invasive retouch.

Comparison of the dimensional and shape indices for the bifaces with the plain and unifacial groups shows significant differences in width with the plain and scalar unifaces and in thickness with the scalar (KS - one tail - H1: bifacial flakes are smaller: plain lancet - width: $\chi^2=15.5$, df=2, $p<.01$; scalar unifaces - width: $\chi^2=20.8$, df=2, $p<.01$; thickness: $\chi^2=16.5$, df=2, $p<.01$). Marginally significant differences in length with the scalar and plain lancets and in thickness with the plain lancets are also present (KS - one tail - plain lancets - length: $\chi^2=8.4$, df=2, $p=.02$; thickness: $\chi^2=8.2$, df=2, $p=.02$; scalar unifaces - length: $\chi^2=6.7$, df=2, $p=.04$). Again the differences are not large, although in the direction predicted by the general reduction model (table 5.31).
Of the bifacial flakes with partial retouch 12 retained scalar only, with no apparent tendency for there to be any correlation in the degree of dorsal and ventral flaking (\( \tau = -.07, \ p = .37 \)) To test this further the proportion of retouch in opposed quadrants was compared with that expected by chance. This was calculated by taking the total number of ventral and dorsal quadrants in the sample (48 per face) and calculating the probability of there being a quadrant with retouch on either face - (30/48 = .63) for the dorsal and (17/48 = .35) for the ventral. The probability of retouch in opposed quadrants is .22 (.63 * .35) giving an expected number of 10.6 if ventral and dorsal retouch are independent events. At 5, the observed number, the binomial probability for selecting 5 or less with opposed modification is \( p = .03 \). This suggests that scalar retouching of the ventral and dorsal surfaces are largely unrelated, except for the tendency to avoid the retouching of opposed quadrants on opposite faces. This is the complete opposite to that expected by any of the bifacial reduction modes presented above and suggests that these flakes are derived from unifacial scalar modification - mode (1) above.

Nineteen flakes classified as partially invasively flaked retained a combination of scalar and invasive flaking on the dorsal face and a range of ventral modification from fully flaked invasive to the presence of scalar retouch in only one quadrant. Twenty-one flakes retained comparable invasive and scalar retouch
### TABLE 5.31: Dimensional and Shape Index Means (mm) - Bifacial Lancets

<table>
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<tr>
<td></td>
<td>$\bar{x}$</td>
<td>37.6</td>
<td>18.4</td>
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<tr>
<td></td>
<td>$S_x$</td>
<td>9.8</td>
<td>4.8</td>
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<tr>
<td>l/w</td>
<td>$\bar{x}$</td>
<td>2.0</td>
<td>.42</td>
</tr>
<tr>
<td></td>
<td>$S_x$</td>
<td>.4</td>
<td>.1</td>
</tr>
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</table>

### TABLE 5.32: Dorsal and Ventral Retouch Combinations

<table>
<thead>
<tr>
<th>Dorsal Retouch</th>
<th>Ventral Retouch</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>22</td>
<td>4</td>
</tr>
<tr>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>20,21</td>
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<td>41</td>
<td>2,2</td>
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<td>42</td>
<td>1,41,42</td>
</tr>
<tr>
<td>60</td>
<td>21,41,42</td>
</tr>
<tr>
<td>61</td>
<td>1,40</td>
</tr>
<tr>
<td>80</td>
<td>1,2,4,20,22,22,40,40,40,41,60,61,80,80,80,80,80,80,80,80,80,80,80,80,80,80,80</td>
</tr>
</tbody>
</table>

### TABLE 5.33: Flaking Coincidence on Opposite Faces

<table>
<thead>
<tr>
<th>Dorsal scalar</th>
<th>Ventral scalar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ds-Vs</td>
<td>7</td>
</tr>
<tr>
<td>Ds-Vi</td>
<td>9</td>
</tr>
<tr>
<td>Ds-o</td>
<td>26</td>
</tr>
</tbody>
</table>

Ds - dorsal scalar  Vs - ventral scalar
Di - dorsal invasive Vi - ventral invasive
Quad. total = 68   Quad. total = 88
combination on the ventral, coinciding with an equally wide range of dorsal modification.

To test for the presence of 'true' bifacial reduction (mode 4) above, the degree of correlation between the modification of both faces was assessed by ranking the invasive retouch scale, using quadrant number and retouch combination (from 20 to 61) as major and minor determinants for both dorsal and ventral faces. For the dorsal and ventral invasive groups (which hold 8 of their members in common) the correlation between the degree of retouch on both faces is negligible with tau=.03, p=.44 for the dorsal and tau=.02, p=.44 for the ventral. This shows there to be no tendency for both faces to be retouched together and suggests the utilization of a extended unifacial invasive sequence. The presence of members common to both dorsal and ventral partial invasive sets also excludes the possibility that they represent only the platform shifting of an essentially unifacial sequence.

Table 5.32 shows the retouch combinations found in the ventral and dorsal sets. The left hand column ranks the invasive dorsal retouch from a single invasive (20) to fully invasive flaking for the dorsal surface (80). The ventral retouch combinations associated with each row are listed against the dorsal scale. It can be seen that the highest proportion of partially flaked ventral surfaces are associated with a completely flaked dorsal and that there is a similar, but less pronounced, association of partial dorsal with complete ventral modification. This
is consistent with the completion of one face before rotating the flake and attempting to follow the same procedure on the opposite - reduction mode 3 above.

The presence of these two unifacial sequences does not preclude the possibility that some bifacial flaking reflects the shifting of platforms, in the process of invasively flaking, towards the first surface to be worked (which is principally the dorsal). To test this, the flakes with only scalar flaking on one face were compared for the type and frequency of removals in directly adjacent quadrants of the opposite face (table 5.33). The table shows the frequency of coincidence to be little different from that expected by chance in all but the ventral to dorsal scalar, which suggests a tendency to avoid the combination when ventral retouch is scalar only. The behavioural significance of this is, however, problematic. By assuming ventral and dorsal retouch to be independent events, the frequencies expected by chance association could be calculated by multiplying the proportion of scalar to total quadrants on the artifacts which had only scalar retouch on one face (ie., Ds and Vs artifacts) with the proportions of scalar, invasive and empty quadrants on the opposed face and multiplying the fraction by the total number of quadrants in the dorsal and ventral scalar only groups. If, for example, ventral scalar were strongly associated with dorsal invasive retouch we should expect a greater association than that derived from chance. The results show, however, there to be no clear evidence that extensive scalar platform

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preparation proceeded invasive flaking.

Tests for reduction sequences comparable to those seen in the unifacial flakes was substantially restricted in the bifacially retouched by the size of the sample. On the dorsal face both the scalar (sample size 14 for stages 1, 2 and 3) and invasive (sample size 13) flaking showed a concentration on the modification of quadrants 1 and 3, similar to that seen in the invasive unifacial sequences, with modal scalar sequences of [134] (64%) and [132] (43%), and invasive of [341] (46%) and again [134] (39%). Both sequence sets differ from the unifacial in tending to concentrate on the basal quadrants as opposed to moving on the diagonal to the opposed distal (except from the scalar [132]). The difference between the observed and expected values for the combined scalar and invasive tree analysis are, however, only marginally significant (chi² = 37.9, df=23, .05>p>.02) and of ambiguous interpretative significance.

The ventral scalar and invasive sequences both retained [789] (45% and 41%) as the sequence of best fit which is equivalent to a dorsal sequence of [124] and therefore of greater similarity to the unifacial scalar sequence than to the dorsal above. The overall departures from expected in the tree analysis are not, however, statistically significant (chi²=13.3, df=23, p>.9).

In summary, the analysis of the bifacially flaked lancets has shown that where this flaking is scalar only, there appears to be no systematic association between
ventral and dorsal removals and that these flakes may best be seen as the product of a unifacial scalar reduction applied to both faces independently. As there is no evidence for any consistent agreement in the degree of ventral and dorsal modification, it is also probable that the invasively worked bifaces were the products of the extension of separate and successive unifacial invasive sequences to opposed faces, rather than the parallel reduction expected from a 'true' bifacial sequence. The evidence for bifacial flaking resulting from platform preparation is also lacking, but the presence of the procedure is not as yet discounted. A factor which may affect the assessment of this and all bifacial procedures is the possibility of discarded bifaces being incorporated into the unifacial scalar sequence and receiving an obscuring second round of scalar retouch.

5.6: Manufacturing Technique

As noted in Chapter Two and section 5.3b elongated flakes, like the lancet, are not ideal blanks for invasive unifacial or bifacial retouch. Their low thickness to width ratio can not sustain extensive marginal retouch and their thin edges provide little support for platform formation. As Patterson (1979:4) points out, the dorsal ridges on blades also make them difficult to flake invasively and they are also more prone to break when
retouched, possibly due to the relatively low areal moment and high numbers of micro-fractures. Despite the disjunction between the blank and retouch modes, the Ingaladdi knappers, like those on other north-western sites, have frequently transcended the difficulties of blank form to produce points of high aesthetic appeal. The techniques used to produce these artifacts have not, however, been extensively discussed.

Davidson (1935:170) noted that the local Wardaman were receiving in exchange pressure flaked spearheads from the Kimberley region to the west. These spearheads were highly prized and as Davidson saw it, the Wardaman were in the process of attempting to replicate, in a crude fashion, the pressure flaking technique. The Wardaman, he observed, lacked control of force and direction in flake removals and were ignorant of the types of stone to which pressure flaking could be best applied. Davidson (1935:172) went on to suggest that this was a case of trait diffusion in progress without, "the accompaniment of much knowledge". Mulvaney (1975:217) has argued that this is not relevant to the origin of the technique and suggested, on the basis of the Ingaladdi material, that the influence had worked in reverse.

Flood (1966:125) has claimed that experimental reproduction of Yarar points using pressure flaking and trimming with the teeth was achieved - although this success did not extend to semi-serrated points. She was, however, not certain that there was any evidence for
pressure flaking in the Yarar assemblage because the same results were achievable using direct percussion (Flood 1970:48).

Dortch (1977a:113) reported both pressure and percussion flaking in the Ord Valley assemblages and Bradshaw (1986:289) noted points with "characteristic channel trimming" in Clarke's Kimberley sites. Although Bradshaw (1986:289) goes on to suggest that pressure flaking is also evident in Schrire's (1982:fig. 77, 3B/4-1, 6C/4-4) Jimeri II material Schrire (1982:245) is less certain, due to the rarity of edge serration and the absence of Kimberley type points. Conversely, Barton (1979:53) has claimed that the typical point from Ngarradj was "created by delicate pressure flaking around its perimeter".

The problem with these statements is that what characterizes pressure and scalar flaking remains largely implicit; the assumption being that pressure flaking always produces some clearly definable difference in flake form. In reality indifferent pressure flaking is, as Flood (1970:48) observed, comparable to indifferent percussion in its ability to create scalar and invasive removals. While the highly crafted Kimberley points may be securely said to be pressure flaked in the final phases of their production, the distinction in less well worked pieces is far from certain. The reason for this is that highly controlled flake removals are, besides the application of technique, also a product of the care with which a knapper works; highly skilled percussion removals
may be comparable over a large range to poorly controlled pressure. The search for early pressure flaking may be confronted with the problem of distinguishing an underdeveloped technique against a background of normal percussion working. It is only when care and technique are combined that percussion and pressure can be expected to produce qualitatively different removals.

While it may, in the Ingaladdi assemblage, be reasonable to assume that the scalar flaking principally derives from direct percussion, the invasive is more problematic. Some evidence of technique is supplied by the small number of artifacts (24 quartzite and 5 chert - 2 and 6% of modified quartzite and chert lancets) which retain serrated edges (figure 5.20). The serrations are shallow closely spaced and consistent with the application of a narrow tipped hammer or an indenter similar to a pressure flaking implement. Serration is associated with both scalar and invasive removals and is present throughout the overlying assemblage from spit 10 to 1.

Mulvaney (1975:217) has suggested that this may indicate that some form of pressure flaking was associated with the modification of lancet flakes in the assemblage. It is not, however, certain how great a role it played in lancet reduction, beyond what is essentially edge modification. Some forms of serration can also be carried out using narrow hammer stones. The only artifacts in the assemblage which approach the standard of Kimberley working are a quartzite lancet from spit 4 and a glass
Figure 5.20: Illustration of reduction technique: (a) and (b) possible pressure flaking; (c)-(f) serrated quartzite lancets from the Ingaladdi assemblage.
section from spit 2 (figure 5.20a,b). Two surface finds also exhibit high degrees of regularity in flake removals from the dorsal face only. There is, however, no evidence in the assemblage, or on the neighbouring surface sites, of there being the combination of 'true' bifacial reduction and careful pressure flaking which characterizes the Kimberley points.

The possible antiquity of an association between lancet reduction and some form of pressure flaking in the Ingaladdi assemblage casts doubt on Davidson's hypothesis that pressure flaking was a recent introduction to the area. Given the proportion of chert material in the Ingaladdi assemblage, it is also unlikely that the Wardaman were as unaware of the difference in the flaking quality of fine grained material and the local quartzite, as Davidson maintains. A more tenable hypothesis is that what Davidson interpreted as attempts at a crude replication of Kimberley pressure flaking was simply the traditional way in which the Wardaman utilized the technique. The poor control Davidson observed could have been a product of what must be assumed to have been aged nature of his informants. It is argued that the problem for the inhabitants of Ingaladdi was not that they could not pressure flake, but that fine grained chert material suitable for the purpose was extensively incorporated into the standing reserve (term explained in Chapter Six), and was not readily freed in a form suitable for extensive pressure reduction. Secondly, the underlying process of reduction (ie., the formation of lancet flakes) did not
supply blanks suitable for the parallel bifacial reduction necessary for full implementation of the technique. The development of the process was constricted by the underlying structure of production organization in the region, not an incapacity to understand the technique.

5.7: Temporal variation in Invasive and Scalar Lancet Reduction

The analysis of bifacial reduction has shown that technically the reduction is composed of two unifacial sequences placed in series. This suggests that the invasive bifacial reduction may be an extension of the invasive unifacial process.

Figures 5.21 and 5.22 compare the distributions of scalar unifacial lancets with the invasive unifacial and bifacial groups. The graphs show the invasive distributions both peaking in spit 8 and declining to very low levels by spits 1 and 2. In contrast the scalar unifaces exhibit a bimodality with a major peak in spit 6 and a secondary in spit 9. The tau and partial tau time series coefficients for each are given in table 5.34. Despite the variation in the peaks the correlation between the series remains high.

The separation is, however, improved if the 12 bifacial flakes which retained scalar flaking only are placed in the unifacial scalar distribution. This has a
Figure 5.21: Quartzite scalar and invasive uniface reduction modes - flake percentage numbers by spit.

Figure 5.22: Quartzite bifacial flakes and bifacial invasive mode - flake percentage numbers by spits.
### TABLE 5.34: Time Series Correlation Coefficients

<table>
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<tr>
<th></th>
<th>$\tau$</th>
<th>$\tau_{up}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasive/Scalar unifaces</td>
<td>.60</td>
<td>.60</td>
</tr>
<tr>
<td>Bifaces/Invasive unifaces</td>
<td>.77</td>
<td>.76</td>
</tr>
<tr>
<td>Bifaces/Scalar unifaces</td>
<td>.63</td>
<td>.63</td>
</tr>
</tbody>
</table>

### TABLE 5.35: Time Series Correlation Coefficients for Reduction Modes

<table>
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<tr>
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<th>$\tau_{up}$</th>
<th>(1) $\tau_{up}$</th>
<th>(2) $\tau_{up}$</th>
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<td>Invasive/Scalar unifacial</td>
<td>.68</td>
<td>.54</td>
<td>.50</td>
<td></td>
</tr>
<tr>
<td>Invasive Bifacial/unifacial</td>
<td>.75</td>
<td>.75</td>
<td>.70</td>
<td></td>
</tr>
<tr>
<td>Invasive Bifacial/scalar</td>
<td>.46</td>
<td>.47</td>
<td>-.12</td>
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</table>
negligible effect on the scalar distribution while increasing the peak on the bifacial (figure 5.22). The resulting time series coefficients give a better picture of the agreement between reduction modes, which exhibit a greater degree of separation than that based on flaking type above (table 5.35).

As none of the correlations were greatly affected by time it was possible to gauge the degree to which they were a product of intercorrelation by carrying out a second series of partial correlations on the primary coefficients, factoring out the third sequence in each case. The third column in table 5.35 (2) shows that while the (a) invasive unifacial/scalar unifacial and the (b) invasive bifacial/invasive unifacial are not greatly affected by the removal of bifacial invasive and unifacial scalar respectively, the correlation between the (c) invasive bifacial and scalar unifacial is due entirely to their joint correlation with the invasive unifacial sequence. The stronger correlation between the invasive unifacial and bifacial sequences than that between the invasive and the scalar unifacial also supports the suggestion that the bifacial and invasive unifacial reduction were sequentially related.
5.8: Breakage

Although the breakage of modified lancets is similar to that of the plain, in the dominance of lateral snap fractures, it shows some variation in the proportion of segments (table 5.36). If the segment proportions for the three modified classes are compared with those for the plain lancets in table 5.15, it can be seen that the proportion of tips is markedly higher in the modified, constituting from 28.6 to 46.3% of the total, compared to 12% in the plain. A chi² test shows there to be a significant difference in the segment proportions between all four lancet classes (chi²=83.6, df=6, p<.001), which is largely a product of the tip proportions. A comparison of the proximal (tip-off and butt) and the distal segments, represented by the sections only, shows there to be no significant variation in the proportions between the modified and plain classes (chi²=.56, df=3, p>.9).

Comparison of the mean lengths of the modified segments (tables 5.37 and 5.16) shows a tendency for the bifacially flaked segments to be smaller than the scalar unifaces which is consistent with the difference in the size of the whole artifacts and reflective of the degree of reduction. Overall, however, the means of the modified segments are comparable to those of the plain lancets.

A feature of the modified segments’ length, like that of the plain lancets, is that the addition of butt, section and tip means produces a longer mean length than that of the whole artifact, again suggesting that sections
### TABLE 5.36: Segment Numbers of Broken Modified Lancets

<table>
<thead>
<tr>
<th></th>
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<th>butt</th>
<th>section</th>
<th>tip</th>
<th>total</th>
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<tr>
<td>Scalar unifaces</td>
<td>87</td>
<td>93</td>
<td>80</td>
<td>174</td>
<td>434</td>
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<tr>
<td>Invasive unifaces</td>
<td>23</td>
<td>22</td>
<td>20</td>
<td>56</td>
<td>121</td>
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<tr>
<td>Bifaces</td>
<td>44</td>
<td>30</td>
<td>28</td>
<td>41</td>
<td>143</td>
</tr>
</tbody>
</table>

### TABLE 5.37: Mean Length of Modified Lancet Segments (mm)

<table>
<thead>
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<th>butt</th>
<th>section</th>
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</thead>
<tbody>
<tr>
<td>Scalar unifaces</td>
<td>43</td>
<td>28</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>Invasive unifaces</td>
<td>36</td>
<td>26</td>
<td>19</td>
<td>18</td>
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<tr>
<td>Bifacial</td>
<td>35</td>
<td>23</td>
<td>20</td>
<td>19</td>
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</table>
and tips are the results of similar breakage and that there was an overlap between the two in breakage width. Table 5.38 shows the mean breakage widths of the tip breakages (W1) to be intermediate between the proximal (W1) and distal (W2) breakage widths of the sections. The width of tip-off is closer to that of the W2 on sections and that of the butts closer to the W1. Combining all the modified segments, the frequency distribution of break widths for proximal segments (butt and tip-off) and distal segments at the proximal break (W1) and the distal (W2) show, like the plain lancets, a decline in numbers of proximal breaks in the size class >5-10mm, with only 15.6% of the widths <10mm, compared with 35.3 and 52.8% in the other break classes (table 5.39).

From the frequency distributions for bifaces and unifaces it can be estimated that from 30-25% respectively of the distal segments have been lost through the sieves. If this is added to the tip component it brings the proximal to distal ratio up to 1:1.2 for the bifaces (which is not significantly different from 1:1 - \( \chi^2=1.05, \text{ df}=1, \text{ p}>.5 \)), 1:2.1 for the invasive unifaces and 1:1.7 for the scalar unifaces. Even subtracting the 44 tips not accounted for in the plain lancets from the unifacial groups in proportion to the frequency of scalar and invasive flaking (ie., 1:3) brings the unifacial ratios down to 1:1.9 and 1:1.6. This is greater than would be expected by chance and reflects a real disproportion in the ratio of proximal to distal segments. The high number of tips is opposite to that noted by
### TABLE 5.38: Mean Breakage Widths (mm)

<table>
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<tr>
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<td><strong>Scalar unifaces</strong></td>
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<td>24</td>
</tr>
<tr>
<td><strong>Invasive unifaces</strong></td>
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<td>21</td>
</tr>
<tr>
<td><strong>Bifaces</strong></td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>tip-off</td>
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<td>butt section</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>tip</td>
<td>16</td>
<td>13</td>
</tr>
</tbody>
</table>

### TABLE 5.39: Frequency Distribution of Widths at Break

<table>
<thead>
<tr>
<th>size classes</th>
<th>proximal segments</th>
<th>distal segments (W1)</th>
<th>distal segments (W2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>20</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>&gt;5-10</td>
<td>83</td>
<td>62</td>
<td>50</td>
</tr>
<tr>
<td>&gt;10-15</td>
<td>69</td>
<td>132</td>
<td>22</td>
</tr>
<tr>
<td>&gt;15-20</td>
<td>55</td>
<td>112</td>
<td>21</td>
</tr>
<tr>
<td>&gt;20-25</td>
<td>36</td>
<td>49</td>
<td>9</td>
</tr>
<tr>
<td>&gt;25-30</td>
<td>14</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>&gt;30-35</td>
<td>9</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>&gt;35-40</td>
<td>3</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>&gt;40-45</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;45-50</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Schrire (1982:246) and Flood (1970:48). A possible explanation for the frequency of modified tips is that while the tip is discarded the proximal sections are retained and transported off-site. If the disposition to retouch is inversely related to the on-site availability of replacement flakes, the more even proportions in the plain lancets reflects a higher on-site availability and a reduced disposition to conserve the broken flakes which are subsequently discarded on-site. Using this correlate the even proportions of the bifaces may also be seen as a product of the flakes high reduction affecting its curation rates.

5.9: Cores in the Overlying Assemblage

As a proportion of the total number of artifacts, the cores in the overlying assemblage constitute approximately .56%, comparable to the core percentage of .87% in the underlying. Of the total modified, however, they represent only 4%, compared with the 16% in the latter.

The proportions of the core types are also substantially altered in the overlying assemblage with high numbers of lateral and bifacial cores in both the chert and the quartzite (compare table 5.40 with 4.5). The shift in proportions is not, however, uniform with the overlying quartzite cores exhibiting a higher frequency of bipolar and the chert an increase in lateral forms.
### TABLE 5.40: Core Type in the Overlying Assemblage

<table>
<thead>
<tr>
<th></th>
<th>Ro/n</th>
<th>bipolar</th>
<th>lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartzite</td>
<td>8</td>
<td>21</td>
<td>8</td>
</tr>
<tr>
<td>Chert</td>
<td>12</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>

### TABLE 5.41: Mean Mass of Core Type (gms)

<table>
<thead>
<tr>
<th></th>
<th>Ro/n</th>
<th>bipolar</th>
<th>lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartzite</td>
<td>$\bar{x}$</td>
<td>41</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>$S_x$</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td>Chert</td>
<td>$\bar{x}$</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>$S_x$</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>
Figure 5.23: Overlying assemblage quartzite and chert Ro/n, lateral and bipolar core numbers by spit.
Figure 5.23 shows there to be a temporal displacement between the types with 69% of the chert and 75% of the quartzite Ro/n occurring in spits 11 and 10, and the bipolar and laterals dominating from spit 8, peaking around spits 5 and 6, and declining towards the surface.

As the mean mass of the Ro/n cores (table 5.41) is directly comparable to those of the same type for the later half of the underlying assemblage (see tables 4.18 and 4.19) they may be seen as an extension of the underlying assemblage into the upper units. This is consistent with the low levels of retouch in the quartzite and the increase in mean flake size seen in these spits. The means of the bipolar and lateral cores are substantially lower and coincide with the flake dominance of the assemblage from spit 9.

