Functional and Technological