In the quartzite, 16 of the 21 bipolar, all of the laterals, and in the chert 1 of the bipolar and 7 of the 14 laterals are on flakes. Of more technological significance is that, of the bipolar and lateral quartzite cores on definable flakes, 84% and 50% respectively are on lancet butts (see figure 5.24).

In section 4.2 it was noted that the lateral cores have been classed, with some reservations, as burins by Mulvaney (1969:129, 1975:235). Some doubt on the general applicability of the type to Australian assemblages as been continued by the writer's suggestion that some eastern Australian examples could represent a highly specialized core which had been reduced via a twin ridge
Figure 5.24: Bipolar cores on quartzite lancet butts from the overlying assemblage.
technique (Cundy 1977). The process, first described by Crabtree (1968:461), utilizes the two ridges formed by the removal of an original spall to guide the detachment of two further flakes, the single ridge which remains may be further detached and the sequence began again. If the process is halted by step and hinge terminations the resulting artifact will appear burin-like. A number of the lateral cores in the Ingaladdi assemblage (figure 5.25) retain evidence for abandonment at various stages of a twin ridge reduction process.

The suggestion that these are the product of a specialized flake core reduction is further supported by Kamminga's (1982:92) finding of little edge damage on a sample of 143 'burins' for a wide range of Australian sites including 24 from Ingaladdi. The utilization of chert flakes as lateral cores is consistent with the secondary use of lancet proximal segments for bipolar working - the difference in the modes of reduction being attributable to the better flaking qualities of the chert. The appearance of both core types is also consistent with the extensive reliance on flakes to supply on-site reduction in the overlying assemblage. As there appears to be little on-site reduction of primary cores of the type seen in the underlying assemblage, a solution to situational shortfall is to extend the reduction of flakes beyond edge modification to their utilization as flake producing cores.
5.10: Tula Adzes

Of the large number of tula adzes reported by Mulvaney (1975:234) for the 1963 and 1966 assemblages 20 were identified in the sample analysed above. The majority (70%) of these are well worn slugs and all specimens are on what appear to be regionally available chert. Although no specimens occur below spit 9 the small number make this an uncertain indication of their introduction to the lithic technology of the region. Chert pieces with heavy step fractured and undercut edges, consistent with hafting, occur also in low numbers down to spit 11 (see Sheridan 1979).

As there is no evidence of tula manufacture in the Ingaladdi assemblage the 'adzes' have not been analysed in any detail. Their presence in the site is enigmatic, as tula are invariably made on high quality chalcedony type material, there is no apparent mechanism for locally replacing those discarded. Given the manner in which quartzite and chert reduction is organized on the site (see Chapter Six), it seems improbable that 'adzes' would be discarded simply because they were worn, without some available on-site replacement. Either the replacement was derived from the knapper's personal reserve transported to the site, or the adze was not being utilized as a specialized hafted woodworking tool at the time of discard. As chert is extensively curated, worn slugs may be re-incorporated into the standing reserve as a piece of
usable stone and discarded on the site as replacement local material because available. The presence of tulas in the assemblage need not, therefore, be interpreted as being related to the on-site utilization of their specialized wood working function. There is also doubt whether tula slugs could have functioned as adzes in extreme stages of reduction (Sheridan 1979).

5.11: Summary of the Overlying Assemblage

1) In terms of flake size, the percentage of flake retouch and core discard in spits 10 and 11 appears to be more closely related to the preceding Mode C than to what follows.

2) From spit 9 on, the assemblage is dominated by the appearance of standardized lancet flakes of local quartzite. Bifacial and unifacial reduction of these flakes exhibits diachronically separate modalities with peak discard of the former preceding in spit 8 that of the latter in spit 6.

3) The flake debitage is uniformly small (<2cm²) and its distribution corresponds to the peaks in both bifacial/unifacial invasive and unifacial scalar lancet discard. A cluster analysis shows there to be little variation in the flake size proportions through time (ie., comparable to the variation within a single Mode of the
underlying assemblage).

4) Examination of the production of lancet flakes shows their internal platform and flake dimensional structure to be a transformation of that seen in the underlying assemblage. It is suggested that the mechanism for this is the transference of motor 'habits' from the reduction of small cores to larger stone material. This only required an increase in the care with which the PFA was located behind guide ridges to consistently produce standardized lancet flakes.

5) Analysis of the reduction modes associated with the unifacial lancet flakes showed scalar reduction to be structured only by the disposition not to retouch diagonal quadrants in the early stages. The invasive, on the other hand, appears to reflect a disposition to retouch complete sides of the flake before preceding to the next. The invasively worked unifaces show a strong correlation with the invasive bifaces through time.

6) There is no indication of 'true' (or parallel) bifacial reduction (ie., the synchronous reduction of both faces) in the lancet flakes. Those that are worked bifacially are the extension of a sequential unifacial reduction in which one face is completed before work on the second is begun.

7) The primary mode of core reduction on-site sees a switch to the secondary use of flakes, including quartzite lancet butts. Flakes are reduced principally in the chert via a twin ridge sequence and in the quarzite via bipolar
An interpretation of the overlying assemblage will be forwarded in the following chapter. As a conclusion to the analysis it can seen that, compared to the earlier assemblage, the overlying is more technically uniform with less diachronic change. The main features, summarized above, point to a substantial shift in both the mode of flake production and their subsequent reduction. The analysis has, however, suggested that the production of lancet flakes is largely understandable in terms of a transference of primary core reduction off-site to specialized stone sources. The resulting lancet flakes are reduced in a series of separate reduction processes consistent with their functioning as both general purpose implements and as more specialized 'points'. The reduction model presented in Chapter Two has also been seen to be generally applicable to the Ingaladdi assemblage, although features like the separation of unspecialized single platform (A-1) and lancet core (B-1) reduction modes have to be modified, and the 'true' bifacial sequence (D-1) appears to be absent.

At a more general level, the analysis has for the first time in Australian prehistory, shown there to be a structural continuity between the early amorphous flakes and later forms. This provides evidence for local development and suggests the possibility of separating local from the externally derived features of the later
technological changes. The separation of scalar and invasive reduction modes on lancet flakes has also demonstrated these flakes to have retained a more extensive infrastructural role in the north-western lithic technology than previously realized.

Footnote

[1] It has been suggested that the variation in the underlying and overlying assemblage may reflect shifts in artifact function. As noted in the text the primary use wear in the assemblage is a gross form of edge rounding which occurs on both flakes and cores in the underlying and lancet flakes in the overlying assemblage. Microscopic examination of the wear shows it to be an abrasion with little silica deposition (Fullagar pers. com.) - possibly from bark working. This suggests that at least one of the functions to which artifacts were put stayed relatively constant through time on the site.
6.1: Behavioural Correlates for the Underlying Assemblage

In section 4.3b it was suggested that the presence of both chert and quartzite cores in the underlying assemblage implied transportation of the cores to the site. The point may seem obvious, yet the organization of core transport and reduction appears to be an important structural feature of the assemblage. The significance of reduction organization has not been extensively discussed in relation to Australian prehistory generally, or the underlying north-western assemblages in particular.

The extreme distances between the chert and quartzite sources, relative to Ingaladdi, suggests some variation in the behaviours associated with the transport, discard and the state of the cores being brought to the site. The movement of chert material over distances of 30kms to the site and its high proportion in the assemblage shows that it was favoured for certain purposes, and suggests that it was part of a 'curating behaviour' which transported
The chert cores discarded in the underlying assemblage show there to have been a high disposition to reduce these curated, (and at Ingaladdi irreplaceable artifacts) as much as possible (see Byrne [1980] for a further archaeological example of this behaviour). The similarity of the size of the Mode I quartzite cores to that of the chert suggests that these cores may also have been part of the material transported onto the site as curated cores. In contrast, the heavier Mode II quartzite cores appear to represent the supplementation of the curated by available local material.

The curation of cores to serve as on-site sources of stone is recorded in the ethnography. For example Basedow observed:

One frequently finds a fair-sized block of suitable stone among the paraphernalia of a native in camp, from which he chips pieces as he requires them. The blocks have been termed "cores" or "nuclei"; they are six inches or more cube in the beginning, but by the time a goodly number of flakes have been removed, the parent piece becomes much smaller and gradually assumes the shape of a truncated core whose surface shows many faces from which flakes have been removed. (1925:364)

Core transportation has also been recorded by Aiston (1928:123-4), Cane (1984:146), Gould (1977:164) and Thomson (1964:405). Although data on the way in which the reduction of these cores was modified by the availability of local materials does not accompany these observations,
evidence for the substitution of 'exotic' by a local material has been recorded archaeologically (Byrne 1980, Hiscock 1984, O'Connell 1977:277).

Although the chert and the bimodality encountered in the quartzite material can be explained by this behaviour, it is not sufficient to account for the differences in rotation numbers seen in the quartzite cores on a material which is locally available. In his Lawn Hill analysis Hiscock (1984:184) has correlated the degree of core rotation with a decline in the availability of material, when measured by distance from the source (see also Byrne 1980). The positive relationship between this distance and general artifact reduction (both primary and secondary) has also been observed ethnoarchaeologically (see Wright [1977:2] quoting Bates and Holmes [1893:6] for an early discussion of this correlate).

While this provides the basic correlation of decreased availability producing increased rotation (or conservation), it does not deal with the problem of varying degrees of material conservation occurring in an assemblage within a constant distance of local sources. Some way to resolving this may be made by suggesting that the restriction of material is related to linear distance from the source only as an extreme case of a more general way in which procurement is matched to material requirements in the routine of daily activity. As Harvey (1970:210) has pointed out, distance must be measured in terms of process and activity. In her discussion of time budgeting constraints Torrence (1983), drawing on
geographic and ecological models, suggests that scheduling behaviour is a response to time limitations via the avoidance of "competition among various activities for particular periods of time" (1983:12). Using this approach it may be argued that the situational shortfall of lithic materials occurs when procurement becomes incompatible or disjunctive with other subsistence activities and the allocation of a block of time and labour for procurement retains a low scheduling priority.

While this form of explanation is a useful description of the limitation of human activity in time and space it is strongly reflective of a modern conception of objectified time and labour which demands efficient use of both "resources" (Giddens 1981:118-120, 1984:117). The projection of these onto hunter-gatherer societies is, however, problematic for reasons which will be more fully discussed in section 7.2. Because human activity occurs in time which is not immediately perceived as separate from activity, it is unlikely that hunter-gatherers apprehended the problem in the form that Torrence's model suggests, although their behaviour may exhibit an ordered task performance which appears consistent with the juggling of competing tasks. Unlike Torrence's model, it is not assumed that these tasks were objectified into a series of necessary actions to be carried out over a specific time period.

Although there are examples of Aborigines exhibiting behaviour consistent with the allocation of priority in
residential location above ease of lithic procurement (see Cane 1984:117; Hayden 1976:283), it is argued that shifts in activity focus may also operate intensely in extremely narrow time periods and over what, to conventional archaeological analysis, are extremely short distances. This is because they occur in non-uniform environments where the content of the daily routine can not be completely fixed. Observations of the use of what Binford (1979) has termed "situational gear", in which locally available materials are used to pursue immediate requirements and are then discarded can be seen as a response to extremely short term activity shifts (see also Horne and Aiston 1924:91; Gould 1977:164; Gould, Koster and Sontz 1971:163; Hayden 1979).

Shifts in activity focus could have the effect of restricting access to lithic material, producing on-site shortfall. For example, at Ingaladdi this could take the form of an increased concentration on the waterhole resources in preference to those of the hills and grass plains. The rotation of quartzite cores in the assemblage may reflect a succession of these small scale shifts, with the resulting shortfalls appearing in the lower levels to have been sufficient to create a parallel pattern of reduction disposition, such that knappers would behave at times as if the quartzite were relatively close and easily replaceable, and at others as if it were farther and less procurable. This patterning in relation to the factors affecting longer term change in the sequence will be discussed further below.
It is suggested that the Ingaladdi assemblage does not represent a single organizational structure but two; a regional and a local. The regional structure, represented by the chert and the Mode I quartzite cores, comprises materials which were brought to the site as part of a curated set of artifacts which constituted a "standing reserve". This is superficially similar to what Schiffer (see Shott 1989:288) has termed as either the "founding curated" or "donor" assemblage. The function of these artifacts was to provide lithic material for reduction where the resource was not locally available. As the on-site availability of the local quartzite is increased, we may expect the curated material to be conserved as the structure of the on-site reduction becomes more site specific.

Before proceeding, an important distinction must be made between the concept of the standing reserve and the donor assemblage. The term 'standing reserve' is taken from Heidegger (1977:17). While it can be used to describe a structural component of lithic organization similar to "donor assemblage" and "curated gear" it also represents a process of ordering material. In Heidegger's essay it describes the manner in which modern technology, through its "setting-upon", is bringing all things to stand in a specific relation to human ends as a standing reserve. This ordering threatens to "Enframe" humans and things together in a single structure which reduces human nature to and end. This is not a process controlled by
human ends, although this may seem to be the case. From Heidegger's analysis, it can be seen that the development of modern technology is not simply the appearance of new machines and processes, but the development of a structure which conditions the relationship between things and human existence. The use of the term in this thesis is an attempt to suggest an origin for the process in the archaeological record. It must be stressed that the standing reserve should not, therefore, be taken as simply synonymous with some component of lithic organization.

The variable interaction between the local and regional structures may be examined in more detail by dividing the underlying assemblage into the three periods suggested by the behavioural Modes A (spits 20-23/4), B (spits 16-19) and C (spits 12-15) (see section 4.6a).

In the lower third of the assemblage, Mode A, we see relatively high proportions of large flakes and a rise in the mean mass of non-flake debitage, particularly in the quartzite sample. The latter peaks in spit 20 where the highest numbers of discarded cores occur. The majority of quartzite cores in Mode A are unrotated yet the proportion of rotated cores rises steadily from spit 22. In the chert, both unrotated and rotated cores are discarded equally. The number of on-site core rotations, measured by the redirecting flakes, also retains a high proportion in relation to the total flake discard in both the chert and the quartzite, although this is not reflected in the discard of quartzite rotated cores.
The low reduction disposition exhibited by the modal flake size combined with the high core discard in both materials is consistent with high on-site availability of material. The rise in both quartzite and chert core numbers in spit 20 suggests that the core discard criteria (see Byrne 1980:118) for the standing reserve was modified by local replacement availability but not in the manner suggested above. Both the chert and quartzite core to flake ratios in spit 20 approach those consistent with primary reduction (see table 4.21). The highly reduced state of chert cores suggests, however, that its high ratio may be a product of the discard of cores as exhausted material in response to the availability of the quartzite, rather than as a product of their increased on-site reduction.

The Mode A assemblage can not be seen simply as a response to high on-site availability. The presence of rotated cores in higher proportions in the quartzite above spit 22 and the relatively high occurrence of core rotation, indicated by the redirecting flakes, points to periods in which core reduction was extended. The inclusion of the quartzite from spit 22 in the Mode B assemblage (which sees the highest proportion of rotated cores) supports this and suggests periods of on-site material restriction. The absence of rotated quartzite cores from spit 22 and below probably results from the low artifact totals and the reduced archaeological visibility which rare artifacts retain in small samples (see Smith
The chert shows no clear correlation with the quartzite in the above regard. As a highly curated material it appears less responsive to periods of on-site shortfall were the reaction is to extend the reduction of the local quartzite and conserve the chert.

The Mode B material (spits 16-19) appears to be a more developed version of the trend towards extended quartzite reduction seen in the Mode A. The quartzite unrotated cores decline sharply after spit 20 to remain at proportionally low levels, while the number of rotated cores climbs erratically to peak in spit 17 before declining. Numbers of quartzite flake and non-flakedebitage progressively rise to peak a spit later in 16 as do the redirecting flakes (figure 4.25). The Mode B flake size, dominated by flakes between 2-8cm², is also smaller than the Mode A, which showed higher proportions of large flakes (>8cm²).

In the chert the fall-off in both rotated and unrotated core discard declines less sharply throughout the middle section of the assemblage. Chert flake numbers also progressively rise in the Mode to peak in spit 15 of Mode C. Non-flake numbers also show a rise, peaking a spit earlier in spit 16, similar to the quartzite. Redirecting flakes retain a comparable pattern, but show a sharp decline in their proportion of total flake numbers in spit 18. The decline from 1:38 to 1:100 suggests either, an increase in the spacing of rotation consistent
with greater attention to flake production, or that chert cores represented consistently earlier stages of reduction. Although both may be possible, the former suggests some alteration in the flaking process which was not observed in the flake analysis. Without access to the original core population the meaning of the decline in the chert redirecting flake ratio remains, however, enigmatic.

Perhaps the most significant behavioural feature of the Mode B assemblage is the progressive increase in the core to flake ratio which shifts from 1:53 to 1:286 in the quartzite and from 1:31 to 1:169 in the chert (see table 4.21). There are a number of ways in which this may be interpreted. The ratio may be seen as a shift from primary core to secondary flake reduction consistent with tool manufacture (see McAnany 1989:337, Schrire 1982:97, White and Peterson 1969:54). The problem with this interpretation for the Mode B assemblage is that there is no evidence for increases in the discard of retouched artifacts and no evidence that increased retouch would produce the flake size proportions in Mode B.

It has already been suggested that Mode B exhibits features of extended core reduction. If the increased core to flake ratio were simply a product of extended reduction (without increased control of flake formation) we would expect the slope of core discard to stay level while flake numbers increased. For example, while 30 flakes may be removed from an initial platform giving a ratio of 1:30 an extended sequence may add a further 20.
flakes from a second platform producing 1:50. The discard of cores remains unity while the number of flakes increases by 66%. While this would account for some of the rise in the ratio it can not be the only factor as the discard of cores also declines in in Mode B. Although the small sample size casts doubt on the validity of this decline in Mode B alone, the discards continue to decrease into the upper portion of Mode C, producing a significant variation for the expected by spit 14.

There are two further factors which might account for the decline in discarded cores in the face of extended reduction and increased flake discard. The possibility that it may reflect increased clearing of larger debris from that part of the site has been discussed in section 3.4. Because the rubble content remains high throughout the lower two thirds of the deposit with no consistent shift in the mean size of the non-artifactual rubble (figure 3.4) or in the Mode B non-flake debitage (table 4.4) it seems unlikely that there was any increasingly systematic removal of large pieces from the deposit throughout this period.

A fourth interpretation of the increasing core to flake ratio, already suggested in the conclusion to Chapter Four, is that there was an increase in the disposition to transport cores off-site as part of the standing reserve. This behaviour is mirrored in the decline in the discard of chert cores after spit 20, which suggests an increase in the general disposition to
conserve material through its retention in a curated set. Some further support for this may be found in the marginally significantly decline in the size of the rotated quartzite cores discarded in spits 17-16 (x = 33.7gms) compared to those in spits 19-18 (x = 104.8gms) (MW-U, U=36,.05>p>.01) and earlier (see table 4.19). This is a product of the low number of larger R2 cores in the upper spits and is consistent with the bigger cores being selected for incorporation into the curated material.

The analysis of the internal relations of quartzite flake production has also shown that inertia response was located high in the range of flakes produced in the Mode B material, and that the morphology of flakes in the most affected size classes had been altered by inertia threshold conditions. This is consistent with knappers trying to retain flake size on relatively large cores. While the evidence above suggests a period of stress on the reduction process, with poor on-site availability and the possibility of increased material conservation, the high inertia response shows no attempt to improve the effectiveness of the primary reduction process in the face of this stress.

Mode C (spits 12-15) is characterized by the high proportion of small flakes (>2cm²) in both materials and a general decline in all artifact classes. The flake debitage tends to exhibit a higher proportion of overhang removal and there is a small but significant rise in the proportion of retouched quartzite flakes. The response to threshold conditions is confined to small flake classes.
and coincides in both materials. The primary features of the Mode C assemblage appear to derive from the decline in the on-site reduction of local quartzite. While figure 4.15 shows there to be a slight rise in the discard of single platform quartzite cores in spit 14, the overall trend is towards decreasing core discard. Without high levels of on-site reduction, Mode C appears to reflect most clearly the discard related to material in the standing reserve. The small size of the flakes, the increased concern for platform morphology, and the coincidence of the threshold responses are consistent with the more careful reduction of small highly curated cores. The significant rise in the proportion of chert material in spits 14 and 15 is also consistent with an increased reliance on material brought onto the site as part of a "founding assemblage".

Although the rise is only slight, the increase in the proportion of retouched flakes discarded - if taken as an indication of on-site retouch - can also be linked to a general decline in the on-site reduction of local quartzite following Hayden's (1977:180) observation that the disposition to retouch appeared to be inversely proportional to the availability of replacement material. Hayden (1977:179) quotes Horne and Aiston:

Casual stones are any that have a sharp edge. They are used for scraping. Directly they are blunt they are thrown away and another picked up. Sometimes they are chipped, but usually they are not kept. (1924:91)
and states later, based on his own field observation that:

Fresh, primary flake cutting edges or breaks seemed to work best for scraping; retouched edges were more irregular and seemed to scrape less efficiently in general. Thus men were usually reluctant to retouch flakes - they preferred to look around for another fresh edge among the flaking debris rather than sharpen the flake in use. (Hayden 1979:79)

Where replacement material was not ready to hand the knapper would, as Hayden suggests, be forced to retouch the edge of the flake being used.

In the Mode C, the quartzite material appears in a generally more reduced form compared to the preceding modes, and it has been suggested that this is consistent with a greater reliance on the standing reserve for the fulfilment of on-site requirements. If this is the case, it points to a substantial shift in the way the quartzite material represented in the assemblage had been procured and transported to the site.

Figure 6.1 summarizes the changes in on-site reduction organization suggested above. The interpretation is based on the presence of a two tiered structure of a standing reserve (SR) and that defined by the reduction of locally available material. The pattern of change reflects two features: (1) the extended reduction of quartzite and chert through time and, (2) the increased role of the standing reserve. Although the extensive on-site reduction of local material masks direct evidence of the latter trend in Mode B, the increased
Figure 6.1: The lithic organization associated with the three behavioural Modes defined in the underlying assemblage.
disposition to incorporate cores into the curated material suggests a development in the concern for the replacement of material in the standing reserve, either as a response to its on-site consumption, or in increased anticipation of future shortfall. The latter may also be related to an increased frequency of a shift to a location with fewer local stone resources, or at a more general level, a wider ranging reduction in the predictability of movement, and a decline in the capacity of the procurement organization to cope with the conditions to be encountered.

In the light of the argument that the shift from the underlying to the later stone technologies may be a response to technological problems, it can be seen that the sequence does point to some disjunction within the on-site technological organization. For behaviour consistent with the on-site restriction to be present on a site within close proximity to local resources suggests that some disjunction between on-site requirement and the mechanism for providing material was a structural feature of the lithic organization. The increased concern for the standing reserve also indicates that this disjunction may have been a growing element of the regional structure. There are two groups of factors which could account for the variation in on-site availability:

1) Shifts in settlement pattern may produce a range of organizational responses, with Mode A representing infrequent but moderate length occupation where residents have time to "map-on" to local lithic resources during the
daily routine. Mode B is seen as an extension of this pattern, with longer occupation periods where the spacing of activities which allow procurement is increased, producing on-site shortfall and extended reduction. In the later period of Mode B this may also be accompanied by an intensifying of the occupation frequency. Using this model, Mode C represents the other end of the spectrum with a shift to low frequency short duration occupation (ie., an overnight camp) in which residents have little time to obtain local resources. These must be closely related to the manner in which landscapes were utilized, reflecting more general economic and socio-ideological structures:

a) A shift in the economic structure could produce restriction of on-site availability by exaggerating the disjunction between daily routine and lithic distribution. As noted above, this may be a shift towards the greater reliance on the resources of the waterhole and the local sand sheet and its outliers during dryer conditions (see section 3.7). Independent evidence that these shifts in procurement focus occurred in the region is, however, confined to the correlation of the ethnographic observation of seasonal behaviour with the limited evidence for environmental change. The restriction may also reflect a longer term broadening of the economic base, with an increased reliance on seed resources similar to that suggested for the arid zone by Smith (1986) and noted by Arndt (1961) as a feature of Wardaman economy. There is again no archaeological evidence for this in the
b) The effect of on-site material restriction may also occur via changes in the ideological context in which the site was occupied. Although Ingaladdi is an important mythological centre the validity of the suggestion that we are observing the progressive development of a new symbolic structure and its attendant behavioural restrictions must take into account the behavioural interpretation of the Modes presented above. The site's occupation would have to be seen as a switching between 'sacred' and more 'secular' contexts. As traditional Aboriginal society is capable of simultaneously understanding a location at various levels, the interpretation begs the question of whether such recursive shifts were a part of the dynamics of ideological structures over the long periods of time covered by the assemblage. In traditional culture, important ceremonial sites are separated from normal residential locations because of the secret nature of the proceedings. It is, however, suggested below (in the conclusion to section 6.3b) that the formalization of landscape which this requires may be a relatively recent component of Aboriginal society. This leaves open the possibility that the ideological factors associated with the formalization of landscape creation and utilization were more fluid over the early occupation period.

2) Decline in the availability of lithic resources relative to a particular mode of landscape utilization may
also affect on-site availability. Although prehistorians
tend to consider stone a natural component of the
landscape it is not a self-renewing resource. Long-term
supply of stone can be ensured only by matching
consumption with replacement. The slower geological
processes of lithic replacement may, however, be more
difficult to correlate with the short-term procurement,
resulting in a progressive decline in local availability.
Given the geomorphology of the area it is difficult to
identify a process which would, over relatively short
periods of time, regulate the amount of lithic material
available to the site's inhabitants. Quartzite material
is part of the underlying geology and appears both as
pebbles and exposed in veins on the low hills. While
climatic amelioration may have stabilized soils, it is
unlikely that it would have produced soil buildup and
erosion sufficient to affect local availability.

Relating these factors to the patterning of changes
in the underlying assemblage presents interpretative
difficulties because the change exhibits both recursive
and longer term features. Taken overall, the pattern is
towards the reduction of smaller material. This is not,
however, progressive, showing distinct episodes of rapid
change between periods of modal stability. The modal
interaction also shows recursive patterning in the early
stages (i.e., AABAB), which suggests the appearance of
facies of the same organizational structure. Whether this
represents a change from the longer run (i.e., BBBCCCC)
higher in the sequence is dependent on an assumption of
uniform accumulation rates which is problematic at this stage of the analysis. As noted above, there is also the suggestion of extremely short term recursive patterning in the disposition to extend reduction seen in the rotated and unrotated quartzite cores.

Of the two factors, changes in settlement patterning, whether due to change in the economic base or socio-ideological context can be accommodated with the recursive and long term trends. The progressive decline in the local resource does not, however, appear to be of primary importance because this is more suited to the action of long term changes only.

In understanding the sequence it should be remembered that the modes do not represent uniform behavioural blocks but composites of a range of behaviours. As their name suggests, they represent the most frequent behaviour and do not, for example, preclude the occurrence of on-site reduction of quartzite material characteristic of Mode A in Mode C, only that it is a comparatively rare event. The shifts in the modes may, therefore, be best seen as representing aspects of a single organizational structure varying through time. Whether the sequence represents a shift towards longer term structural change, or simply the normal range of recursive behaviours in response to the contingencies of daily activity in the face of changing environmental conditions requires further testing. However, as stated above, evidence for the increasing concern for the standing reserve in Mode B suggests that we are seeing a patterning of behaviour which extends
beyond Ingaladdi.

Turning from the problem of the interpretation of the modal shifts to that of the organizational structure, the analysis has revealed a potential for conflict within the structure of on-site reduction. The problem derives from the fact that the standing reserve appears to be dependent on the local procurement procedure - as suggested by the incorporation of the quartzite cores into the reserve in Mode B. This, it is argued, opens the system to a series of organizational disjunctions in which the function of the standing reserve, as a structure, is restricted by its dependence on the priority afforded local procurement, and what appears to be the short-term rationality which governed the on-site reduction of both the local material and the standing reserve.

If, for example, the material for the standing reserve were procured via a procedure separated from that of the local material its ability to overcome situational shortfall would be dependent on the viability of that procurement structure alone, and could in theory be regulated against the failure of the local procedure. This separate procurement would also afford the tailoring of the availability and reduction of the material in the reserve to the requirements of the reserve's structural role, i.e., a capacity to sustain extended reduction. There is no evidence for a separate procurement structure in the Ingaladdi material as the chert, which makes up most of the reserve, was not available locally and there
is little evidence for any increase in a concern with maintaining the viability of the cores observable in the flakes produced.

One of the most important behavioural features of the underlying assemblage is that there appears to have been little attempt to increase the control of the reduction process in the face of either, the extension of reduction, or the increased reliance on the standing reserve. If, for example, the most common fate of Mode B cores was incorporation into the standing reserve some form of increased control may be expected in the Mode B flakes, particularly in response to the extension of reduction also seen in the mode. Even in the Mode C, the one most associated with the utilization of the standing reserve, the evidence of greater care in flake formation is confined to a marginally significant increase in platform modification.

The apparent failure of the knappers to adjust the technique of flaking to, what can be seen as the requirement for a more controlled flaking procedure by the structure of lithic organization, may be due to a tendency to discount the importance of future events in the face of recurrent immediate demand. Strotz (1955/6:177) (see also Ainslie 1975) suggests that failure to precommit to a future behaviour may be due to the presence of risk and uncertainty. The certainty of future core reduction may be affected by a discontinuous reduction process; the core having been used and discarded on the site several times, in what are essentially
separate reduction events. Under these conditions the knapper is under no immediate compulsion to commit himself to a conservative reduction process, although this is not consistent with the long term role of the core. Any shift towards the increasing use of the material on-site as a secondary source would also be consistent with the reduced access to the local source material suggested above.

This sets up what is, in effect, a conflict between what may be seen as two levels of rationality: the situational and the systematic. While the transference of locally procured material to the standing reserve requires the individual to precommit to the possibility of a core being incorporated into the curated material and to reduce the core carefully, the uncertainty of this in any situation makes it more individually rational to discount this event and reduce the core in a less controlled but more immediately effective manner. The result, it is argued, is an example of what may be situationally rational producing an irrational outcome; the structural suboptimality of the standing reserve.

While the problem of suboptimal outcomes from situationally rational responses has been most extensively studied in the behavioural sciences, its emphasis on planning and intention is not completely consistent with the theoretical perspective of this thesis which is concerned with explanations which avoid the assignment of particular mental states to the prehistoric agents. The emphasis on precommitment to a future possibility also
fails to account for the similarity of the chert reduction, which was already committed to the standing reserve, to that of the quartzite. Some way to explaining this behaviour may be made by reference to what Elster (1983a:85-7) has distinguished as 'hot' and 'cold' mechanisms of preference formation. In the former preferences are created by the action of the basic "drives and pleasure wirings of the individual" and are of little direct relevance in this case. In the 'cold' mechanisms the preference is affected by what Elster defines as "cognitive distortions" due to the manner in which the choice is enframed.

The primary enframing mechanism in lithic technology is the form of the knowledge base in which the process of reduction occurs. As argued in the introduction and in greater detail in section 7.2 the actions which make up a production process, like making a spear, boomerang or digging stick represent a logically prior form of human knowledge. This 'know how' is not of isolated objects or functions but of the packages of actions which make up a process. The failure of knappers in the underlying assemblage to vary the reduction control may be largely due to their understanding of lithic reduction only as a subprocess within the wider sets of actions which make up the structure of practical knowledge. Under these conditions reduction is not perceived as a distinct procedure, as it is enframed by the production process in which it occurs. Carried out only within the context of a wider manufacturing practice it is completely contingent
upon that process and is required only to produce materials necessary for the procedure to be carried out.

The contextual distortion which this enframement produces has been recorded in the ethnography but not recognized as such. For example, Horne and Aiston (1924:91-2) in describing the casual nature of Aboriginal tool use state that:

...it must always be remembered that the casual nature of the black does not allow him to keep any tools for the one purpose. He is just as likely to use his best stone knife to scrape a weapon as he is to use any flake that he may pick up. (1924:92)

What Horne and Aiston interpret as some form of racial trait is an illustration of the status of an implement being redefined by its role in a wider manufacturing activity. While these types of observations have tended to perplex prehistorians looking for a modern industrial type of correspondence between tool form and function, the 'casual' and amorphous quality which many Australian assemblages exhibit may, it is suggested, be largely a function of the knowledge structure which enframes the lithic reduction.

In summary, the underlying assemblage reflects the interaction of two organizational structures: local procurement and the standing reserve. The standing reserve is transported between sites to counteract situational shortfall, but it is dependent on local procurement which appears to be 'embedded' within the site-specific pattern of daily activity. Where
disjunction exists between the routine of landscape utilization and lithic distribution there will be on-site shortfall in materials, reduction will be extended and the standing reserve will be drawn upon. This, however, degrades the quality of the material in the standing reserve. The quality of the reserve is also affected by the manner in which reduction is enframed within wider production processes which allow it to respond to only the most immediate reduction demands and in only a limited way to situational availability. Hence, we see the peak discard of chert cores in a period of high on-site availability.

Within this enframing process lithic reduction can not be tailored to the wider requirements of organizational structure until it is separated as a distinct process. It will be argued in the following section that this disjunction between context of reduction and the structural demands of the wider organization is the factor which preconditions the transformation of the underlying assemblage to into the overlying. Only with the transfer of primary reduction off-site in the later assemblage is the reduction process freed from the immediate demands of on-site manufacturing processes and the inherent conflict in the lithic organization resolved. Once this was achieved primary reduction was able to take on the formality and control seen in the production of the lancet flake.
6.2: The Overlying Assemblage in Behavioural Context

Relative to the underlying, the later assemblage represents a period of continuity in the organization of lithic reduction. As Sanders (1975:15) noted, the central feature is that flakes were produced off-site and transported to Ingaladdi for reduction as required. In the quartzite, and to a lesser extent the chert, this is associated with the appearance of the standardized lancet flake. The production of these flakes also appears to be connected with the utilization of more localized stone sources like SS/1.

Lancet reduction occurs as both a scalar modification of the flake margins and as a more highly structured invasive retouch. Scalar reduction is the more persistent mode through time and, it is argued, represents the reduction of lancet flakes contingent upon the on-site availability of replacement flakes. The positioning of this retouch, strongly confined to the left and right distal margins in the early stages of reduction, with no clear ordering in the later, is consistent with the flakes being incorporated into a wide range of processes other than point manufacture. This is in agreement with Bradshaw's (1986:171) suggestion that a proportion of the pointed implements in Clarke's assemblages performed "scraping functions". Of more direct relevance is Davidson's (1935:168) comment, that local lancet flakes

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had been used as scrapers and spokeshaves, as well as knives and spear heads. After noting the scarcity of more conventionally defined scraper forms in the regional assemblages Davidson (1935:159-160) stated that small quartzite points were also hafted as adze points, which represented the only use which the Wardaman made of the 'blades' in the 1930's. His informants also insisted that this was the function of finely worked archaeological specimens usually defined as spear heads by archaeologists (Davidson 1935:162). Despite Davidson misleadingly terming of all hafted artifacts as 'adzes' his observation confirms a wider role for the lancet flake well into the twentieth century. Although from further to the southwest, Cane's (1984:163-4) observation of unifacial points used for woodworking in the region of the Great Sandy Desert supports this suggestion.

In contrast to the scalar, the invasive mode of lancet reduction is more diachronically restricted (principally to the lower spits 8-10) and appears to be associated with the production of unifacial and bifacial points. It has been argued, however, that lancet flakes are not ideal blanks for the utilization of invasive working and that the emphasis on the production of a pointed form via extensive retouch appears incompatible with a flake which is generally a thin, elongated and well formed point. This appears to represent an example of a disjunction between the production of lancet flakes and the use of these as blanks for a secondary reduction process producing invasively worked points. It is also
suggested that this disjunction between blank and reduction process has limited the utilization of a fully parallel bifacial reduction sequence of the type seen in the production of Kimberley points. As the bifaces are produced via back to back unifacial sequencing there is technically no separation between the unifacial and bifacial point types in the Ingaladdi assemblage. Their comparable temporal distribution confirms this association.

In terms of its organizational structure the overlying assemblage appears to reflect a standing reserve which, unlike that of the underlying, is composed principally of flakes rather than cores. The secondary use of flakes as cores via a shift towards bipolar and twin ridge modes of reduction also confirms the dominance of flakes as the primary lithic material available on-site in the later period. Why this shift occurred represents the central historical problem in the interpretation of the overlying assemblage.

The examination of the underlying cores showed them to be derived from surface pebbles of variable size and flakes struck from larger surface rocks. This is consistent with a procurement organization which requires the widely dispersed allocation of relatively short blocks of time to off-site reduction. The procurement procedure can be run parallel with other extractive activities over the foraging range of the Ingaladdi residents. Where there is sufficient access in daily activity to material which is well dispersed, convenient core size can be
maintained via a process of selection (see Rolland 1981:37). This procurement organization is comparable to Binford's (1980) concept of "mapping on" to a resource which is widely and evenly distributed in the landscape. The increased reliance on the standing reserve and specific sources in the overlying assemblage sees a shift toward what may be described as a more "logistic" structure (Binford 1980).

As Davidson (1989:77) has pointed out, Binford's model can explain shifts of this sort only by reference to either a change in the distribution of resources, or the ability to cope with the extant distribution. In the underlying assemblage procurement disjunction appears to have been the principal factor reducing on-site availability, forcing extended reduction and increasing reliance on the standing reserve to cover growing shortfall. Under these conditions it was suggested that, the standing reserve would be especially affected by the replacement of exhausted material with already extensively reduced cores. It has also been argued that this problem is principally due to an inherent incapacity to free the reduction process from its production context and to meet efficiently the structural requirements of the standing reserve.

Theoretically, this could be alleviated by a general switch to a more logistic procurement, where specific sources were systematically used to balance on-site requirements and availability by incorporating all
procurement into the standing reserve. This need not, however, precipitate the shift to off-site primary core reduction. As the presence of cores in the underlying assemblage made on large flakes shows, core production could cope with an increase in material size (although this would be restricted to very large material only). A simple switch to 'logistic' procurement need not, therefore, alter the composition of the standing reserve unless, as the lithic distribution in the region suggests, the variable nature of the stone sources required some procedure for dealing with a range of source morphology. As noted in section 4.3a the size and form of flakeable quartzite varies from small pebbles to weathered outcrops. Increased utilization of specific sources productive enough to repay logistic procurement appears to have required the use of a wide range of material forms. Although SS/1, for example, features the exploitation of large surface rocks, more extensive quarry sites were located to the west on Innesvale Station and the utilization of smaller isolated outcrops of vein material occurred along Aroona Creek to the south. Where the uniformity of reducible material appears to have been maintained in the underlying assemblage via pebble selection or utilizing large flakes when this was not possible, the off-site primary reduction associated with the upper assemblage could ensure uniformity only by the institution of a standard mode of reduction to a wider range of larger primary core morphologies (ie, pebbles or quarried blocks).
As noted above, the relocation of primary core reduction from on-site to off-site would also have the effect of eliminating the structural conflict between the requirements of a standing reserve dependent on a loosely organized procurement structure and the process dependent rationality which appeared to govern the reduction of this locally procured material in the underlying structure. By removing primary reduction from its on-site manufacturing context, all material is effectively incorporated directly to the standing reserve, cutting out the intervening local procurement and reduction process.

The infrastructural importance of lancet flake production in the overlying assemblage is not, therefore, the product of the development of a new tool in the conventional sense. It is the product of the transference of primary core reduction off-site onto larger and morphologically more variable stone sources. The effect is to supply on-site reduction with large numbers of standardized easily transportable flakes which had been incorporated directly into the standing reserve. While this eliminates the disjunction between the earlier mode of procurement and the organization of reduction, the cost is in the increased organizational complexity involved in the extension of larger blocks of time and labour to off-site primary reduction.

The consequences of the transformation of all material into a standing reserve can also be seen as having wider effects than that of overcoming on-site shortfall due to procurement disjunction. The off-site
relocation of primary reduction freed this procedure from its incorporation in wider production processes (eg., making a spear or digging stick), and allowed it to become a more developed form of practical knowledge. Primary reduction is by this move successfully separated from the problem of its occurring within a contextual rationality enframing the process itself. An extensive reliance on curated material, of the type seen in the overlying assemblage, also radically alters the relationship between environment and technological process. The alteration is in the appearance of the precursor to a modern structure, where daily activity is conditioned by technology as a standing reserve and not as a more direct interaction of situational requirements and material availability, ie., contingent upon the relation of lithic distribution to the more general pattern of landscape utilization. As a consequence of this shift, the overlying assemblage may be expected to reflect a procurement and reduction organization which exhibits a more regional structure than that seen in the lower levels, where local resources were being directly procured and primary core reduction was being carried out on-site. This difference is reflected in the relative behavioural uniformity of the overlying assemblage.

The question of why this shift occurred around 2800 BP in the Ingaladdi assemblage is a specific historical problem to which this analysis can provide only limited insights. While the examination of a single site can provide: (1) an understanding of the general structure of
reduction organization, as expressed in the assemblage; (2) the relation between differing components of this structure and (3) present these as preconditions of change and account for the form of change, it is limited in its capacity to reflect what may be seen as wider triggering mechanisms (see Smith 1982). These may be changes in population, settlement pattern, resource utilization and availability. This is not, however, to argue for these as the primary determinants of technological structure which has its own dynamic capacity to affect other behavioural complexes. For instance, the discussion of the underlying assemblage showed that even relatively simple structures have the capacity to produce unforeseen or irrational outcomes, the cost of which must be absorbed through other activities. The problem of incorporating poorly reduced material into the standing reserve would limit maintenance and manufacture of equipment and through this the wider processes of economic production, landscape utilization, resource availability, and the degree to which social relations could be carried out via the exchange of material goods. The potential interaction of these factors is, therefore, too complex for simplistic assignments of causal priority.

In summary, the form of technological change in the Ingaladdi assemblage can be seen as a response to the conflicting rationality observable in the organization of the earlier assemblage. The combining of logistic procurement and the transfer of primary core reduction off-site resolved the conflict, it is suggested, at the
cost of a more direct conditioning of daily activity by the new technological structure, and the development of disjunction between lancet flake form and point production. The extent to which these patterns will be seen in other north-western assemblages remains to be tested. From the outline in Chapter Two there appears to be considerable regional variation in the patterning of response to what may have been a common organizational problem. The argument underlying this is complex, but it is suggested, more reflective of the state of human knowledgeability than the assumptions of static typology directly reflecting environmental change or remote evolutionary principles.

The aim of this analysis has been to view the problem from the technological perspective which a change in artifact types or traditions requires. While it is argued that this has identified the structural components which preconditioned the change and accounted for its character, the interaction of individual knowledgeability and its resulting behavioural structures is too opaque a process for this to be regarded as a complete description of what must be understood as a complex of historical events. As Dewey (1959:169) explains no event "was merely dynastic, merely scientific, or merely technological". However, the very act of historical analysis precludes the possibility of a complete explanation for any event because, as Dewey points out, the criteria for the selection of relevant 'facts' precondition the manner in which they can be explained. In the case of archaeolgical
sites like Ingaladdi which contain predominantly stone artifacts, the ability to relate technological to other factors is also limited by the content of the archaeological record.

6.3: Some Wider Considerations of the Ingaladdi Analysis

6.3a: Early Assemblages

Contrary to the simple/complex dichotomy which has generally been used to characterize the differences between the early and later stone assemblages in Australian prehistory the analysis of the underlying assemblage in Ingaladdi has revealed an organizational structure which is complex and subtle. The antiquity of the standing reserve suggests that it would have been an important feature of hunter-gatherer technology generally and of Australian technology in particular. Both Toth (1985:115) and Draper (1985:12) have shown that the transport and curation of material in anticipation of future use was a well established feature of Oldowan and Acheulean assemblages and Gamble (1986:281) cites examples of comparable behaviour from middle and upper palaeolithic European assemblages. In the Australian context the curation of materials and the incorporation of local on-site production into a standing reserve may also be seen in Draper's (1987:7) interpretation of the Cape du
Couedic site and as a wider pattern in the Kangaroo Is. assemblages. It has already been noted in section 2.3 that although there appears to be substantial differences between the underlying assemblages of Jimeri II and Nauwalabila I in terms of the organization of on-site reduction, some of the components of the Nauwalabila I assemblage, particularly the chert material, also reflect the extended curation of material consistent with the presence of a standing reserve. This is can also be seen in the more extensive reduction of chert in Jimeri II(iii).

In Australian prehistory the type of material incorporated into the standing reserve may be expected to vary through time and space in accordance with the distribution and the on-site availability of local resources. The earlier underlying assemblages may also reflect a complex interleaving of an regional lithic organization (via the standing reserve) with distinctly local structures related to the stone resources available to specific sites. Because this proposed interaction will occur at a local level, the model presented above suggests that aspects of the composition of the earlier assemblages will be more reflective of very small scale local conditions than the concept of a pancontinental tradition with regional variants has to this point allowed. For example, Lampert's (1980:201) proposal that the underlying assemblages reflect a more restricted ecological and social space compared with the later, may be seen as a function of the organization of lithic reduction not, as
he suggests, a reflection of the restricted state of culture as a whole.

The importance of a two-tiered structure may also be seen in the discussion of whether Australian lithic technology reflects primarily opportunistic reduction with little formal patterning (see Hayden 1979, Flenniken and White 1985:132, White and O'Connell 1982:84), or a more structured form resulting in formal types (see Cane 1988). This may be based on a false polarization of what are features of the same organizational complex, with the more highly structured and extended reduction of material in the standing reserve producing a formal convergence consistent with the pseudo-typological regularity seen, for example, in Australian scraper classifications. The analysis has also shown that while primary core reduction, when separated from the context of a wider production process, may be highly controlled, the subsequent reduction of the products may be more 'opportunistic' and situationally dependent (e.g., the scalar lancets). The problem appears to have derived from the failure of both sides of the debate to recognize the variability in the context in which the reduction process may be enframed.

As noted above, the structuring of a standing reserve in parallel with the exploitation of local materials bears some relationship to Binford's (1980) collector/forager distinction which Lourandos (1987:159) has used to suggest a separation between the later collector and earlier forager economies in Australian
prehistory. In broad terms, the model of the organizational difference between the underlying and overlying Ingaladdi assemblages supports Lourandos' suggestion in so far as the later structure is strongly reflective of logistic procurement. However, the earlier organization is not simply the result of the immediate consumption of 'map-on' procurement. Although the incorporation of material into the reserve does not appear in the early structure to require the extended utilization of specific locations for lithic production, it does incorporate the transportation (as personal equipment) and the delayed consumption characteristic of more complex 'logistical organization'. If this structure is, as already shown, an extensive component of the earlier assemblages, then Lourandos' distinction between the later and earlier economic structures in terms of foraging and later logistically organized collecting may prove too simple a distinction, as the primary features of the more complex organization appear to be already present in the earlier assemblages.

Binford (1980:12) sees logistic and map-on procurement as poles of a cline in which movement along the series is via the addition and subtraction of these "properties". This analysis has shown that the combination of these features at different levels of a single organizational structure may not necessarily produce a harmonious process of cultural transformation. The potential for disjunction within the structure is, upon behavioural analysis, high and it is suggested a more
likely consequence of movement along the cline than Binford's simple addition and subtraction of behavioural units implies.

In summary, the apparent uniformity of the 'Core Tool and Scraper Tradition' is largely a product of the failure of conventional typology to capture the organizational subtleties which these assemblages have the potential to reflect. Although the unity of the tradition is currently under some attack (see section 1.2) the swing appears to be generally focussed on the amorphous quality of the material which is essentially a form of negative typology, having neither the virtues of distinguishing formal variation, or organizational structure. The primary point to be made is that typological amorphousness should not be mistaken for organizational simplicity, rather the success of a highly flexible structure which made the extended modification of formalized tools unnecessary. This was achieved through its capacity to overcome situational short-fall via rapid switching between its two organizational levels. It was not, however, a perfect system. The organizational structure retained an inherent conflict between the context of reduction and the requirements of wider organization of the process. This conflict preconditioned the later technological change which produced a more complex 'typology' while reducing its organizational flexibility. The assumption that technological change in Australian prehistory reflects some evolutionary process from simple to complex should, on these grounds, be abandoned.
6.3b: Later Assemblages

Placing the overlying assemblage in Ingaladdi in a wider perspective requires some examination of its relation to the 'Australian Small Tool Tradition'. For the purposes of the discussion the concept will be interpreted as a descriptive one.

An obvious, but not unimportant point to be made about the components of the later assemblage is that, relative to what preceded it, they are not particularly small. Lancet flakes are on average larger than those produced in the underlying assemblage and derive from larger cores. While it may be conceded that they are smaller than some facies of the 'Core Tool and Scraper Tradition' there is no historical relationship between these facies and the Ingaladdi assemblage.

A possible explanation based on the suggestion that lancet flakes represent the early appearance in North Australia of some post 'Small Tool' component, which occurs later in eastern assemblages, presents some interpretative difficulties for the tradition. Firstly, this would reverse the conventional picture, as the later assemblages tend to be less formalized in the eastern sites. It would also equate the underlying Mode C material with the 'Tradition'. While the flakes produced in this mode are small, the assemblage lacks any of the
formal types (ie., points, adzes) which are used to characterize the 'Tradition' in northern assemblages.

In terms of the second component of the definition - 'tool' - the lancet flake appears to be a direct transformation of flake production in the underlying assemblage and of local origin; a result of transferring earlier reduction modes off-site in response to increased disjunction between on-site reduction and material availability. It was not, therefore, principally designed as a tool in the conventional sense (ie., its morphology being governed by some perceived function). The use of parallel scalar and invasive reduction modes supports the view that the lancets' infrastructural role has, in this case, played a greater part in the formation of an artifact type than their ends as tools. The traditional understanding of the later assemblages purely in terms of tools with functions and its inherent 'style/function' deadlock, seen in White and O'Connell's (1982) discussion of the later tradition, can be effectively circumvented by this form of explanation (see section 1.2).

The structure of the Ingaladdi assemblage has also diverged from the general picture of the 'Small Tool Tradition' as a series of new traits, either of types or as technological packages which were added as complete units to a base formed by the older 'Core Tool and Scraper' (Dortch 1977a:123, Flood 1983:186, Lampert 1981:159, Morwood 1981:45, Mulvaney 1975:213). The appearance of lancet flakes in the upper unit of Ingaladdi
sees a substantial shift in the spatial organization of the primary reduction process which produces a new mode of reduction and changes the technological structure of the assemblage. The process is transformational rather than purely additional. The continuity between the underlying and overlying assemblages is not typological but structural. This structural continuity is based on in the increased reliance on lithic material standing in a specific relation to the knapper, transported and ready to hand as a standing reserve, and in the underlying transformation of flake form via the translocation of reduction behaviour.

While criticism of the coherence of the 'Small Tool Tradition' has been principally derived from its broader spatial and temporal inconsistencies (Kamminga 1982, Jones and Johnson 1985, Smith and Cundy 1985, White and O'Connell 1982) this analysis has shown that it also lacks the technological security which the description implies. The problem which the Ingaladdi analysis raises is one of whether any unifying features can, or should, be expected or securely recognized in the later material.

In their overview of the later assemblages of north-western Australia Allen and Barton (nd) have identified three "technological patterns": (1) the predominance of bifacial points in the Arnhem Land assemblages, (2) the predominance of unifacial points to the west in the Victoria/Daly/Kimberley regions, and (3) the production of large end struck blades (i.e., leilira type) in Arnhem Land and northern Central Australia. They argue that these
"entities distinguished by the archaeologist" are "products of a unified technological situation", all deriving from a single population of flakes differentiated by a large range of cultural/historical factors.

The point forms, they suggest, represent a gradation from those most to least reliant on secondary trimming, with an accompanying reverse trend in the control over primary flake production. The bifacial, unifacial and large blades (leilira) represent stages in an evolutionary progress towards economy of effort, utility and robustness (ie., bifacial>unifacial>large leilira blades). Despite their connection of the first two stages with different geographical areas Allen and Barton (nd:127-9) suggest Arnhem Land as the origin for the large quartzite blades, linking their spread from the region to the expansion of ritual, social organization and exchange networks.

Although Allen and Barton's view represents the most detailed synthesis of north-western assemblages it differs in a number of significant points from the picture presented in this thesis. Firstly, the concept of the overlying assemblages representing some technological unity is not, it is argued, based on the types of detailed analysis of assemblages and reduction processes which such a proposition would require, and may as such be premature. The single population of flakes from which the elements of the overlying assemblages are said to be derived is also not defined historically, as Allen and Barton (nd:113) themselves prefer to see the preceding
material as "separate core and flake assemblages". While their stressing of the "technological similarities" between the points is aimed at counteracting the view of these as "type implements signifying the presence of different assemblages or industries" (Allen and Barton nd:123), the connection between them is essentially typological, with the actual technological relationships remaining obscure.

It is also unclear how the evolutionary trend in point form is to be understood. As the bifacial and unifacial stages are geographically separated, the progression appears to relate to some general teleological principle which does not have to be directly observable in any individual assemblage. The mechanism for this trend is again unspecified and the actual advantages which the progression is to ensure are not consistent. For example, unifacial points provide an economy of raw material, reduced breakage and are less demanding of skill, the larger quartzite blades, utility, economy of effort and robustness. Yet, Allen and Barton (nd:123) note that the move to the more controlled primary reduction, which the blades represent, would increase raw material consumption and clearly associate the production of these artifacts with the development of large quarries and extended social obligations. The economy of effort in this wider context appears problematic.

While arguing strongly against the imposition of the 'Core Tool and Scraper Tradition' on the underlying assemblages of Arnhem Land, Allen and Barton appear to
make a similar imposition of uniformity on the overlying assemblages. In the light of the Ingaladdi analysis, their argument that this results from some underlying technological unity, rather than a typological one, is difficult to support at this stage of our understanding of north-western assemblages.

The image of north-western assemblages presented in this essay is not one of technological unity but a behavioural complexity which requires more detailed analyses before the broad patterning can be effectively understood. For instance, the development of the lancet flake in the Ingaladdi assemblage about 3000 BP marks the archaeological origins of a production process which has been recorded ethnographically over a wide geographic area in its association with its larger leilira form (see section 2.4). Like that of Ingaladdi the wider lancet/leilira production is concentrated on specific and often highly regarded stone sources, but differs in what appears to be the artifacts' functional restriction to knives, fighting picks and spear heads, and their extensive utilization as an exchange items in Central Australia and Arnhem Land. Although examination of the relation of lancet production on quarries in the Katherine region (Baker and Hughes 1983, Cundy 1987, Edwards, R. 1967) shows some utilization of the flakes on nearby rockshelters, production at Renner Springs and the extensive Newcastle Waters quartzite quarries to the south appears to be largely unrelated to the 'domestic' lithic organization which is chert based (Paton, pers. com.).
In western Arnhem Land assemblages large leilira type blades are rare but occur in the upper levels of sites (see Jones and Johnson 1985:208, Schrire 1982: fig. 65b, fig. 82). While the Jimeri I and II (Schrire 1982) examples exhibit marginal retouch similar to that illustrated by Davidson (1935) the Nauwalabila I (Jones and Johnson 1985) specimen retains retouch on a transversely broken edge of a butt. This form, not seen in the Ingaladdi assemblage, is found to the south around Pine Creek and Sleisbeck and may be related to the patterns of lancet reduction found in the Tandadjal assemblage (McCarthy 1951). Allen and Barton's (nd) claim for a west Arnhem Land origin for these blades seems unlikely given the Ingaladdi material, which provides a more convincing origin for the production process. Lancet reduction in the Kimberley sites appears broadly similar to that seen in the Ingaladdi assemblage with comparable dates. Dortch (1977a) has, however, identified a form of 'backed point' with a steep oblique retouch on one margin which is not systematically repeated in the Ingaladdi materials. Although the process has yet to be defined in detail, the role of lancet production appears to be geographically varied with those produced in central Australia and eastern Arnhem Land playing a less central role in the infrastructure of lithic organization. The development of this technology in the Ingaladdi assemblage about 3000 BP marks the earliest date for lancet/leilira type production—suggesting a later date for the spread of this process over the region for which it was
more widely described ethnographically.

In the Ingaladdi assemblage lancet production is also closely associated, both diachronically and technically, with the appearance of invasively worked bifacial and unifacial 'points', which are type artifacts for the 'Small Tool Tradition' in northern and Central Australia. While Jones and White (1988) have seen lancet flake and retouched point production in eastern Arnhem Land as two aspects of a wider point making tradition, their relation in the Ingaladdi material appears to be more complex. Interpreting the overlying assemblage in terms of a single 'point tradition' would not explain the infrastructural importance of the lancet flakes and the division of its reduction modes. A second possibility, that the adoption of invasively worked points placed stress on material availability precipitating the transference of primary reduction off-site and the production of lancet flakes, also fails to account for their central importance.

As seen in section 2.2, the earliest dates for invasively worked points in Western Arnhem Land assemblages can be conservatively estimated to be from 4-5000 BP and possibly back to 6000 BP if we accept Jones and Johnson's (1985) interpretation of the Nauwalabila I sequence. The dates for the Kimberley, Yarar and Ingaladdi cluster about 3000 BP. While the correlation between lancet production and invasive working has yet to be clearly defined in the Kimberley, examination of the Yarar assemblage shows no apparent relation between the
production of points and the few lancet flakes in the assemblage. This supports the picture of a late adoption of a trait (i.e., invasively worked points) originating in western Arnhem Land over the upper Daly, Victoria and Ord River regions which, if Ingaladdi is typical, is simply superimposed on existing lithic production structures. Why the trait travelled at what appears on the current dating to be a relatively slow rate does, however, raise questions about the nature of the social interaction in north-western Australia at that time.

Although the relation between the development of lancet production and the invasively worked points, as seen in the Ingaladdi assemblage, may be related to wider structural changes, they can equally be seen as separate historical events. One possible scenario is that the appearance of the points may be correlated with an expansion of neighbouring exchange networks, precipitated by local conditions beyond those that prompted lancet production. While this argument is similar to that of Allen and Barton (nd:130) for the expanded distributions of large leilira blades, it does not require an extensive regional change in social relations. This expansion simply feeds a new product into the on-site production process via an extant exchange structure. Despite their archaeological prominence, the invasive bifacial and unifacial points in the Ingaladdi assemblage remain peripheral to, and dependent on, the underlying structure of lancet production.
Expanding on the problem of relating technology and social behaviour, the suggestion of some relation between the appearance of new stone 'tools' and social organization in Australian prehistory has been made by a number of writers (Allen and Barton n.d.; Flood 1983; Gould 1978, 1980; Jones 1977; Lampert 1980); including specific attempts to correlate change in technology and art styles (Morwood 1984). The total reliance on typology has, however, forced these to utilize a simple juxtaposing of new types with the suggested appearance of exchange networks, complex ceremonies, or art styles. The linking arguments are invariably left to unobservable 'cultural' processes. The advantage of examining lithic organization in this context is that it allows a direct comparison of behavioural structures across various organizational levels.

It was suggested above that the transformation of the underlying assemblage in Ingaladdi involved a radical alteration in technological organization, from a structure conditioned by local patterns of resource distribution and landscape utilization, to a reliance on a standing reserve with a component of standardized flakes. Compared to the earlier organization, the later gives the impression of a rigid structure which formalizes the manner of material procurement and responds to technological contingencies only via the content of the standing reserve.

While remembering that technological and socio-ideological correlation requires high levels of generalization there is some similarity in structure
between the later technological organization and that forwarded by many anthropologists for wider social relations in Aboriginal society. Traditional society has been seen as deeply conservative (e.g., Elkin 1979; Strehlow 1947), exhibiting what Maddock (1974:193) has described as a "utopian conception of society" where the problems of regulating social relations have been answered by the ancestral beings which continue to exist in a parallel time through their association with named places. The recognition of these places creates landscape which incorporates humans into nature "by transposing it [nature] into an ideological pattern of social and cultural meaning" (Berndt 1976:133). While Berndt (1976) and Maddock (1974) have seen the ideological component of the transposition as primary, it is suggested that a late technological and social parallelism may have derived in Aboriginal society from an underlying disposition to formalize behaviour over longer temporal spans - whether this is in the utilization of specific stone sources and the resulting standardization of artifacts, in the carrying out of ceremonies at important locations, or in the disposition to relate sites in a formalized discourse. The effect of this is the creation of a 'humanized' environment which formed a specific historical response to the existential contradiction between human existence and nature (Giddens 1984:193-4; also Berndt 1976:133). The response to this contradiction can not be only ideational as it is central to human existence itself and is evident in the disposition to order material and action. The
ordering appropriates nature through the creation of 'landscape' to human ends, forming a standing reserve which extends beyond lithic technology.

A complete account of the factors behind the development of the specific structural principles which govern the expression of, and the response to, the contradiction is delimited by the very selectivity of the process of historical analysis. However, the problem may be examined via a consideration of the factors which could restrict the process of ordering in hunter-gatherer societies. This thesis has already pointed to a possible factor in the disjunction between situational and what may be seen as a temporally extended organizational or systematic rationality. Another, may result from a relative lack of what may be termed 'environmental closure'. Strehlow (1965:131-2, 1971:705) has, for example, utilized this factor in his suggestion that the rigidity of the Aranda/Loritja landscape ideology could be related to their occupation of the relatively bountiful central ranges confining movement within this environment. He contrasts this with the more nomadic desert tribes to the west with a less "closely settled" mythological landscape and a comparable lack of conservatism. Strehlow also tells us that, compared to the "civilized" Aranda, the "ignorant" desert nomads were also prone to laughter. Following Schopenhauer's (1966[1844],II:99) analysis of humour, it is suggested that the serious-mindedness of the Aranda derives from their "...consciousness of the perfect agreement and congruity of the concept, or the
idea, with what is perceptive, with reality. The serious person is convinced that he conceives things as they are...". The formalization of behaviour producing the ontological security from which the serious-mindedness derived.

The formalization of landscape appears to increase in more northern groups with the identification of individuals with natural features (Merlan 1982) and the autonomy of clan estates. Although rites to estate utilization also tend to become more restricted this is not necessarily correlated with the more highly productive environments (Layton 1986). This should not, therefore, be seen as an argument for environmental determinism because 'closure' is dependent on all the factors which affect productivity including technological and socio-ideological structures. What is suggested, is that the concept might function as a focus for this complex of factors and represent one of the possible ways in which prehistorians might approach the problem of the limitation of ordering and its relation to technology and socio-ideological behaviour given the content of the archaeological record.

Although the technological change in Ingaladdi has been seen to be preconditioned by structural disjunctions within the earlier technology, the historical factors which triggered the shift in procurement behaviour require further examination. Whether these factors are also the same as those which structured the ideology of traditional social relations via a similar creation of a formalized
landscape also remain problematic. It is suggested, however, that the examination of lithic organization may go further in accounting for both problems than the usual correlation of technological traits and social behaviours.

* * * * *

In conclusion to the main analysis, the overall picture presented by the Ingaladdi assemblage is one of a structure differing in a number of significant ways from the conventional view of change in Australian lithic technology. While the assemblage replicates the general picture, the characterizations of this change are pressed to accommodate the behavioural complexity which the analysis has revealed. The differences are derived from the utilization of an approach which sees chipped stone technology as understood by its makers and understandable archaeologically primarily as a reduction process organized in time and space. The result, it is argued, is a more realistic picture of an assemblage as a product of a functioning technology, in contrast to its perception as a collection of disconnected types related to a series of largely imputed functions. The aim of this part of the thesis has been to forward an approach to lithic technology in Australian prehistory which provides an increased understanding of technology as form of human knowledge, and a more viable approach in its capacity to structure investigation than the standard utilization of
technological change for culture-historic narrative. This is not an argument against the use of types or of culture-historic approaches, but an assessment of their limitations. The analysis has shown that change need not be related to changing functions, but a response to a complex set of historical and structural factors focused through disjunctions within the structure of lithic reduction itself.

While the central part of this thesis has concentrated on demonstrating the utility of this approach in seeing new aspects to the problem of change in Australian lithic technology, the following chapter provides a detailed discussion of the theoretical underpinnings of the argument.
CHAPTER SEVEN

THE UNDERSTANDING OF THE PROCESS OF MANUFACTURE IN LITHIC TECHNOLOGY.

Having discussed the utility of approaching some of the problems in north-western Australian lithic technology from the perspective of reduction processes, this chapter returns to a wider exposition of the theoretical basis for the approach outlined in Chapter One (section 1.3). It is argued that, despite the changes in theory and method over the last hundred years, the understanding of the process of manufacture in lithic technology has been dominated by a perspective derived from classical models. In the final analysis it is suggested that this model has considerable common sense appeal because it parallels our modern conception of how products are produced in industrial societies. Contrary to its appeal, the perspective is not adequate. The understanding of lithic technology in pre-industrial societies should be based on a more developed model of human knowledgeability.
7.1: Historical Perspective

And in their stead, intricate wheels invented, wheel within wheel, To perplex youth in their outgoings and to bind labours in Albion,...

Jerusalem: William Blake (1804-20)

By machines mankind are able to do that which their own bodily powers would never effect to the same extent. Machines are the produce of the mind of man; and their existence distinguishes the civilized man from the savage...

A Letter to the Luddites:
William Cobbett (1816)
(Jennings 1985:142)

7.1a: The Science of the Artificial

Nineteenth century Europe was well aware of the great effects that technological change had wrought on society. The contrary sentiments of Blake and Cobbett as to the virtues of this process remain as central today as they were in the intellectual climate which surrounded the discussion of technological change in the nineteenth archaeology and anthropology.

Cobbett's letter demonstrates that the principal factors in the equation of technological development and social progress were well in place by the turn of the century. The equation derived from the tradition of the Enlightenment which traced human development from 'savagery to civilisation'; a process guided by the application of human reason (Trigger 1981:139-40). This
faith in the guidance of reasoned progress probably derived less from a need to justify a superior evolutionary position than to make sense of rapid social and economic change. In the case of radical political writers like Cobbett one might add the need to reconcile the unpleasant social consequences of industrialization with the possibility of more humane social reform.

The problem of documenting and explaining the process of technical progress was an established theme in the literature of the nineteenth century (see Jennings 1985). The developmental concepts of the Enlightenment scholarship presented an evolutionary framework which could not only support the concept of prehistoric artifacts but could also be used to organize them diachronically and provide a mechanism of change. It was not, however, until Thomsen provided a workable chronological system, through an analysis of both artifact form and context, that the concept of developmental ages was more than inspired speculation (see Gräslund 1987, Trigger 1989b:73-79). Although this must be seen as a significant methodological advance, Thomsen’s system proved too generalized to provide any important insight into the process of technological change itself.

Alternative ways of examining material progress were being sought not within archaeology, but within what Simon (Steadman 1979:2) has subsequently termed the "science of the artificial". The tracing of human progress could not only be derived from archaeology but also by careful
examination of different kinds of man-made artifacts. The resulting analyses were explicitly evolutionary with much of their explanatory mechanism in place before the publication of Darwin's *Origin of Species* in 1859. Steadman (1979:83-5) points to the importance of gradual technical improvements via the process of copying in, for example, the works of Fergusson (1849) and Greenough (1947[1840/9]). The process of technical improvement was seen as slow; the product not of individual genius, but of many minds making small alterations to traditional designs. The interaction between design and environment producing higher evolutionary forms characterized by their "grace and efficiency". The interaction of form and environment is analogous to the adaptation of biological organisms. Although Fergusson and Greenough did not see it as governable by rational processes the actual mechanism of change was not made clear.

Darwin's theory, that individual differences among animals of the same species were acted on by natural selection to alter the species as a whole, provided an alternative model. Sundt (Elster 1983a) influenced by Darwinian theory argued in 1862 that:

> Even when people who set up new buildings did not intend to deviate from custom in any way, it could easily happen that some variation arose. This would then be accidental.

(in Elster 1983a:136)

Errors in production were the primary source of artifact variation, which was acted on via a process of selection.
similar to natural selection, producing increasingly more advanced forms. The details of the process of selection are again not developed.

A similar concept is found in archaeology in Hildebrand's (Gräslund 1987:101) view that artifacts changed under the influence of "practical need and the craftsman's taste", and that the resulting forms had to struggle for existence. Although the mechanism of change is explicitly Darwinian, Hilderbrand does not define the environment in which the struggle for existence takes place. The process of production in these theories was essentially neutral, serving only as a method of copying or realizing the slight modifications to traditional designs.

The viability of deriving evolutionary sequences from well documented artifacts, combined with the failure of archaeology to provide sufficiently detailed information, raised the possibility of constructing evolutionary schemes by comparing elements of material culture from existing societies and ranking them in order of their technical development. The "comparative method" was generally used by both prehistorians and anthropologists (see Harris 1969:150) and heavily influenced the work of Pitt-Rivers (1906) whose documentation of technical progress contains further examination of the role of manufacturing processes in the development of artifact form.
They were not designed outright, as the nineteenth century man would have designed them for special uses, but arose from a selection of varieties produced accidentally in the process of manufacture... Indeed, so completely does the fabricator appear to have been controlled by the necessities of his art, that in tracing these successive forms one is almost tempted to ask whether the principle of causation lay mostly in the flint or the flint-worker.

Pitt-Rivers (1906:34-35)

In the model presented by Pitt-Rivers the process of manufacturing is a dynamic interaction between the maker and the materials of production. Production, itself flawed by the maker's imperfect control, results in a range of accidental departures from the 'ideal'. These departures form the basis of new forms and improved functions which are selected because of their advantage. This is shown in Pitt-Rivers' (1906:32) account of how accidental changes in the process of manufacture generated the development of simple stone tools. These accidental departures could also halt the process at various stages resulting in forms which appeared primitive.

Pitt-Rivers did not see the mechanism of technical change as the direct product of applied reason, nor was it the product of will which was seen as being capable of only selecting and organizing ideas, not in originating their change (Pitt-Rivers 1906:30). While 'spontaneous or automatic' mental activity provided the associative power required to perceive change, it was natural selection which conditioned its effectiveness and acceptance (Pitt-Rivers 1906:26,30). This not only fitted well with the
Darwinian concept of selection but also allowed artifacts to continue to be seen as "manifestations of mind" and for it to be possible to chart the mind's power to move from "simple cohesion of states of consciousness to the association of ideas, and reason to broader generalisation" (Pitt-Rivers 1906:29). Pitt-Rivers did not make the simplistic equation of artifacts and ideas and can not, as has been claimed, be seen as the precursor of approaches which utilize this as a central proposition (see Oswalt 1976:6).

Despite the importance of the production process in his theory, Pitt-Rivers continued to view it principally in terms of an evolutionary mechanism not as a part of an investigation of the process itself, nor did he initially realize the implication of production failures and parallel developments for evolutionary sequencing. The importance of this point for nineteenth century European archaeology can be seen in the problems presented by the Pressigny cores and the 'Cissbury celts'.

The Pressigny cores were a series of flaked artifacts; boat shaped with a rounded ventral and crested dorsal surfaces. In their initial examination Steenstrup and Lubbock (1867) concluded that they were not the products of the later gun-flint industry but prehistoric blade cores. In his subsequent discussion Evans (1897:27) presented the evidence for a wider distribution and discussed the possibility that the artifacts were highly specialized implements. He rejected the latter and presented a detailed discussion of how they may have
functioned as cores. Their presence in Scandinavia and Greece did not necessarily represent a cultural connection, merely the presence of similar production processes - the product not of individual cultures but responses to more generalized conditions.

Evans (1897:83) in his discussion of the antiquity of the Cissbury celts demonstrates the conflict between the application of evolutionary principles and problem presented by the recognition of production failures. Pitt-Rivers had previously argued that the absence of ground edges on some of the bifaces indicated that some were palaeolithic. In a detailed examination of the various types present on the site Evans (1897:83) suggested that they could all be considered failures in (what we would now call) a bifacial reduction sequence and dated them to the neolithic. Pitt-Rivers (1906:34) later conceded this possibility. Prehistoric artifacts could not, therefore, be considered merely the reflection of final cause, in both a functional and evolutionary sense, but could also represent the dynamics of production itself.

This principle had also been applied by Holmes in a series of studies on prehistoric quarries and assemblages in the United States (see also Mason 1895:132). Holmes (1890, 1893) argued that the Palaeolithic forms found in north coastal region were not evidence of a great antiquity but the rejects from a single reduction sequence. Unlike his European contemporaries Holmes
addressed the implicit counter question of why the unfinished artifacts of an advanced society should be morphologically similar to the finished tools of earlier ones. He supported his argument via a complex theory centred on a model of the stages of manufacture which not only represented the course of an individual artifact's production, but also represented the evolutionary development of stone technology. The model is derived from the biological "law of recapitulation" which acquired an evolutionary status in Haeckel's concept of ontogeny (Russell 1982[1916]:252):

...as in biology the growth of the individual epitomizes the successive stages through which the species passes, so in art the flaked-stone tool...

Holmes (1890:23)

...in a way, however, the progress of manufacture of each individual of the highest type repeats the steps of the evolution of the species or group to which it belongs. (1891:49)

Using this argument Holmes accounts for the similarity of all ancient forms. Fundamental to his model is the concept that similar artifact forms are produced via similar or identical stages of reduction:

...every implement resembling the final form here described made from a boulder or similar bit of rock must pass through the same or much the same stages of development, whether shaped to-day, yesterday, or a million years ago...

Holmes (1890:13-14)
...forms of flaked implements employed in cutting, pecking, scraping, and striking are necessarily shaped by like processes, pass through like changes of form and reach closely identical results... (1894:137)

This made it theoretically possible for researchers to distinguish between the products of prehistoric design and the by-products of manufacture in the reconstruction of the stages of reduction. The argument also makes it possible to use a single reduction sequence to represent evolutionary development. Holmes (1894) used a core tool bifacial sequence to represent this evolutionary process, although it is not clear how much he saw this as representing the whole picture or simply the limits of contemporary knowledge.

Although he held similar views of the effects of production failure on individual artifact form, assemblage composition and its consequences for evolutionary chronology to those of his European contemporaries, his model differs significantly in its view of the effects of error in the evolutionary process. The importance of artifacts bearing 'evidence of design' (1890:11) in Holmes' theory distinguishes it from Pitt-Rivers' selection model, in which artifacts evolve from the variations derived from production error. Although Holmes' does not detail the mechanism of evolution his model appears to bear more resemblance in its evolutionary aspect to the pre-Darwinian models of Enlightenment scholarship in which the progress towards higher states of technological order is controlled by increasingly rational
processes governed by teleological 'laws'. Artifacts with evidence of design are the only ones which can reflect the increase in the control of the "result desired" (Holmes 1890:10, 1894:130).

Holmes viewed manufacture as a single static process in which errors in reduction are equated with failure and discard:

If at this stage, and may I say if at any preceding stage, the stone developed defects or unmanageable features ... it was thrown away and thus became part of the refuse.

Holmes (1890:12)

The causes of error were seen as a complex interaction between material, technical, formal and final causes. Holmes also (1894:134-135) distinguished between 'breakage' and 'rejectage'. The former resulted from the poorly controlled interaction between the specific technique of applied force and the contradictory properties of the material (Holmes 1890:11-12,16). Rejectage was due to "some fatal eccentricity of contour" (Holmes 1894:135) including "too great thickness, crookedness, or humps that could not be removed" (Holmes 1890:12). Holmes does not elaborate on the causes of eccentric contours beyond the failure to achieve final forms which are "kept in view throughout the progress of work" (Holmes 1890:13).

The concept that lithic production processes could be divided into stages was a central component of Holmes'
model. As seen, this model functions at two levels. The first relates to the general reduction sequence found on specific sites (like the Piney Branch Quarry [Holmes 1890]), the second at the level of an evolutionary sequence tracing the course of technological development. Holmes' discussions do not distinguish effectively between the two which his model appears to have viewed as aspects of the same process. The concept of stages of production is not, however, compatible at each level.

In his discussion of the general reduction sequence at the Piney Branch Quarry Holmes (1890:14-15) divides the sequence into three separate stages marked by a combination of formal and technical features; unifacial flaking followed by bifacial flaking with hard hammer and thirdly bifacial flaking with a small hammer. The final stage is inferred from the presence of controlled flaking. These stages were, he states, the most convenient and indicated well marked steps in the reduction on-site. The final forms on the site are referred to as 'blanks' (Holmes 1891:52, 1894:132) because Holmes believed that they were subsequently removed for final modification into specialized forms. It is not clear whether he saw these stages as analytic or real units, nor how stages in general reduction sequences (like that of Piney Branch) related to stages in his evolutionary model.

The assumptions underlying Holmes' evolutionary model makes the definition of stages a problematic procedure. As all designed artifacts were seen to share a common reduction sequence, the refinement of their final form is
dependent on the point in the process at which their forms are 'specialized'. Axes are specialized early and are crudely formed; arrow heads are specialized later and are highly regular and refined forms (see Holmes 1894:diagram 1). The problem with this model is that Holmes could not progress from a notional evolutionary to a definition of stages related to a specific or general process of reduction. As rejected forms may represent the primary stage of an arrow head or the final stage of a hand axe, concepts like 'blank' denoting a specific stage of reduction, relying on knowledge about the intended final form, could not be transposed with certainty from the evolutionary to a general reduction sequence. Similarly, although the evolutionary model maintained that the increase in artifact refinement was achieved by the successive application of more controlled flaking techniques, these do not necessarily take place at uniform stages in a specific reduction sequences because of variation in raw materials (Holmes 1894:127).

Holmes (1893) also made a pioneering investigation of the way in which synchronic variation in the organization of lithic production (i.e., the external relations of production) affected artifact form and assemblage composition. He argued that the geographic distribution of lithic resources was a major factor in determining the organization of production and could affect assemblage composition at different sites relative to source location. His investigations of surface sites in the region of Washington DC produced a series of propositions.
on the way this organization would be reflected in the archaeological record:

1) The size and form of lithic source material will directly control the production process and the extent of reduction.

2) The various stages of production will be differentially distributed with primary production close to stone sources and final products furthest from the source.

These and two further propositions about the effects of activity variation on assemblage distribution and composition were used by Holmes (1893) to present an explanation for the variation in assemblages found in the study area, emphasising the importance of considering the systemic context in which prehistoric artifacts functioned.

These aspects of Holmes' work have been dealt with in some detail because it will be seen that his discussion of the reduction process and its organization in time and space prefigures and surpasses much subsequent work.

In summary, by the end of the nineteenth century the importance of the process of manufacture and its organization had been acknowledged by both British and American archaeologists. It had been argued that failure in the sequence of artifact reduction could account for the range of artifact forms within single assemblages without recourse to evolutionary chronology. The role of failure in production, however, formed a central point of
difference between the two alternative models which were beginning to develop. In Pitt-Rivers' (1906) error provided the variation necessary for the selection of improved features required for technological progress. In Holmes' (1890, 1894) model error was equated with failure to conform to a rigidly defined reduction sequence which operated at both a general and evolutionary level. The process of manufacture was, and continues to be viewed, as either inherently unstable but progressively more manageable or rigidly organized but not fully controllable.

A further important step made by the end of the century was Holmes' (1893) investigation of the organization of the process of manufacture in terms of resource location and activity variation. Although a detailed discussion of why these approaches did not have a more lasting effect on subsequent archaeology is beyond the scope of this essay, a number of related points can be made. Enclosed within the explicitly evolutionary framework of the time, nineteenth century prehistorians sought to use production process theory as a structure providing a mechanism for the development of evolutionary schemes and chronological frameworks. With the decline of interest in evolutionary studies came a decline in the wider question of technological change and its mechanism as a separate process. Stripped of this wider perspective, subsequent research into lithic technological change has concentrated on the now traditional questions of production techniques and artifact typology.
Both Harris (1969:271) and Trigger (1981:144-5, 1989b:102-3) have pointed to a number of factors which could account for the decline of evolutionary studies including: the rise of professional anthropology, the failure of the evolutionary narrative to cushion the middle class against the spectre of revolution, the move towards more acceptable 'anti-materialistic' explanations, the persistence of nationalist archaeology and continued religious opposition. A further factor in the decline of an evolutionary perspective in archaeology can also be seen in the increasingly contradictory elements which interest in the manufacturing process and its organization was exposing within the evolutionary perspective itself. Although the process was not of central concern its implications for archaeological sequences were considerable.

The argument that failures in the process of manufacture could not be distinguished from earlier completed forms threatened to undermine the very rationale for applying, or deriving, evolutionary sequences to, or from, the archaeological record. As the view that primitive meant old, based on the absence of developed traits, could not be defended, the ability of archaeological sequences to exhibit clear evolutionary trends could be called into question. Although this problem was not made explicit, Evans (1897:12) was, for example, careful to utilize only the stratigraphic context (such as it was) to distinguish neolithic from
palaeolithic artifacts. Similarly Holmes (1919:46), despite arguing that the 'law of betterment' was a dynamic force in human evolution, preferred to await further archaeological evidence before recognising any Palaeolithic implements in America and presented his summary of American antiquity (The Handbook of Aboriginal American Antiquities) as a series of studies of lithic procurement and production techniques.

7.1b: Industry and Technique

The realization that rigid evolutionary schemes (eg., see Daniel 1975:237,245) did not accord in detail with regional sequences (De Morgan 1924:45), combined with the developments noted above, contributed to a prehistory concentrating on the history of regional cultural developments. This culture-history utilized the 'archaeological culture' as its primary explanatory unit and saw the elucidation of its patterning in time and space as its primary aim.

The approach relied heavily on the concept of archaeological cultures which could be derived from the archaeological record via the systematic application of methodology. Childe describes the process in the following way:
...by pots and house plans, personal ornaments and burial rites, the materials they fetched from afar...Such remains archaeologists divide and classify into types and when the same types are repeatedly found together at different sites within a limited region, they are grouped together to represent what we term culture.

Childe (1958:10)

Childe's description is a simplified account of the complex and arbitrary manner in which archaeological cultures were defined. In the European palaeolithic, for example, the Solutrean had been characterized by a form of invasive retouch, the following Magdalenian culture by the relative absence of that retouch and the presence bone implements (Breuil and Lantier 1965:144-5). In Australia Tindale defined the three upper cultural units of Devon Downs in terms of the occurrence of unifacial points, bone bipoints and ethno-historical data respectively (Mulvaney 1969:105).

The formation of artifact types, fundamental to higher level definition of cultures, has been characterized as intuitive (Bonnichsen 1974, Hill and Evans 1972, Shawcross 1964) and criticised for its assumption that these types convey 'inherent' cultural meanings (Hill and Evans 1972). As much of the culture-history approach was concerned with the identification of cultures and their chronological relations (Trigger 1989b, Spaulding 1985:305), discussion of the way in which artifact types reflected culture was not extensive, particularly in Europe where detailed artifact typologies had been established in the nineteenth century. In
America the later association of culture-history with a "normative" view of culture (Binford 1972:195-7) has provided the most explicit discussion of the process of manufacture.

The central tenet of the normative or idealist approach is that "culture is a mental construct of ideas" and that ideas are "objectified and made observable through the action systems of the body" (Taylor 1948:99) (see also Ford 1954:47, Gifford 1960:346, Kreiger 1944:272). Deetz's (1967) discussion of the role of mental templates in determining artifact form may be used to exemplify this normative view (see Watson, Le Blanc and Redman 1971:61-3). Although the equation of culture with ideas was well established the concept of the 'mental template' appears to derive from Deetz's concern with the manner in which deeper mental structure was reflected in artifact form (Leone 1982):

The idea is the mental template from which the craftsman makes the object. The form of an object is a close approximation of the template, and variations in a group of similar objects reflect variation in the ideas which produce them...

Deetz (1967:45-6)

The production of prehistoric artifacts is here clearly equated with a process of giving ideas a material form (ie., reification). The degree to which archaeological classification could (or should) replicate the ideational norms, however, continues to be a matter of debate (Dunnell 1971:132-4, Harris 1968, Kreiger 1944:280-1,
Culture change in culture-history depended on diffusion, migration and adaptation via the process of innovation which was invariably triggered by unspecified needs for new inventions or environmental change (e.g., Burkitt 1949, Childe 1958:20, 1973[1954]:46, De Morgan 1924) (see also Trigger 1989b:206).

The process of artifact production was modelled, mainly by default, as neutral; artifact form was equated with final cause because assessments of functionally and culturally determined morphology were viewed as the most viable approaches to the correct formation of types (Cahen and Van Noten 1971:211). For example, Bordes (1968:136, 1971:212) considered variation in stone material as only a minor component of total artifact variation. Similarly, Bordaz (1971:6-13) in discussing stone materials emphasises the similarity of their fracture properties without examining the ways in which variation in distribution and form could affect the process of manufacture. In a general work like Bordaz's Tools of the Old and New Stone Age this may not be a viable expectation, however, the publication sets out manufacturing techniques and final artifact forms in chronological sequences which does characterize the way in which technology and more specifically lithic technology was viewed in culture-history.

The way artifacts were made was considered important in the formation of types, its value lying in its ability
to indicate cultural norms which could be used to further differentiate archaeological cultures by resolving the problem of isomorphic types (Burkitt 1949:26, Rouse 1970:188), and determining which attributes were intentional (Bordes 1968:22). As Bonnichsen (1974:41-2) points out, this reality was not satisfactorily achieved due mainly to poor correlation between attribute and specific behaviour. A further factor may also lie in the necessarily circular way culture-history defined prehistoric technology. If the processes of manufacture were useful in defining types it was sufficient only to define the processes to the point where types could be defined. The normative perspective allowed variation in the way artifacts were made to be equated with a single cultural norm, which could be combined with other norms as the defining characteristics of a culture. As stated above, norms were either fixed to form traditions or represented behaviours which constituted traditions in themselves. The distinction is not made clear in most cases. While Rouse (1972:285) combines both, the concept of 'mental templates' favours the former interpretation (ie., ideas fixed to form traditions). By necessity, prehistoric stone technology was also seen as organized into rigid industrial structures reflecting this fixed normative structure.

The conversion of prehistoric technological processes into static structures was carried out via the concepts of 'industry' and 'technique'. In culture-history the term 'industry' has been used as a higher order grouping of
types of assemblages (see Burkitt 1949) and was synonymous with 'style' and 'culture complex' when applied at that level (Rouse 1972:84). Industry was not defined necessarily by specific processes unless the process (eg., Lavalloisian) was considered a defining trait. Similarly, this equation of industry and culture can be seen in Breuil and Lantier's (1965) discussion of the Solutrean industry and the Magdalenian culture as equivalent historical phenomena. Although this equation was acceptable within the limits of culture-history, as part of the process of organizing the archaeological record for the purposes of its historical narrative, a danger lay in the equation of industry as an organizational unit with industry as a description of a technological structure. Bordes (1969:2), for example, argued that although there were a number of possible technological responses to a particular environment, tradition dictated the character of the local industry. In his view prehistoric industries were organized to produce a series of regular artifact forms designed to fulfill increasingly specialized tasks. The 'specification' of designs was cultural; correlated directly to task complexity and the resulting artifacts were produced in proportion to need.

Bordes' view has considerable intuitive appeal because it closely resembles the structure of the standardized mass production and specialization which dominates present industrial technology. Its weakness lies in its derivation from the methodology of culture-history; its applicability to prehistoric technological
organization remains unproven. When challenged on this point by Cahen and Van Noten (1971) Bordes (1971:212) relied on an analogy with modern industrial products to demonstrate his point:

If in 10,000 years, archaeologists should uncover cars, it would be very useful for them to know that cars were used for transport (functional typology). It would be even more important, however, for them to discriminate between Fords, Volkswagens and Renaulds (morphological typology)...

Bordes (1971:212)

Typology works in Bordes' view because both prehistoric and modern industrial processes are essentially similar, so similar modes of inference could be applied. As Cahen and Van Noten (1971:214) point out, however, the application of Bordes' typology to motorcars would produce nothing like a modern classification. It may also be argued that the distinction of brand names is only one of many classifications used in the 'Car Culture'.

As the organization of prehistoric technologies was seen in culture-history as analogous to those of industrial societies and the process of manufacture had little effect on final artifact form, the thing which directly affected form was the application of technique. Although the discovery (via experiment and ethnographic observation) of the techniques and processes which may have been used to produce prehistoric artifacts was an integral part of nineteenth century archaeology (see Evans 1897, Lubbock 1869) its perspective differed to that of
later culture-history. Culture-history's static view of technological structure emphasised the use of technique as a cultural norm. As Bonnichsen (1974:42) points out, "Bordes' concept of technique... is no more than a historical index type", shedding "little light on underlying process".

In his discussion of prehistoric lithic technology Bordaz (1971) presents knowledge of techniques as well developed and increasingly self-contained; the main problem confronting archaeologists being the determination of artifact function via ethnographic analogy, experiment and use-wear analysis (Bordaz 1971:41). Those who felt themselves competent at knapping were increasingly confident that prehistoric technologies were well understood because techniques as norms were well understood. As Bordes (1971:212) states: "...anyone who has really mastered stone-working knows that, within very broad limits, the influence of the raw materials on typology is small". Although Bordes' observations may be valid in terms of technique and material they present a danger of being equated with knowledge of the total prehistoric technological system. A series of techniques learned on weekends and used to teach undergraduates exists in a totally different operational reality to anything which existed in prehistory (see Collins 1975 for similar criticism).

Culture-history's equation of techniques with cultural norms produced specific processes of manufacture
which were idealized, often to the limits of operational reality (eg., Bordaz [1971:fig.2] description of the Levallois technique, also Bordes [1968:27,30]). This approach did not also differentiate between the complex levels of interaction among techniques themselves. Techniques which control force application are discussed as equivalent to processes of manufacture combining several types of force application. The poor correspondence of idealized reduction sequences with the reality of archaeological assemblages did, however, prompt some examination of the wider production process.

The few discussions of how the process of manufacture may have affected artifact form show some marked similarity, in terms of the role of failure, to the model presented by Holmes. Bordes (1969:5) viewed the working of stone to be less controllable than that of metals and clay, and the resulting artifacts to be be much less standardized, but not to the point where the validity of types was threatened. He also suggested that the control of the manufacturing process was directly related to the tightness of type specifications (ie., the definition of the 'mental template'). Deetz (1967) had earlier formalized manufacturing processes into subtractive and additive. The latter was inherently more controllable than the former:

One would ... expect a greater amount of variation, in those artifacts which are made subtractively, than in those made by an additive technology. Deetz (1967:48-9)
As in Holmes' model, the manufacturing process was seen as prone to error and failure resulting in discard. Unlike Pitt-Rivers' approach, this was not part of the process of technological change but a natural result of the failure to achieve a desired conformation to mental template. The process of production and its accompanying problems were seen as in some way removed from cultural systems because it acted simply as a mechanism for the production of artifact forms. Deetz (1967:49), for example, doubted whether "problems of technology" could be "germane to cultural reconstruction".

This understanding of lithic technology was not without its dissenting voices. In his criticism of Holmes, Bryan (1950) characterized the contemporary view of stone knappers in the following manner:

One can view the primitive flintworker as hidebound by ignorance and custom so that he knew only one or two types of implements and only one method of quarrying and reducing flint. Or one can view him as a casual and aimless brute who broke out rough masses, reduced them by careless blows... (1950:31)

He argued that this image dominated the contemporary view of the European Palaeolithic in which the final product of each step in reduction was foreseen and that these rigid processes are "supposed to have lasted for thousands of years... succeeded by a different but similar procedure" (1950:31-32).
Bryan (1950) presented an alternative to these views in which a rational interaction between the knapper and a controllable but not entirely predictable process of reduction is the central tenet. The process of manufacture employed was principally dependent on stone availability and technical capacity. In line with this approach he argues that errors or departures from formalized reduction sequences need not be discarded but could be further modified, producing assemblages characterized by either, a wide range of variable shapes, or a series of formalized recovery techniques resulting in a number of subsidiary forms:

One must suppose that the defects of material were known and that the stages in the process of fashioning at which defects would appear or breaks would occur were also known. Many of these defective pieces were not immediately rejected but were slightly modified and used.  

Bryan (1950:33)

Bryan presents a model of behavioural interaction in which reduction sequences, poorly structured in terms of their production of fixed types, are seen as a valid technological alternative to the rigid industrial structures of culture-history. He argued that both alternatives could be found in advanced lithic technologies. The role of error in Bryan's model is not simply to provide selective variation or failure, but could also play an active role in structuring reduction sequences and the resulting assemblages. Bryan presented the possibility that some prehistoric technologies may have been centred about a single
reduction sequence producing a small range of specialized artifacts, with the rejects from this process being systematically modified to complete the suite of tools required.

As an argument based on a view of the prehistoric knapper as an intelligent coping individual in a discipline whose primary explanatory mechanism was 'culture', Bryan's views remained outside the mainstream and largely unnoticed.

The difficulty of applying standard typologies to amorphous flake assemblages outside and on the fringes of European and American 'traditions' produced further attempts at understanding assemblages in non-typological modes. Shawcross (1964) in a comparison of three New Zealand flake assemblages argued that an adequate typology could be based on an understanding of the techniques which produced the flakes. Unlike the standard typological equation of technique as type seen above, Shawcross (1964:9) saw technique as variation in the central process of core and flake reduction; the primary determinants of flake morphology being variation in applied force and core geometry. The character of assemblages was definable not by a type list, but a series of metrical profiles which reflected technical differences.

Although this approach to the problem of amorphous flake assemblages pointed to the centrality of the reduction process in determining flake morphology, it was largely ignored by a parallel interest in edge
characteristics. Following Mellar's (1964:231) suggestion that "...edge alone is the important part of the tool; the overall shape is of little importance" in his analysis of racloirs from Kokkinopilos, a number of attempts to classify assemblages according to edge characteristics were carried out in Australasian archaeology (see Allen 1985). These studies, in focusing not on standardized morphology, but on standardized attribute (i.e., edge form), retained the structure of culture-historic interest in the construction of types based on regular trait or attribute combinations at a more fundamental level. Although White (1969:18) questioned the usefulness of 'mental templates' in approaching amorphous assemblages he saw the manufacture of artifacts as a product of an idea "...to produce a tool in which certain features were appropriate to the intended use."

In contrast to many of the canons of culture-history the later works of both Childe (1944, 1956, 1957) and Clark (1952, 1972) show an interest in viewing the archaeological record as evidence of a functional system and explaining the record in terms of the operation of that system. Childe, in particular, maintained sophisticated theories on the relation of technology and social change. Although he was explicitly evolutionary when discussing broad problems of culture change Childe (1957:212) argued against the validity of developing evolutionary sequences of artifacts in the fashion of the nineteenth century's 'science of the artificial'. For Childe, knowledge was a social phenomenon and its
progressive accumulation was operationally determined (Trigger 1986). As this progressive accumulation was determined in practice, the effectiveness of some process of production or technique could not be assigned in individual instances on evolutionary principles, as it was the context in which the process functioned which ultimately determined its efficiency. While Childe's operational definition of knowledge justified his examination of long-term evolutionary changes, at the same time, he was therefore cautious in assigning significance to specific cases of technological change. His caveat that "armchair archaeologists" should not claim "esoteric knowledge of what practical man did find the fittest instruments" (Childe 1957:212) in given circumstances is a salient criticism of the simplistic attributions of technological efficiency (see Cundy [1989] for examples applied to the effectiveness of the spearthrower).

Although the problems which technology solved were socially determined (Childe 1956:2), the final form of the artifact could be as much a result of the economic structure of production as the idealized social form (Childe 1957:213). In some cases the form of the production process could also affect the division of labour necessary to achieve the desired end products (Childe 1944:9). Social relations could, however, also fetter the development of new process and products (Childe 1944:23, 1958:169).
Although Childe (1944:8, 1951:75, 1965:49) saw social evolution as an increase in control over the environment through the standardization and specialization of tools, he does not supply any detailed discussion of how the two processes were achieved. What advantages do standardization and specialization hold? Childe's discussion of the advantages of metal working, for example, concentrates mainly on the ability of metals to produce stronger and more varied products. The production 'modes' which Childe used to discuss metal working are defined by groups of artifacts which could be used to plot the increasing use of bronze objects in a society. The 'modes' are, however, fundamentally typological constructions, which may not have been the most suitable way of examining the processes which produced bronze. Although Childe (1944:9) points to the complexity of the cost structure of production and its importance in affecting the social relations of production, he does not examine in detail were the costs of bronze production lay, and whether this could account for the variability in its adoption and use.

Despite the sophistication of Childe's ideas on technology generally (see Trigger 1986), they did not contribute greatly to the understanding of lithic technology, which he saw as principally "conditioned by distinct social traditions" (1973[1954]:38). This stems from his reliance on typological approaches to artifacts and his greater interest in social development than in the practical detail of prehistoric life (Trigger 1980:171).
In comparison to Childe, Clark's functional approach was more concerned with the details of technological, economic and social activity. His perception of lithic technology, which centres on its part in the way in which communities "manipulated the environment to ensure survival" (1975:9), impressed the concept - more strongly than had Childe - that the making and using of stone artifacts was carried out in the context of a practical human existence. Technology was, however, an element of conservative cultural traditions, with its components discussed primarily as 'tools' and 'techniques'. For example, Clark had earlier (1952:173) interpreted the character of northern British flint usage as the product of "flint-using peoples penetrating an area where this material was scarce" and continuing, by tradition, to utilize flint rather than adapt to locally available materials.

7.1c: The Process of Manufacture in the 'New Archaeology'

The implications of Bryan's and Childe's later work, particularly their theories of technology have not been fully examined by subsequent archaeological theory, which has been dominated largely by the 'New Archaeology'. The New Archaeology remains poorly defined as an alternative, particularly in its approach to the problem of technological change. Trigger's (1980:183) observation
that its unity is structural, dependent on common perspectives not common problems echoes Leone’s (1972:25) earlier view that groups of activity could not be distinguished with any clarity within the school. It is in a real sense only just within historical perspective and the plurality of approaches makes it difficult to consider historically, however, the common perspectives which do exist can be used as a basis for discussion.

In its rejection of the normative view of culture-history, the New Archaeology has been characterized by a varying combination of neo-evolutionary, cultural ecological and systems theory (Gibbon 1984, Leone 1972, Kushner 1970, Trigger 1989b). In accord with Binford’s (1972:198) rephrasing of White (1959:8), culture is seen as "...an extrasomatic adaptive system that is employed in the integration of a society with its environment and with other socio-cultural systems". The role of technology, generally viewed as an important subsystem (Binford 1970), has been to articulate the cultural system with its physical environment (Binford 1970:327,329) (and other sub-systems [Clarke 1978:130]).

Although technology, functioning as an infrastructural component, is afforded causal priority in both the cultural materialism of Harris (1969) and the neo-evolutionary approach of White (1959), both viewed as important to the development of the New Archaeology (Binford 1972, Gibbon 1984, Kohl 1981), causal priority has tended to be concentrated on the adaptive interaction
between cultural systems and the environment. Despite Flannery's (1972:104) claim that the "...strategy of the process school is therefore to isolate each system and study it as a separate variable", the New Archaeology has provided little new insight into the operation of the technological subsystem itself, maintaining an ambivalence about its existence and the importance of its internal relations. Kohl (1981:105-6) has pointed to a "sharp contrast" between the role of technology in the work of Childe and its "secondary or dependent status" in the New Archaeology, which he argues is a result of the tendency to equate explanation stemming from intra-subsystem interaction as a form of cultural vitalism (see Binford 1972:430). Technology's close link with other subsystems, and possibly more importantly its own internal structure, has largely been sidestepped in favour of viewing the technological subsystem as neutral, dependent upon external factors to condition its effects (see Binford 1972:442). Kohl (1981:106) further argues that the acknowledgement of intra and inter-subsystem dynamics threatens the viability of explaining cultural change via a set of general laws, one of the central tenets of the New Archaeology (see also Trigger [1980:168-184] for discussion of the relation of Childe's theories to the New Archaeology). The problem of adequately integrating the role of technology into the the culture theory of the New Archaeology can be further illustrated by Gibbon's (1984:30) failure to discuss it as a separate subsystem, despite his affirmation that the infrastructural primacy of technology and its organization is a central assumption.
of processual or 'New' archaeology.

Although the integration of the intra and inter-subsystem dynamics of technology has not received much attention from current theory, the system's adaptive function (Binford 1972, Gamble 1986, Rathje and Schiffer 1980) and its role in the correlation of prehistoric systems with the archaeological record (Schiffer 1972, 1976) has been the focus of more detailed research. Both approaches have focused on the question of how prehistoric technologies were organized. The former, heavily influenced by functionalist theory (see Steadman 1979), the latter concentrating more on the development of transformational models (Schiffer 1976:42).

In his functional argument against the culture-historic interpretation of variation in the Mousterian, Binford (1973:242, 249–251) argued that the organization of prehistoric technologies could be characterized by an evolutionary cline between expedient and curated technologies. Curated technologies were seen as more highly organized in terms of the preservation of artifacts for future use, with increased maintenance and recycling of tools (see also Binford 1977:34). They are also seen as more efficient, as the more energy expended in the production and maintenance of a tool, the more efficient the technology. Expedient technologies are not defined in detail and seem to maintain these features to a lesser degree.
Although the usefulness of these categories for the description of technologies has been questioned by both Newcomer (1979:675) and Bamforth (1986), the underlying principle that technologies are organized structures reflecting both anticipated demands and expedient solutions, when combined with Schiffer's (1972) argument that the various stages in the process of production and use may be variously distributed in space and time, have proved useful models for explaining assemblage variation (see for example Gamble [1986]). We should note, however, that Holmes (1890,1894) anticipated both.

Of more relevance to this discussion is the manner in which the process of manufacture is modelled in Binford's account of the organization of prehistoric technologies. Binford (1979) concentrates principally on what he terms logistically organized systems (Binford 1980). In these, both the procurement of stone for artifacts and the manufacture of curated (or 'personal') gear is embedded in other activity schedules. This contrasts with the production of 'situational' gear which is produced and discarded to meet the requirements of previously unforeseen situations (Binford 1979:268-271). Binford (1979:271) further argues that artifact form and reduction strategies are dependent on the nature of the "intended technological role". Using this approach, Binford like Bryan (1950), has challenged the concept of rigidly structured stone industries which predominated in culture-historic approaches.
In his discussion of the "fabrication model" of manufacture Binford retains some idealist elements in the propositions that "...fabrication plans are guided by some ideas regarding the desired outcomes" (Binford 1978:3). He is, however, sceptical of its relevance to all artifact variability, as the relation between the product and the producer is itself an organizational variable (Binford 1978, 1986).

Via the concept of "embeddedness" Binford (1979) avoids the possibility that lithic production imposes a cost structure independent of other economic subsystems, but does not provide sufficient reasons why the process of manufacture should be assigned a subordinate role. His approach is consistent with the functionalist position that technology operates as an adaptive interface between culture and environment and that variation in its organization reflects this interaction exclusively (eg., Gamble's [1986:279] comment that "technology is a tactical variable").

This approach is furthered by Torrence (1983) in her discussion of the effects of time stress on the scheduling of activities. Torrence (1983:12) appears to deny the subsystemic nature of technology, stating that as it is used in a number of activities the "...relationship between scheduling behaviour in procurement, manufacture, use and discard...needs to be examined within the context of a wide range of activities". The process of production of artifacts is seen as subordinate to the problems of scheduling higher level subsistence activities. Bleed
(1986:745) follows a similar argument in his suggestion that the organization of hunting technologies is divided into maintainable and reliable systems reflecting "...different systemic relationships between hunters and quarry".

Although they can not all be seen clearly as exponents of the New Archaeology, more detailed discussion on the process of manufacture has come from those using lithic analysis to: investigate problems of culture-history and typology (Bonnichsen 1974, Bucy 1974), construct transformational models correlating archaeological and systemic contexts (Collins 1975, Schiffer 1972, 1976, Sheets 1975) and develop understanding of the factors affecting morphological variation (Dibble 1981, Muto 1976, Phagan 1976).

The wide use of flow models to represent diagrammatically complete production processes is a feature common to many contemporary analyses (Bradley 1975, Collins 1975, Flenniken and White 1985, Fowler et. al. 1987, Leach 1984, Sheets 1975, Schiffer 1972, 1976:46, Stevenson et.al. 1984). Unlike the flow and block models of cybernetics (Porter 1969) those used in archaeology do not model causal relations between the various stages of production, although goal directed behaviour is assumed in both. The former is at least true in the sense that it is not, for example, argued that procurement causes manufacture. At its simplest the flow model can be seen as representing stages in a continuous process. The
relation between the stages is linear, determined in Collins' (1975:17) view, "...by the fact that all but the initial step are dependent upon the output qualities of the prior steps as preconditions for their initiation". This is true only if the output of earlier steps is consistent with the requirements of subsequent stages, which are in turn, consistent with the production of the ideal final form. The flow models are more correctly compared with current diagrams in which a current moves via a series of switches which increasingly delimit the final form (eg., Schindler et. al. 1982:538).

Although criticized as idiosyncratic (Katz 1978:362) the models of process underlying these analyses are essentially similar to that of Holmes' discussed above, in that the process is seen as an interaction between material, technical and final/formal causes. The process of lithic production is an idealized transformational one in which raw material is changed into cultural products. The primary interactions between the material, the knapper and the culturally desired end forms are defined by a set of relations in which there is a continual process of comparing the artifact at each stage of production with a desired end form. The interaction between the knapper and the material is poorly controlled and provides the source of the unpredictable nature of the process; the more perfect the material and the more controlled the application of force the more the product will conform to the desired end form.
These types or systems approximate to a greater or less degree the ideal types or systems within a culture most probably in direct relation to the expertise and enculturation of their makers.

Muto (1976:10)

In his discussion of the factors affecting the 'manufacture of implements' Bucy (1974) states that lithic materials affect the qualities of manufacture and quotes Pond:

...if a stone worker obtains a supply of very good material he is able to register his ideas more accurately than he could in poor quality stone.

Bucy (1974:5)

The two factors which limit a knapper's ability to control end products are:

...unsuspected flaws or changes of texture in the material or miscalculations of the amount of force angle of applied force on the part of the worker.

Bucy (1974:7)

Binford (1979:267) relies on a similar argument when he suggests that personal and household gear will, by virtue of greater production expenditure, exhibit maximum design compatibility relative to function, and maximum fit between the appropriate quality of raw material and tool design. Clarke (1978:152-6, 202-3, 469) presents a comparable model with the attributes of artifacts representing "premeditated and deliberate hominid behaviour" and the finished artifact constituting a coded message of intentions plus the 'noise' resulting from the
process of manufacture and attributes not selected by the investigator.

Given an underlying model in which the primary relation is a strong but unstable interaction between the manufacturer, the material and the culturally defined end product, the two related questions which tended to arise were: what factors control the knapper/material interaction, and secondly how could interaction with wider cultural processes explain technological variation or vice versa (see Bonnichsen 1974). The first of these questions resulted in a series of studies in which "the crucial problem in understanding production" was seen to be in the "understanding of the interrelated variables of lithic fracture" (Phagan 1976:6) (see also Bonnichsen 1974, Faulkner 1972). Speth (1972:34-36), for example, equated technological variability with the processes governing flake formation, in the hope that this might enable archaeologists to formally sort technological from stylistic and functional variation.

The second of the above questions is more directly derived from the essentially culture-historic problem of distinguishing or articulating technological attributes (stemming from the knapper/material interaction) with the culturally defined end types. Muto (1976:19) presented a solution via a decision model in which the three spheres defined as contributing to the production process - cognitive, behavioural and natural - are integrated. At each stage of manufacture the products are compared with the idealized type and assessed as to whether it is physically
possible, culturally acceptable or ideally desirable to continue manufacture. Artifacts which do not comply with these criteria are rejected as waste. Muto (1976:19, fig.7) distinguishes between ideal 'trajectories' in which artifacts move through the stages of production to completion and modified trajectories in which errors in production (producing arrested trajectories) force knappers to compromise the fit with the ideal forms, discard the artifact (truncated trajectory), or redirect manufacture towards a new end product (redirected trajectory). Bonnichsen (1974:65-66) presented a similar model in which contingency plans are utilized in order to achieve end goals. Failing this the artifact may be abandoned or new goals selected. The interaction in each model is between knapper/material and a single end goal.

The study of the stone tool making of the Duna of the Western Highlands of New Guinea represents a major attempt within ethnoarchaeology to "explore the problem of mental templates". In his interpretation of the evidence Thomas (1974:54-5) concluded that the variation between two of the test groups (the Hareke and the Aluni) was "... unquestionably the result of mental templates carried about in the heads of each artisan". The informants were, however, not aware of the templates' existence. While Thomas' conclusion was consistent with those of an earlier paper with White (White and Thomas 1972:298) White and Modjeska (White, Modjeska and Hipuya 1977) later suggest that the 'mental template' among the Duna was a "covert category" derived from the consistency of the lithic
material, the method of hafting and the use of the artifacts studied. Their view that the template is not formed in isolation but in interaction with the material relations of manufacture and use parallels one of the arguments presented in section 7.2.

Following a perceived failure of conventional typological and experimental approaches to place adequately artifacts within the "domain of human action and thought" Hassan (1988:281) has extended the model by arguing that the order underlying the production of lithic artifacts "...cannot be explained solely in terms of purely mechanical principles or functional/adaptive goals" (Hassan 1988:282), and that their proper understanding may only be achieved via an approach which sees artifacts as the "...exemplification of [structured] cognitive processes" (1988:281) (see also Young and Bonnichsen 1985, Gowlett 1986). The transformation of structured conceptual elements is governed by a system of rules of which artifacts are surface manifestations. The primary system of rules (the syntactic) are deeply embedded in "[universal] cognitive and psychological rules". At a still deeper level, the "manufactural rules" are grounded in sensory-motor behaviour. The manufactural and a third set of rules, the functional, act as constraints on the combinations of "syntactically feasible artifacts" (Hassan 1988:284).

The breaking down of artifact form into cognitive rules of action represents a sophisticated restatement of
the primacy of mental behaviour in the structuring of artifact production. Despite the hoped for new direction, the cognitive approach appears to be well within the traditional understanding of the manufacturing process in lithic studies.

In summary, current discussion of technology is structured at two levels. The first of these, derived from the tenets of the New Archaeology, seeks to explain technology and its component artifacts as an organized response to an external environment, often described in terms of single variables: settlement patterns (Binford 1980), the interaction with prey distribution in time and space (Bleed 1986, Torrence 1983) and raw material availability (Bamforth 1986), or in more general terms like "functional field" (Schiffer and Skibo 1987). Parallel and to a varying degree underlying this approach is a more traditional interest in explaining artifact variation in terms of technical interactions (ie., flaking mechanics, techniques and materials) and/or their relation to underlying cognitive processes. The process of manufacture is characterized by the production of a series of well defined end products which structure technology. Manufacture involves a constant referral to the mental template, or is conditioned by rule structures which artifact types reflect. The process is seen as a 'throughput' system, modified only by the interaction of knapper and material.
A central component of this 'traditional model' which follows from its incorporation of both reification and means/ends distinctions, is the neutrality of the act of reification which controls the manufacturing process. This implies that the components of artifact variation maintain relations in which the interaction between material, formal, technical and final causes are inherently synthetic. The process of manufacture is seen as one in which various causal relations are reconciled via a process of prior mental synthesis to produce final artifact form (see Crabtree 1967). The belief that a general reduction sequence would represent the most efficient method of achieving desired results (see Bryan 1950:31, Johnson 1978:358) is also predicated on the belief that inputs may be expressed as variables which are capable of synthesis, and that there is again a single defined end goal. This synthesis is a mental operation carried out prior to the manufacturing process. The form of an artifact is, therefore, derivable directly from the inherent cognitive capacity of the knapper to synthesize the causal elements and to form these into a mental template (an 'idea') which is transferred into material form by the process of manufacture, which serves only as a means. The process of making transposes form from the cognitive to the material. The act is neutral, but leaves the process open to the imperfect interaction of knapper and material.

The main strength of this model, in some points considerably simpler than Holmes' initial discussion of it
in the late nineteenth century, lies in its common sense appeal and its applicability to both culture-history and functionalist approaches. The strength of common sense is, however, also its greatest weakness, in that it overlays or diverts our attention from a more fundamental relationship between the objects and practices which make up technology and the maker's understanding of these objects and practices. It is this relationship which lies at the heart of human interaction with technology and its manifestation in the archaeological record.

7.2: The Counter-Tradition: 'Knowing How' as a Prior Form of Knowledge

In the preceding historical account of the way in which the process of manufacture has been modelled in prehistory it was shown that, despite substantial changes in general theoretical perspective, the underlying view of this process has remained largely unchanged. As it is outlined at the end of the section, the traditional model contains three primary assumptions: (1) the form of an artifact reflects prior mental or cognitive processes which supply the formal cause, (2) the clear definition of end products and goals and (3) the neutrality of the process which converts the cognitive into the material. The model retains a distinctive causal structure in which the final, technical and material causes which exist in the external world were subject to a rationalist synthesis
embodied in the mental entity of the formal cause (i.e., the mental template). Errors are not a source of change as in Pitt-Rivers' 'architectural Darwinism' but a cause of realignment of goals and/or failure and discard. The process is neutral in the sense that it has no power to positively structure technology and may be further distinguished from 'architectural Darwinism' (Alexander 1964) by the term 'negative error', as the process is primarily characterized by the negative effects of error. The variability resulting from technological factors has been primarily equated with discussion of technique and mechanics of flaking, neither being sufficient to account for final form or effectively related to the structure of the manufacturing process.

The underlying components of this view of technological process maintains a long history in the western intellectual tradition. The first of these, the priority of mental behaviour in which the production of artifacts involves a process of copying or referring to an idea or template, is first expressed philosophically in Plato's discussion of art and illusion. In Plato's view craftsmen do not produce "ultimately real" objects but reflections of ideal 'Forms' which are apprehended mentally.
we normally say that the maker()has his eye on the appropriate Form... For no one could possibly make the Form itself...
...what he [the craftsman] makes is not the ultimate reality, but something that resembles that reality. And anyone who says that the products of the carpenter or any other craftsman are ultimate realities can hardly be telling the truth...

Plato The Republic X:597

Plato uses an analogy with the physical act of observing an object to describe the way the idea or Form is apprehended. Hence he states that a craftsman has his "...eye on the appropriate Form". Rorty (1979:38-45) has suggested that the concept of the "Eye of the Mind" was a model developed within Greek philosophy to deal particularly with the epistemological problem of what can be known. Historically this was transformed in 'mirror' images by seventeenth century scholarship and taken as a definition of that which separates human from animal. To question the existence of mind as a reflecting glass was to question human uniqueness.

Arendt (1958:141-142) has argued that the quality of permanence of the mental model or image retains an intuitive power which preceded and influenced Plato's discussion of the eternal Forms. Mental images, stripped of their transcendental quality continue to dominate the understanding of the process as Arendt shows:

The actual work of fabrication is performed under the guidance of a model in accordance with which the object is constructed. This model can be an image beheld by the eye of the mind or a blue print in which the image has already found a tentative materialization through work.

Arendt (1958:140)
This process is possible because the act of reification which Arendt describes is itself "easily and naturally" carried out (Arendt 1958:141) (i.e., the neutrality of process). Marx used a similar argument when he suggested in *Capital I* that human labour is distinguished from that of animals in its capacity to create something which "...already existed in the worker's imagination, already existed in an ideal form" (1930[1867]:170) (see also Elster 1985:63, Rosenberg 1981:14).

The popular understanding of Aristotle's 'Four Causes' ('material', 'formal', 'efficient' and 'final') also appears to have played a part in the preconception of form as a template or idea. Kojiro (1965:20), for example, presented Material, Idea, Hand and Purpose as the determinants of form (see also Mason 1895:14-15). These are a direct transformation of the Aristotelian 'causes' which Modjeska (White, Modjeska and Hipuya 1977:368) suggests correspond to the archaeological concepts of material, mental template, technological skill, and function. While these may appear reasonable approximations, the equation of idea with 'formal' cause is questionable in terms of the original model. The 'causes' are not four distinct causes in the conventional sense but four aspects or fashions in which the cause can be discerned. The Aristotelian model does not assert causal priority in the manner of later mechanistic approaches (see Russell 1946:84), and as Lear (1988:33) points out, Aristotle did not see the 'formal' cause of an
artifact lying in the mind of the maker, but as a potentiality in the maker's soul. The form is actualized through the maker making an artifact and it is this making which is the actual as opposed to the potential cause (Physics II.3,195b). The form as a potentiality is the art of making a particular artifact and is the craftsman's capacity to create an object.

With the discarding of Aristotelian physics the four aspects of cause could only be generally retained in their relation to the making of artifacts, where they were converted into factors affecting form. Through the persistence of the mirror metaphor and the later idealist paradigm it is not difficult to simply retain the original structure by equating an idea of a form (template) with the formal aspect of cause.

The second element of the 'traditional model' of artifact production, the distinction of means and ends, is derived from Aristotle's distinction between 'making' and 'doing'. While doing (which may be any piece of human conduct more in accord with nature) could be an end in itself 'making' was directed to external ends only:

For when a man makes a thing it is always to serve some purpose: the process of making it is not an end in itself but only the means to an end and is subordinate to something else.
Aristotle, Nicomachean Ethics VI:2,(1139b)

The main influence of this separation in the traditional concepts of technology (structured by a series of ends)
has been to see the activity of making as meaningless and neutral (Hood 1972:347).

Arendt (1958) suggests that both the idealized model of manufacture and the understanding of technology as something carried out "in order to" (achieve an end) are components of the definition of homo faber, "the toolmaking animal" - a definition which Marx (1930[1867]:341) saw, with some ambivalence, as the central perception of the modern age. This is amplified in Engles' (1954[1896]:177-8) comment that the tendency to explain actions as the result of ideas had focused attention away from the importance of labour in human development (ie., action by which the environment is changes to serve human ends in response to material needs).

The problem with a model of technology as a series of reified products is that it provides no positive mechanism by which technological change can be explained technologically. This is because the change is directed to ends outside the process of manufacture, which has no significant role in the production of artifacts except, as noted above, in the introduction of error and failure. Because the model is fundamentally idealist in orientation its main weakness lies in the relationship between the "formal cause" located in mental events, and the physical events which produce the artifact.

Without becoming ensnared in some component of the mind/body problems, the key to questioning the three assumptions contained in the model lies in an assessment
of the significance and logical priority of mental events in the manufacturing process. Beyond the confident dictum that "the manufacture of lithic artifacts involves thinking" (Hassan 1988:282) there has been no formal examination of the proposition in prehistory.

The template model, as it is used in prehistory, does not appear to be directly related to the copying of the Platonic 'Forms' because the templates are particular varieties of a class of object. For example, the knapper refers to an idea of a Clovis point not the ideal of all points. If the concept of ideal forms is discarded for the moment, and the template is taken as simply a model, as in Arendt's description, it must be conceded that unless we are willing to argue that these templates materialize in the brain of the maker, their relation to actual mental events remains problematic. The concept of a 'mental template' or image of an artifact governing production cannot simply be analogous to a picture or shape in the conventional understanding of the term; the concept appears largely metaphorical. What the metaphor represents in terms of mental events is, however, a matter of psychological and philosophical debate and can not be dealt with in this discussion.

The replacement of the visual metaphor with the linguistic "recipe for action" by Schiffer and Skibo (1987:597) redefines technology as a series of practices, but fails to deal adequately with the problem because they see recipes as being both defined by the archaeologist from observation (or inference) and as something learned
by the practitioner. Although the practitioners of a technology can not be expected to supply complete descriptions of the rules which underlie their actions, nor are these recipes learned via any formal recitation of the rules, the recipes must have an existence separate from practice for the concept to be anything but a source of difficulty. The term "recipe" implies that at some level the rules are formalized and are referred to, prior to or during the process of manufacture. This can only be via some mental process analogous to that of the traditional model, or as a set of rules derived from the structure of thought as in the cognitive model. The approach appears, therefore, to repeat the error of placing the formal aspect of artifact form in the contemplation of a template or the following of formal rules.

The fundamental assumption of the current understanding of artifact manufacture in prehistory can be challenged on two levels. The first of these is that 'templates' can not be prior to the development of a form; they are, as White and Modjeska (White, Modjeska and Hipuya 1977) suggest, dependent on the interaction of the material conditions of a forms' production. While there may be a number of arguments which can support this view (eg., Ingold 1983), it will be examined in this discussion via a debate within design theory over the possibility of producing optimal solutions using the rationalist process of synthesis central to the traditional model of artifact manufacture in prehistory. The discussion has relevance to
prehistory because it also shows that the optimistic reference made to the value of aspects of design theory in the archaeological literature may not be well founded (i.e., Bleed 1986, Horsefall 1987)(see also Steadman [1979] for a wider discussion of the problem).

Although this approach does not deal adequately with the means/ends distinction and the neutrality of process, the argument against optimal solutions leads into a consideration of technology as a response to problems and how these problems would appear in pre-industrial technologies.

The second, and strongest case against the 'traditional' model of manufacture is forwarded in an answer to the above question. The logical priority of what Ryle termed "knowing how" as a form of knowledge echoes the Aristotelian concept of the formal cause actualized in the making or the performing of an action. As the knapper understands an artifact principally within the context of knowing how to make it, or to manipulate it in the context of some wider technological process, the formation of mental templates is an adjunct to this understanding which may be formed and referred to only when the performance of a particular action is restricted.

In his influential Notes on the Synthesis of Form Alexander (1964:27) argues that the object of design is not to achieve a set of given conditions but to "create order" in the ensemble of form and context. The interaction between form and context produces 'misfits'
which are recognised by the user and corrected. "The whole system - of artifact, human agent and environment - is in this situation self-regulating, self-correcting. It displays the property of homeostasis" (Steadman 1979:178). The extent to which this may be achieved is dependent on the degree to which 'misfits' are independent variables. In real systems like Alexander's kettle problem (ie., increasing the thickness of a kettle's walls to improve heat storage reduces heating efficiency) misfits are dependent and highly interactive. This may, depending on the structure of the system, develop to the point where alteration of one variable will produce imbalance in others, with the potential to produce wide system failure. To resolve this problem Alexander (1964:99), drawing extensively on cybernetic analogies, suggested that the problem structure of design is resolvable into a hierarchy of subsystems which behave independently at a high level of resolution.

In this approach, the designer is capable of nominating all the potential 'misfit variables' and determining the type and strength of their interaction. The context of design is closely definable and produces a set of definite performance criteria. The negation of misfits is produced by a series of one by one interactions in which critical performance criteria are satisfied and the synthesis of form and context is achieved (Alexander 1964:99).
The assumption that the structure of a design problem, as the designer perceives it, reflects the real context/form interaction is, in Steadman's (1979:206) view, an inductive process of reasoning which can not be wholly sustained. Of possibly greater critical relevance is Alexander's rationalist assumption that in the process of problem definition the designer creates the problem structure. In Alexander's view, interaction between variables can be said to occur only if the designer "...can find some reason (or conceptual model) which makes sense to him and tells him why they should do so" (Alexander 1964:109). As a consequence the perceived conflict between variables is a product only of the designer's inability to overcome preconceptions about the kinds of solutions possible (Alexander 1964:109).

Alexander's argument for the synthesis of design problems has also been criticised on two practical points by Lawson (1980). Firstly, it is not possible for designers to construct comprehensive models of all the potential misfits and constraints which operate on an particular design problem. Secondly, as technological variables are highly interactive, a design solution can hope only to satisfy some of the problems which become evident via the design process. As many of these conflicts only become apparent as the process of design continues the criteria for success and desired solutions are also subject to continued revision.
This discussion shows that the idea of an artifact can not precede its existence. An idea or mental template is not the artifact but a representation of a possible artifact form. It is not, for example, possible for a knapper to simply perceive a new point form and reproduce it because this perception is not capable of synthesizing the complex reality in which artifacts are made and function. The mental template model does not, therefore, provide a explanation of new forms nor can it provide a complete formula for the production of existing ones. As Schopenhauer (1966[1844],I:57) has pointed out, no matter how finely conceptions are defined they are incapable of approaching the "fine modifications" of intuitive cognition which is primary (see below).

The inherent instability of design solutions derives from the structure of technology itself. The structure is not integrated, but made up of 'subsystems' or 'packages' which are highly interactive, as modification of one element causes imbalance in other components. The effect is well documented in industrial technologies (Kranzberg 1986:549-550) where, for example, Rosenberg (1969) has described the development of lathe technology as a continuous attempt to reconcile the imbalance between power and cutting head strength (see also Alexander 1964:1-2, Gille 1986:17, Lawson 1980:45). Similar points of imbalance occur in pre-industrial technologies, as in the relation between the spear and spearthrower in hunter-gatherer technology (Cundy 1989).
This model of technological interaction excludes the possibility of optimal solutions in technology (Lawson 1980:58). Elster (1983a:139-140) has also discussed the possibility that optimal or maximizer solutions may, in reality, be limited by the increased cost of information required for a decision. Not only may information cost be a factor against optimality but the manner in which information is interpreted is also a component. The conditions under which technological decisions are made correspond closely to Elster's (1983b:14) conditions for optimality breakdown: several equally good sub-optimal alternatives, uncertainty of outcome (even if probabilities may be accurately assigned) and problems without solutions. Elster (1983a, 1983b:14) suggests that 'satisficer' solutions may be more appropriate in such cases.

The rejection of optimal solutions limits the applicability of both the functionalist/adaptive analogy and perfect rationalism incorporated in some expositions of optimal theories of technology in favour of an argument based on a limited rationality:

...technical means have always been directed towards limited ends. Technical solutions of perceived problems have always affected a system larger than that encompassed by the planner or problem solver. Thus, in a very real sense, there is no entirely rational plan, nor can there be any assurances in the long run of a rational result.

Ferguson (1974:19)
As part of limited rationality models the importance of problem definition as a component of the design process has been discussed by a number of writers (Ellul 1972, Jarvie 1972a).

Changes in form, and the emergence of 'types' will be the result of processes which represent responses to problems, and which must be referred to purposes.

Steadman (1979:231)

As part of his discussion of technology Dessauer (1972:319) also argued that the formation of problems was a central component of technological change; the only part in his view, retaining any degree of intellectual freedom.

Following from the acceptance of the 'response to problem' definition as a central component of technological change Steadman (1979:231) has argued that the principle aim of technological history is to "reconstruct the particular problems" to which action or object must correspond as a solution. This argument presents some obvious difficulties of interpretation for prehistory. If societies solve only those technological problems that they recognise and are capable of describing, can prehistory recognise and describe these problems without resorting to a mentalist position? This difficulty is compounded by Jarvie's (1972a:52) hypothesis that the exponential rate of technological progress is explained "...by the increasing clarity with which technological problems are posed". The implication of Jarvie's argument is that pre-industrial technologies are increasingly less likely to change via a rational process
of clearly defined problems and solutions.

The principle reasons for this stem firstly from the traditional knowledge base of pre-industrial technologies which is not readily accessible to explicit rational exposition. For example, Stuart (Lawson 1980:12-14), in one of the few detailed studies of traditional crafts by a craftsman, noted that wheelwrights had no formalized expression of the problems which dishing cart wheels solved. In a very limited sense Steadman (1979:233) is correct when he states that in "many respects" a craftsman "does not know what he is doing". Secondly, in simple hunter-gatherer technologies the individual packages of technology are large relative to the total system. Formal problem presentation and resolution in small prehistoric systems would be restricted by the interactive nature of the large packages (with a small number of components), which would not only make the isolation of small problem areas difficult, but also have the potential to rapidly create instability throughout all connected packages and external systems. This may account for the apparent conservativeness of early technology.

A way around the first problem is to argue that formal problem setting is not the only manner in which problems may be perceived and resolved within pre-industrial technological systems. Following Ryle (1945/6, 1963[1949]) (see also Jarvie 1972b) it may be argued that relating to problems via a highly formalized set of factual statements or maxims is only one form of...
intelligent behaviour, equivalent to 'knowing that'. A form of the limited rationality model of technological change could be predicated on problem definitions based on this form of understanding, eg., knowing that rapid quenching of high temperature steel will encourage the formation of hard martensite crystals which can make the metal brittle, or that lengthening a spearthrower will increase the angular velocity only if the concentration of mass about the thrower's wrist is increased. Ryle (1945/6 1963[1949]) argues that this form of knowledge is generally seen to be accompanied by an internalized dialogue in which a highly formalized process of reasoning is carried out.

People equate rational behaviour with premeditated or reasoned behaviour ie., behaviour in which the agent internally persuades himself by arguments to do what he does. Among the premises of these postulated internal arguments will be the formula expressing the principles, rules, criteria or reasons which govern the resultant action.

Ryle (1945/6:9)

He does not argue against the existence of such processes, only that an internal recitation of them is a special and separate form of behaviour.

Ryle (1945/6:4) suggests that a logically prior form of intelligent behaviour is 'knowing how' to perform a process (including arriving at solutions to a problem). This knowledge is not demonstrated "in the propounding of propositions" (Ryle 1945/6:8) but by action: building a house, making Kimberley points, spearing a kangaroo or
doing research. Effective 'knowing how' behaviour is a disposition to observe 'rules or canons'. These rules are embodied in the ways in which particular tasks are carried out and not necessarily in a highly formalized set of formulae which are recited before or while the task is performed. The disposition to perform a task in a particular way may be learned without any discussion of the rules governing the action (Ryle 1963[1949]:41).

The manufacture of artifacts, as an example of 'knowing how', need not be accompanied by a constant reference to some mental image or set of rules, but may be a form of coherent knowledge in its own right. Following this distinction the way is laid open for the definition of technology via the actions which constitute the processes of artifact production, not its motivations nor its products.

In the 'traditional model' the motive for manufacture is to produce an artifact to serve a purpose. As Ryle (1963[1949]:108-110) points out the ascription of motive is to describe a tendency or disposition to bring something about. Dispositions are not causes but propensities to behave in a specific manner in response to some antecedent action. Motives, which are not actions, are not inconsistent with actions having causes, but are externally imputed characteristics not mental prerequisites. Similarly, the fact that an artifact exhibits care or attention to the details of its form are not to be constructed as qualities of some internal shadow process, but the product of a "frame of mind" in which
various associated difficulties were to be coped with when they arose in manufacture (Ryle 1963[1949]:136-7,141).

The objection (of cognitive archaeology) that this process reflects a deeply embedded set of cognitive rules, not just the apprehension of a mental image or formula raise the problem of an infinite regression of rules governing rules (see Ryle 1963[1949]:31). It can also be observed that if this were the case, some part of the observer must transcend the rules and observe and analyse its own structure. If this were not so, the breaking down of an assemblage into its cognitive components would result in the construction of meta-rules, the relation of these to the actual structure which governed their perception being unknown (and unknowable).

In making the distinction between 'knowing that' and 'knowing how' Ryle was not concerned with the reason for behaviour change in particular, but does comment that the rules inherent in a set of actions will only be examined in a formal way when there is some difficulty in operationalizing them (Ryle 1963[1945]:9). He further distinguished between an intelligent and an unintelligent series of actions (as exemplified in training and drilling). Both exhibit operational rules but the former also exhibits appropriate intervention between the performance of the action and the environment, incorporating a set of judgement operations. Long term technological change could be seen as an extension of this process.
Dewey (1922:177) in an earlier discussion saw ‘know how’ as the action of habits which were constantly being restrained by the interaction with an environment. This interference generates an investigation which sparks further action:

Such action tests the idea initiating it, for if the action settles the original difficulty, the idea has worked in reorganizing conduct in a more effective pattern.

Scheffler (1986:227)

The interaction is one of action and environmental response. Although the construction of the problem or survey of the causes of the restraint may be seen to be carefully carried out, its significance lies in its ability to supply successful plans of action.

The success of the resulting action (which is judged only from its ability to free action), does not necessarily lie in the formalized intellectual process of problem definition, nor the recitation of the rules governing the finding of a successful solution. As Ryle (1963[1949]:31) points out reasoning, itself a form of ‘knowing how’, may be carried out poorly. It may, therefore, be possible to reason incorrectly about the nature of a problem (in terms of the mechanical principles governing an operation) yet produce a plan of action which produces effective results. It is also possible that successful action may result simply from an action without extensive problem definition. It should not be inferred
from this that 'knowing how' is simply a mechanism for generating random variation as in 'architectural Darwinism'. The structure of practical knowledge will probably defy complete definition, yet it is possible to follow Polanyi (1969:138-146) in suggesting that the formation of solutions may rely on understandings which are not accessible to discourse or representation as templates or rules.

These accounts of 'know how' are prefigured in Schopenhauer's distinction between rational knowledge (Wissen) and intuitive knowledge (Erkenntnis). In arguing for the primacy of the latter he states:

...savages and uneducated persons, not very accustomed to thinking, perform many bodily exercises, fight with animals, shoot with bows and arrows and the like, with a certainty and rapidity never reached by the reflective European, just because his deliberation makes him hesitate and hang back. ... Likewise, it is of no use to me to be able to state the abstract degrees and minutes the angle at which I apply my razor... if I do not know how to hold the razor.

Schopenhauer (1966[1844],I:56)

In an audacious move Schopenhauer argued that individuals know their bodily actions as both representation (as objects) and as manifestations of the will which is the immediate mode of apprehension (1966[1844],I:100). Although Magee (1983:124) directly compares Schopenhauer's and Ryle's (1945/6, 1963[1949]) argument for the priority of 'knowing how', a more direct influence on Ryle has been seen as Heidegger's view of human "dealings in the world" as fundamentally carried out
in a transparent coping mode (Drayfus in Magee [1987:259]): "The kind of dealing which is closest to us is...not a bare perceptual cognition but rather that kind of concern which manipulates things and puts them to use; and this has its own kind of 'knowledge'." (Heidegger 1962:95).

While these philosophers are seen as belonging to differing, although not unrelated schools of modern philosophy, their arguments for the priority of a form of knowledge of the world based on a practical interaction with the objects in it is an alternative to the rationalistically defined perceiving subject - perceived object model which underlies the thinking about technology in prehistory.

Although it is a truism that technology may be seen as a series of products and practices designed to achieve certain ends, the recognition of the priority of practical knowledge or 'knowing how' shows that this is not the most fundamental manner in which it should be understood. The implication of this is that while prehistorians are forced by the nature of their dealings with the material to objectify prehistoric technology, either as objects or processes, it can not be assumed that a similar form of objectification (ie., making subject/made object) structured the production of artifacts in their systemic context. This is because objects which constitute prehistoric technology were fundamentally understood in the process of their manufacture and in the wider context...
(but less directly) in their use - not as reified copies of mental templates in accordance with a cultural norm. As Giddens (1984:26) points out: "Even the crudest forms of reified thought leave untouched the fundamental significance of the knowledgeability of human actors".

Following these lines of argument, it is suggested that the 'problem' in pre-industrial technologies is the restriction of individual habits or actions which constitute the production process. Dewey (1922:179) saw this restriction of action as a constant condition but variable in form, causing continual readjustment of actions to the environment. By environment Dewey also included the presence of other habits (or actions) which conflict with the one in operation. The long term stability of production processes, suggested by the archaeological record, must at some level be seen as not the product of fixed normative structures, but of the limits on the dynamic relation between factors which restrict and enable action.

These factors derive from the disjunctive interaction between the structural components of organization which endure through time and the enframing context in which action takes place. As noted above, in relatively simple technologies the degree to which individuals can respond to the 'problem' is limited by the capacity of the organizational structures to absorb the effects of component modification and to allow problem definition. The disjunctions provide the impetus of change, but not its enactment, which is situationally determined. In
Chapter Six, for example, it was argued that the trajectory of change seen in the overlying assemblages derived from the earlier structural disjunctions.

The restriction of the process which constitutes the individuals exhibition of 'knowing how' stems from the behavioural systems which stand outside of the process (external relations) and those that occur within it (internal relations). The use of the terms, external and internal relations, refers to the two analytic classes of restriction which structure the process of manufacture and exist only through the process. The terms should not be confused with the definition of external and internal relations as relations of comparison and connection found in the Social Sciences (see Elster 1985:92-5).

An example of a restrictive external relation is the manner in which the immediate demands which enframed on-site reduction at Ingaladdi may have affected the quality of the material incorporated into the standing reserve. In this case the two tiered structure of material availability on-site (external relation) would have affected the capacity of the standing reserve to sustain reduction in a specific production context. Further restriction was seen in the periods which suggested reduced access to local material, reflecting some conflict with a wider structure of social and or economic practices.
The restriction of action will also produce costs within the internal relations of production. As stated above, production systems can only be assumed to be highly integrated packages without also assuming optimal or synthetic relations. There is, however, no mechanism by which internal imbalances can be overcome and costs negated and synthetic relations achieved. While avoiding the popular interpretation of the four factors affecting artifact production the division can serve as a model of the general areas where imbalances which restrict the manufacturing processes will arise. There is not, a priori, reason to assume, for example, that the techniques used in any technology are necessarily the most appropriate for a particular material, or that the forms produced in the various stages of production (ie., blanks, preforms, etc.) are the most efficient in term of the production of the final form.

Although the imbalances between material, formal and efficient factors (ie., rock type, morphology and technique) has been seen as the cause of error in the process of lithic production since the nineteenth century, the model's implicit assumption is that final form could be equated with final cause, seeing imbalances only as impediments to the achievement of the final form. As noted above, the strength of this equation lies in its 'common sense' appeal, based on the observation that a process is stopped when it reaches its goal. The steps in the process are determined by the end goal and an artifact moves through the stages appropriate to the production of
the final form only if the output from each step satisfies the requirements the next stage.

The principle objection to this model lies in the argument that final causes in production may not lie exclusively with the end product but represent a complex set of sub-goals related to all stages of the process, taking priority at various stages of production. The imbalances within the internal structure of manufacture may, for example, be sufficient to force higher priorities in the production of a specific blank form, or the abandonment of expensive high quality material in favour of one of lower quality, limiting the range of forms and forcing a compromise with the idealized end goals of production. As seen above, Dewey (1922:265) has argued that the idea that ends condition means exclusively is a common error. "Ends in view" act only as instruments of present action, which is the only one under control (see also Scheffler 1986:232). The end goal or product is achieved only via attention to the process itself. As the end in view may be seen as a form of 'knowing that' it can not encapsulate the 'knowing how' required in its production.

One of the most direct measures of restriction within the internal relations is production failure. Although seen as the inability of the knapper to control the process, production failure is the result of disjunction within the structure of manufacture itself. It is therefore more than the chance snapping of a biface; it also includes the failures which result from inappropriate
technologies or techniques being used. Techniques, material and form may all be modified in an attempt to reduce this restricting factor. Final forms may, therefore, represent not the most efficient tools, but forms which derive from the use of a manufacturing processes favoured because of its low level of production failure.

An example of the internal restriction of reduction can be seen in the suggestion that lancet flakes are not ideal blanks for the production of invasively flaked points. This restricts the degree of secondary reduction which can be applied and forces the utilization of sequential unifacial processes. The Ingaladdi bifaces can only, because of this restriction, approach the sophistication of the Kimberley points.

* * *

In relation to the broader understanding of technological structure, the restriction of manufacture resulting from the external and internal relations is a component of the total cost of artifact production, which is composed of direct labour expenditure in time (see McLellan 1973:33-38). This includes the labour needed to secure materials, manufacture, maintain and use tools for other forms of production. The consumption of labour can not be separated from artifact production and represents an inescapable component of the production process. As technological systems become more complex the amount of
labour required also rise (Dennell 1983:102, Ellen 1982:149). These requirements are real and can not be dissolved into other activities. In his use of the concept 'embeddedness' Binford (1979:259,266), for example, argues that as raw material in mobile hunter-gatherer groups is embedded in other subsistence activities the costs of procurement are 'largely' negated:

Regardless of the distance of Nassaurak Mountain from the residential camp, what was the procurement cost of the cores? Essentially nothing, since the party carried home the lithics in lieu of the fish which they did not catch.

Binford (1979:259)

Although the Nunamiut may have seen the stone as some compensation for the lack of fish the procurement expenditure of the stone was equivalent to the expenditure of the trip to the mountain. Even if stone procurement or manufacture is carried out in conjunction with other activities it still requires separate inputs of labour. While an embedded activity can be carried out when two operations share common labour components and are spatially congruent, the real expenditures for each production element are separate.

At a more general level the degree to which the amount of labour required is itself a factor in determining technological structure is problematic. If, as it is argued, the manufacturing process is primarily understood as action (i.e., 'knowing how') the reduction of labour would tend to negate the process which the
expenditure of labour defines. The implication of this is that explanations which argue that human action is aimed at greater efficiency in energy expenditure run counter to the very way in which technology is practically understood. While the separation of the individual from the production process is achieved in industrial technology using machines it is not possible in hunter-gatherer production.

Similarly, arguments which see technology as a series of optimal solutions, with optimality measured in the ratio of time and energy inputs and outputs (see Torrence 1989:2) not only beg the question of how these are to be measured archaeologically, but also carry with them assumptions about the way these concepts were perceived in the past and about the underlying rationality of human behaviour. While it exists in time and transforms energy there is no basis for an understanding of 'knowing how' as enframed by a concept of time which would be directly translatable to that of the industrial societies to which the proponents of these approaches belong.

Torrence's (1983, 1989:4) argument, that hunter-gatherer technology gained its adaptive nature from its role in the "complex juggling" of competing priorities for limited time frames is an example of the assumption that either hunter-gatherers objectified their activities as occurring in time, in the same manner as that of industrial societies, or that selective advantage was confirmed on those that acted as if they had made the same assumption. As Giddens (1984:35) points out, however, the
relation of time to human actions can not be viewed in such a 'simple' manner. He suggests that the practical knowledge of daily life exhibits a recursive quality as daily routines are repeated. In a similar mode Thompson (1974:42) has argued that in pre-industrial societies it was task orientation which directly defined time not the other way around. Thompson goes on to show how the invention of accurate mechanical time pieces allowed the objectification of labour as occurring in a set time frame; a vital conceptual tool for the development of industrial processes (see also Giddens [1981]).

This emphasizes the point touched on above, that in discussing technology and technological change many prehistorians have drawn on what they understand to be essentially 'common sense' concepts of how technology was related to past human activity and knowledge structure. What is not largely accepted in this process is that much of this 'common sense' is a product of the way they represent their own relation to technology; as users of designed products produced by industrial process in a world where all activity is measured along a scale of objectively measured time.

Unlike Childe, who saw technological knowledge as a social phenomenon, it is argued that the 'knowing how' which structured technology in pre-industrial societies works at the level of individual action. This form of intelligent behaviour manifests rules of action which are not necessarily preceded as thoughts, templates or
recipes. The contemplation of ends (to the extent that they occur) serve as instruments of action and do not directly establish the final artifact form. As 'knowing how' is manifest in action it is the process of manufacture (or more specifically the lithic reduction process) not the products which structures lithic technology in particular, and all pre-industrial technology in general. And it is the restriction of process which is the primary impetus of technological change.

It has been shown that attempts to define technology and explain technological change in pre-industrial societies from both culture-historic and functionalist approaches have been limited by the retention of a traditional model which see meaning in technology as a series of products only. Both approaches have generally couched technological change in evolutionary terms, using increased efficiency of products to carry out functions as the principle rationale of change. While the questioning of the main assumptions on which these approaches are based may introduce a degree of uncertainty, arising from its diminishing of the relation of culture and technology, it is argued, that this has the effect of holding the understanding of technology in prehistory open to a more detailed examination of the interaction between the structure of its organization through time and the "logic of the situation" (Popper 1961:149).
In pre-industrial societies, technology may not generally be composed of a highly structured set of behaviour patterns dictated by 'cultural systems' but by multiple individual dispositions to action and responses to the restriction of that action. Archaeological assemblages can not only be seen as monolithic structures, characterized by normative traits, or responses dictated by cultural systems, but also as the sum of the ranges of responses available to individuals who occupied the site from which the assemblage is derived. The key to investigating these responses lies in the understanding of lithic technology as a structure composed of reduction processes organized in time and space.
APPENDIX A

Artifact Numbers

A-1: Underlying Assemblage - Quartzite Artifact Numbers

<table>
<thead>
<tr>
<th>Spit</th>
<th>Flakes</th>
<th>Waste</th>
<th>Redirecting flakes</th>
<th>Cores Ro</th>
<th>R 1/2</th>
<th>Modified flakes pieces</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>12***</td>
<td>73</td>
<td>73</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>13*</td>
<td>454</td>
<td>228</td>
<td>5</td>
<td>2</td>
<td>1</td>
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<td>9</td>
</tr>
<tr>
<td>14*</td>
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<td>4</td>
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</tr>
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<td>1</td>
<td>2</td>
<td>8</td>
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<tr>
<td>23/4</td>
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<td>19</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>7</td>
</tr>
</tbody>
</table>

Totals 6665 3706 63 41 38 66 201 10780 +

Multiply by 1.2(*), 1.5(**) and 2.0(***)) for adjusted time series numbers.

(+) total does not include 1 lateral and 2 bipolar cores.
A-2: Underlying Assemblage - Chert Artifact Numbers

<table>
<thead>
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<th>Spit</th>
<th>Flakes</th>
<th>Waste</th>
<th>Redirecting flakes</th>
<th>Cores</th>
<th>Modified flakes pieces</th>
<th>Total</th>
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<tbody>
<tr>
<td>12***</td>
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<td>30</td>
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</tr>
<tr>
<td>13*</td>
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<td>125</td>
<td>2</td>
<td>1</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>14*</td>
<td>229</td>
<td>119</td>
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<td>3</td>
<td>12</td>
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</tr>
<tr>
<td>15**</td>
<td>505</td>
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<td>2</td>
<td>10</td>
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</tr>
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<td>23/4</td>
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<td>2</td>
<td></td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

Totals 3380  2266  55  16  44  29  245  6035 +

Multiply by 1.2(*), 1.5(**) and 2.0(***), for adjusted time series numbers.

(*) total does not include 5 lateral and 2 bipolar cores.
**A-3: Overlying Assemblage - Quartzite Artifact Numbers**

<table>
<thead>
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<th>Spit</th>
<th>Flakes</th>
<th>Waste</th>
<th>Redirecting flakes</th>
<th>Cores</th>
<th>Bipolar lateral</th>
<th>Retouched flakes pieces</th>
<th>Lancet Flakes</th>
<th>Total</th>
</tr>
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<td>12</td>
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<td>545</td>
</tr>
<tr>
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<td>617</td>
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<td>81</td>
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<td>264</td>
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</table>

**Totals**

<table>
<thead>
<tr>
<th>Flakes</th>
<th>Waste</th>
<th>Redirecting flakes</th>
<th>Cores</th>
<th>Bipolar lateral</th>
<th>Retouched flakes pieces</th>
<th>Lancet Flakes</th>
<th>Total</th>
</tr>
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<td>8707</td>
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</table>

Multiply by 1.2(*) and 1.5(**) for adjusted time series numbers.
### A-4: Overlying Assemblage - Chert Artifact Numbers

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<th>Waste</th>
<th>Redirecting flakes</th>
<th>Cores</th>
<th>Bipolar lateral</th>
<th>Retouched flakes pieces</th>
<th>Lancet Flakes</th>
<th>Total</th>
</tr>
</thead>
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<td>1</td>
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<td>7</td>
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<td>4</td>
</tr>
<tr>
<td>9*</td>
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<td>63</td>
<td>2</td>
<td>12</td>
<td>1</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>10**</td>
<td>87</td>
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<td>5</td>
<td>5</td>
<td>9</td>
<td></td>
<td></td>
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<td>5</td>
<td>9</td>
<td></td>
<td></td>
<td>234</td>
</tr>
</tbody>
</table>

Totals 1746 1163 6 12 2 14 61 148 7 10 6 65 3240

Multiply by 1.2(*) and 1.5(**) for adjusted time series numbers.
APPENDIX B

Statistical Notes

[1] The preference in this thesis is for the use of nonparametric statistics as they do not specify the form of the population from which the samples are drawn (see Siegel 1956:18-34). However, where it has been easier to present evidence in parametric form (as in the measures of central tendency) or where the parametric statistics allows a much more powerful analysis (as in path and threshold analyses) they have been used.

a) Measures of Central Tendency

\[ \bar{X} \] - mean
\[ S_x \] - standard deviation of the sample
\[ C_v \] - coefficient of variance = \( \frac{100S_x}{\bar{X}} \)
\[ R \] - range
\[ n \] - sample number

Where it was important to provide an easily understandable measure of the relative variance between samples the coefficient of variation has been used instead of the more usual standard deviation.
b) Hypothesis Tests

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW-U</td>
<td>Mann-Whitney U test</td>
</tr>
<tr>
<td>KS</td>
<td>Kolmogrov-Smirnov two sample test</td>
</tr>
<tr>
<td>Chi²</td>
<td>Pearsons chi² for goodness of fit and k sample proportional differences.</td>
</tr>
<tr>
<td>Fisher’s exact probability p</td>
<td></td>
</tr>
<tr>
<td>zI</td>
<td>z test for instances</td>
</tr>
</tbody>
</table>

The MW-U, KS and Chi² goodness of fit are discussed in greater detail in notes [2] and [4]. Because of its computational complexity Fisher’s exact probability was reserved for cases where the expected cell frequencies fell below those required for the chi² test. Following Wright (1974) Cramer’s index of association strength has been used as a more usable indication of any possible archaeological significance than the levels provided by the chi² test. The zI test is used where numbers in particular spits were compared with those in the remaining and where the proportions and numbers exceeded those suitable for a Binomial test (see Langley 1970:245).

c) Correlation

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>Pearson’s r correlation coefficient</td>
</tr>
<tr>
<td>tau</td>
<td>Kendall’s rank correlation coefficient</td>
</tr>
<tr>
<td>tauₚ</td>
<td>Kendall’s partial rank correlation coefficient</td>
</tr>
</tbody>
</table>

As noted above the parametric Pearson’s r correlation has been favoured in the path and inertia threshold analyses because it is directly related to the regressions used. The assumption of bivariate normality was considered acceptable for these analyses. As cross checks of the threshold results using nonparametric correlation
coefficients showed identical results to those of the Pearson’s $r$ it was decided to present only the $r$ test results for the analyses.

The Kendall tau statistic was used in the time series correlations for two reasons. Unlike the more usual Pearson’s $r$ (Croxton, Cowden and Klein 1968:480-496) it could not be assumed that the time units, in this case spits, represented an interval scale measurement. Although the periods which the spits represented could not be securely fixed they could be ranked in time and it was more accurate to view them as an ordinal scale measurement (Seigel 1959:23-25) requiring either a Spearman $r_s$ or Kendall tau correlation. The Kendall statistic was preferred because it allowed a partial rank correlation which controlled for the effect of time. There is, however, no test of significance available for the partial tau so the usual bivariate tau was used to provide some indication of statistical significance. This was acceptable because of the weak trend effect in most of the time series correlations.

d) Test Computation

The level of significance is set at .01 or 99% with values between .05 and .01 seen as of marginal significance. Because hypothesis tests play an important role in structuring the salient features of the assemblages the .01 level was chosen because it was important to avoid the problem of accepting differences
and defining features which has dubious levels of archaeological reality. Even so, the analysis shows that the tests do not prove or disprove archaeological significance in any particular case. This can only be revealed within the wider framework of the approach applied to the material.

The majority of the statistical tests were carried out by hand on a Texas TI-60 calculator. The manipulation of large samples was carried out on a NEC APCIII computer using Ecosoft MICROSTAT.


The Mann-Whitney U test is used as a powerful alternative to the parametric t test in small samples (Blalock 1981:265,275; Siegel 1956:126). Unlike the t test the MW-U’s null hypothesis is simply that the two samples were obtained from identical populations. A significant difference does not necessarily reflect differing means as in the t test (Pollard 1977:163-164).

In larger samples the Kolmogrov-Smirnov two sample test was favoured because of its ease of computation by MICROSTAT although on interval data it is wasteful of information. The Kolmogrov-Smirnov test is also as versatile in its one and two tailed forms. The utility of the two tailed test is restricted by its requirement that small samples be of equal size. There is, however, some disagreement about the minimum size to which this must apply. Blalock (1981:267) follows Siegel (1956:131) in
recommending 40 where as Roscoe (1975:277) suggests 20 and Conover (1971:309-314) supplies $D_{\max}$ for smaller unequal samples. Where possible 40 has been taken as the limit although some test were carried out on samples in the 40-20 range. Where one or both samples fell below 20 a Mann-Whitney U test has been used. The one-tailed Kolmogrov-Smirnov tests have been applied in cases where there is some theoretical reason for assuming some direction in the sample differences. The chi$^2$ approximation in these cases can be used on small samples without the restriction of equal numbers but is in these cases conservative in the rejection of $H_0$ (Siegel 1956:135). This is in general accord with the approach to statistics used in the thesis which required high levels of significance for rejecting the null hypothesis.

[3] Regression Coefficient Comparison

An analysis of covariance was used to test for differing variable relationships between the three quartzite flake samples (underlying, SS/1 and Ingaladdi lancets) used in the analysis. The procedure, following that described by Blalock (1981:519-525), compares the amount of variation in the Y variable left unexplained by assuming equal slopes and that remaining using the individual least-squares equations for each sample. The difference between the amounts of variation left unexplained by the common slope and the individual least-squares equations is the amount attributed to interaction.
An F test is used to determine the significance of this interaction. These results were checked using a simpler t ratio procedure outline by Edwards, A. (1967:253-254), in which the difference between the regression coefficients is divided by the standard error of their difference.

[4] Chi² Goodness of Fit Tests

As some of the chi² goodness of fit tests used extensively in the sequence analysis will appear to violate the critical minimum conditions for the test it is necessary to briefly review some of the more recent research into the problem. The chi² test, developed in 1900 by Pearson, is a relatively new statistical test. The factors limiting its practical use continue to be discussed by statisticians. Conventionally, textbooks have recommended that the minimum expected frequencies in each cell could not fall below 5 or less frequently 10 without affecting the validity of the test. Cochran (1952:328) has argued that these figures were arbitrarily chosen and that expected frequencies could fall to at least 2 where all expectations were small. This has been confirmed by Roscoe and Byars (1971) who found that with uniform expected frequencies the values could be as low as 1 without affecting the test significantly. Roscoe (1975:252) has also recommended that with moderate departures the average expected frequency can be as low as 1 at .05 but >2 at .01 level of significance. With more extreme departures the minimum expected values should be doubled.
Notes on Ingaladdi - Environment and Ethnography

[1]: Introduction to the Region

[1a]: Climate

Climatically the region is monsoonal with pronounced 'wet' and 'dry' seasons. On average 80% of the rainfall, which ranges from 62 - 75mm, falls between the months of November to February. The relative humidity remains high throughout the year reaching a peak of >90% during the 'wet season', while the maximum temperatures also remain constantly high ranging between 32 - 43°C (Slatyer 1970). The distribution of rainfall and the high temperatures place considerable water stress on both plant and animal communities especially in the late 'dry' season when soil moisture is insufficient for plant growth and all but the largest water sources have dried up.

The Aborigines distinguish a more complex division of five seasons: 'cold weather' (mid May - July), 'little bit warm, hot time' (August - mid October), 'rain coming' (mid October - December), 'rain time' (January - mid March) and 'knock-im-down time' (mid March - mid May) (Chase and
Meehan 1982:48, Carr 1981:11). Each season is not only distinguished by its particular weather pattern but also by the flowering of plants, the movement of animals contributing to new food resources and the land management activities which should be carried out at that particular time.

[1b]: Geology

With the minimal soil development in many parts of the region the underlying geology plays an important part in landscape definition. Geologically the area is dominated by the basalt of the Antrim Plateau Volcanics which form a structural bench some 10-60kms across running north-south along the outer edge of the Victoria/Daly River basins. The formation incorporates a number of cross-bedded sandstone outcrops running in a NW-SE direction in two major belts between Innesvale (40kms ESE of Willeroo) and Delamere stations to the south and Ingaladdi and Willeroo Homestead to the north.

These sandstone belts, remnants of an extensive Lower Cambrian aeolian dune system (Morgan et.al. 1970, Skwarko 1967, Sweet 1972:10), now form a series of low rounded rocky hills which have eroded in parts to form residuals with shelters and overhangs. The belts channel the drainage systems and are associated with a series of water holes and springs running from Price Creek (see figure
3.1) in the north to Bluebush near Old Delamere in the south (site [3] figure 2.1).

Much of the sandstone has been strongly indurated by successive basalt flows, forming bands of a distinctive brown quartzite in the contact zones. Weathering of this quartzite has produced surfaces of quartzite pebbles and small weathered outcrops of poor to good quality lithic material throughout the region (see section 4.3a).

Further sources of stone for artifact production occur in the small quantities of cherts which formed in the vesicles of basalt flows. These cherts are predominantly red with some inclusions of banded agate. Their highly indurated splintery fracture and comparative rarity made them a poor alternative to the more readily available quartzite. The surveyed area is, however, surrounded by a number of substantial chert sources in the extensive outcrops of Monteginni Limestone to the south and Tindal Limestone to the north. Cherts are also found on lag surfaces along the water courses of the Sturt Plateau to the east (Hughes 1983, Stewart 1970:99) (see Section 4.3a).
The land systems of the region are bounded by the rugged and deeply cut plateau of the inner basin of the Victoria River to the west and featureless laterite plains of the higher Sturt Plateau to the east (Stewart et al. 1970). The systems of the surveyed area form a mosaic dominated by three major geomorphological units. In the northern half, extensive 'Blue grass' occurs along the erosional plains of Aroona and Price Creeks (see figure 3.1). These plains are mainly gently sloping tall grasslands *(Dichanthium spp, Sorghum spp, Eulalia fulva, Ophiuros exaltatus)* (Stewart et al. 1970:56) with small stands of open woodland on stony rises and some of the steeper slopes. 'Blue grass' plains occurring in the southern half of the area are associated with volcanic benches which form the upper reaches of Delamere and Battle Creeks. In both northern and southern halves these benches are more typically associated with 'Tippera grass' plains (Stewart et al. 1970) which border the 'Blue grass' plains in both sectors, with the largest expanse further down Delamere Creek. The gently sloping 'Tippera grass' plains comprise tall grasses adapted to lighter soils *(Themeda australis, Sehima nervosum, Chrysopogon falax)* and a sparse upper storey of low woodland *(E. terminalis, E. argillacea, E. pruinosa)*.

Both systems are interspersed by volcanic mesas and buttes with steeply sloping sides up to 170m high and rounded hills. The slopes maintain open low woodlands *(E. tectifica, E. pruinosa* dominant) with tall grasses.
(Sorghum australienses, Triodia stenostachya, Sehima nervosum, Themeda australis). The lower slopes and flats contain 'Blue grass' stands.

Creeks in all systems are bordered by frontage woodlands of moderate to dense medium height trees (10-20m) (E. papuana, E. tectifica) and tall grasses. More substantial water courses like Ingaladdi Waterhole also support fringing forests of dense Eucalyptus (E. camaldulensis), Melaleuca (Melaluca sp) and stands of Pandanus (Pandanus sp).

This description is typical of large areas of the north-western part of Australia which can be generally termed savannah woodland. This is broadly characterized by a sparcce covering of medium sized Eucalyptus over tussock grasses. The biological productivity of the landsystems is low and the severe temperature and moisture regime place high stress on both plant and animal life.

[2]: The Ethnographic Record

In terms of the aims of this thesis the ethnographic record for the study region is limited and equivocal. The rapid and violent disruption of the local Aboriginal groups at the end of the nineteenth century, combined with the difficulties of carrying out fieldwork in the region, have prevented detailed recording of the pre-contact
economic structure. What exists must be gleaned from the generalized accounts of explorers, travellers and anthropologists/archaeologists, made in some cases several generations removed from pre-contact society.

Until the movement of pastoralists into the Victoria River District in the 1880's the direct impact of Europeans on the region had been confined to a series of exploratory expeditions starting with Wickham's (Christie 1944, Stokes 1846) exploration of the lower Victoria River in 1839. A.C. Gregory's expedition, following in 1855-6, explored the headwaters of the river and penetrated the desert regions to the south. Although Gregory's (1884) journal contain few references to Aborigines the expedition's artist Thomas Baines made records of rock art and Gregory's observations on stone working (Baines 1857/8, 1865/7 see also Braddon 1986) in the area to the west of the Victoria River. A. Forrest also passed through the area in 1879 on his trek from Beagle Bay in Western Australia to Port Darwin, but again made no significant observation of local Aboriginal groups.

The early history of the pastoral industry in the region also provided few details of local Aborigines, observations coming mainly from the less than sympathetic Willshire (1896) and a series of traveller's reminiscences (Conigrave 1933, Dahl 1926, Mathews 1901, Searcy 1909). The Aborigines of the Daly and Victoria Rivers regions maintained a reputation for fierceness which resulted, according to one of Arndt's informants in the massacre of the Bilinarra 'tribe' (one of the study regions two
language owning groups) in the 1890's (Arndt 1965:245).

Despite this unrest Spencer (1914, 1928), with the co-operation of the manager of Willeroo station, was able to spend two weeks with a group of Wardaman and Mudburra people on the Flora River in 1912 (see also Vanderwal 1982:132-134). Although this proved less than adequate time Spencer was able to include some basic details of mythology, kinship, totemic structure and food preparation. Basedow also spent some time in the region in 1922 (Kaus 1986:7) making brief references to Wardaman customs and material culture in his *The Australian Aboriginal* (Basedow 1925).

Beyond these beginnings subsequent detailed anthropological work in the region was not carried out until the 1980's. The fact that the region is remote and that no mission stations were established forced all travellers to rely on the good will of station managers which could not, and can not to this day be relied upon (Arndt 1965:243).

Several isolated episodes of work were, however, commenced in the intervening years. In 1930 D.S. Davidson (1935, 1936) carried out archaeological and ethnological studies on Delamere station using the Wardaman people who had been moved there from their traditional country to the north as his main informants. He recorded some of the mythology associated with rain making and published the first account of the now well known Lightning Brothers art site. His archaeological work, which remains of central
importance for the region, has been discussed in more
detail in Chapter Two.

Following Davidson, W.E. Harney wrote a number of
popular accounts of Wardaman myths (Harney 1944, 1957,
Harney and Elkin 1949). Aspects of regional economy and
mythology were also covered in a series of papers by Arndt
(1961, 1962, 1965, nd) who provided the most detailed
accounts of Wardaman/Billinara beliefs generally
available. Although the region contains the richest body
of rock art beyond western Arnhem Land studies have been
confined to discussions of individual galleries (Chaloupka
1978, Lewis and McCausland 1987, Mountford and Brandl
1968) with the results of wider ranging surveys yet to be
reported. Regional ethnography has also in recent years
been supplemented by a series of neighbouring land claim
reports (Chase and Meehan 1982, Merlan and Rumsey 1982).
By their specific nature these reports give details of
current land ownership, mythological associations, some
limited information on economic structure but little on
traditional technology.

Although Baines (1865/7) and Davidson (1935:171) made
reference to stone tool manufacture, there is no
information on the manner in which production was
organized and direct observation of stone artifact use is
probably confined to Baines’ illustration of a lancet
flake mounted as a spear head at Timber Creek to the west.
The compilation by Sanders (1975) of the observations
available for both the Daly and Victoria River regions
does, however, give some picture of the tool types present and their functions.

From the fourteen observations of stone artifacts the types present include: axes (Mathews 1901, Baines 1857/8:6), knives (Mathews 1901, Spencer 1914:353), spearheads - usually unretouched but including the exotic pressure flaked Kimberley points (Dahl 1926:14, Davidson 1935, Tindale 1985), hafted 'adzes' (Davidson 1935, Mathews 1901) and unhafted flakes (Dahl 1926:15, Davidson 1935, Mathews 1901). Sanders (1975:8) concludes that stone tools were used to work organic material, repairing and producing equipment including spears, spearthrowers, fighting sticks, boomerangs, digging sticks, wooden dishes, bags and baskets and water bags (Sanders 1975: 5-6). From this list there is no evidence to indicate that the material culture of the Wardaman/Bilinara, to the degree to which it is known, differed significantly from that of other Victoria and Daly River groups.

The ethnography also provides little information on the factors which affected access to resources and controlled residential location. In semiarid monsoonal climates water availability has been seen as the critical constraint on movement in the late dry season and the 'wet'. Spencer presented a general model of inland seasonality dependent on this and food availability:
In the inland, drier parts they gather together on larger and more permanent water holes where fish and shell fish, birds and vegetable food can be secured longer than elsewhere. The moment the rains fall off they scatter to take advantage of the supplies that do not exist during the dry season. (1914:32)

Davidson outlined a similar regime for the region: "During the wet season, where possible, the open sites are abandoned for the caves situated just under the edge of the high table lands and table hills" (1935:149-150). These could not be occupied during the dry season because water supply was limited. Davidson's (1935) model is, however, more complex in its consideration of food supply, water and shelter, such that, where shelter was available near good water the area may have been occupied throughout the year - food supply being the limiting factor.

Shelter is not only an important variable in the wet season. In periods of high temperature and humidity, especially at the end of the "dry", mammalian physiology is at its limits to cool the body without the provision of shade during the hottest part of the day. Hounam (Lee 1969) calculates that temperature and humidity are sufficient on more than 225 days a year in the region to produce significant heat stress in acclimatized individuals with more than light activity. Under these conditions journeys of more than a few kilometres without water and shade would be difficult (see McCarthy and McArthur 1960:193).
In terms of these factors the accessibility of the region grades from west to east. The Sturt Plateau which borders the eastern margins of the area has little to no surface water during the dry and is considered desert by Aboriginal groups to the west (Chase and Meehan 1982:11). The grassplains and hilly country which makes up the major land systems to the west contain well established creek beds with a series of permanent and semi-permanent waterholes with good shade provided by fringing forest and the residuals of the sandstone belts. Further to the west, the creeks cut deep gorges in to the plateau of the inner Victoria basin, forming strings of waterholes leading to the Victoria River.

In Tindale's (1974: 222,237) reconstruction, the pre-contact territories of both the Bilinara and Wardaman language owning groups run back from the Victoria River on to the Sturt Plateau in the east and the Flora River to the north. The dry eastern section of the region would only be accessible during the wet season and early dry with the permanent water in the creek lines of the western section providing fall back refuges in the late dry. These would, however, only be general trends. As the Sturt Plateau shows little evidence on its western margins of extensive occupation, the main residential focus would have probably remained the lower range country of the Victoria and Daly basins. Occupation of Yiwalalay (the rain dreaming centre, approximately 5kms north of Old Delamere - number [3], figure 2.1) in both the dry and wet seasons (Chaloupka 1978:81) supports this interpretation.
The proportion and seasonality of food resources is less well documented. Baines (1865/7:260), probably the only observer to record aspects of pre-contact diet, saw the remains of fresh water mussels, turtle, crocodile, and fish in camp fires along the Victoria River in the wet season. He also observed excavated ant hills, fish traps, notched trees and bird hides (Baines 1857/8:6-7, see also Mathews 1901 for details of traps and hides). Spencer (1914, 1928) recorded the preparation of flying fox, wild oranges (Capparis sp.) and yam on the Flora River during the late dry season. While the location fits the seasonal model, the degree to which Spencer's observations represent traditional economy is uncertain, because his Wardaman and Mudburra informants had been brought to his camp from Willeroo station (approximately 50kms to the south).

Recently compiled food lists from the region (Chase and Meehan 1982, Merlan and Rumsey 1982) show the exploitation of a wide range of riverine and terrestrial resources including: kangaroo, goanna, flying fox, various fish and tortoise species, mussels, crustacea, various bird species, goose eggs, yams, fruits including Securinega melanthesoides (white currant), Buchanania obovata (black plum), Syzygium suborbiculare (red apple), wild rice and pandanus. Although this list appears adequate Arndt (1961) has suggested that the region is short on farinaceous foods and that the pre-contact diet also contained a high proportion of seeds from the indigenous sorghums (S. intrans and S. plumosum) which
grow in pure stands in both the Blue and Tippera grass plains of both the Katherine and study regions. The seeds were gathered from the ground, separated from the chaff, pounded into a meal, mixed with water and cooked. This labour intensive process was quickly dropped, Arndt (1961:110) suggests, in favour of the pastoralist’s wheat flour when it became available. Its absence from contemporary food lists suggests that it may have performed a role as a fall-back staple similar to the importance of Panicum grasses in the economies to the immediate south (Tindale 1974:98ff).
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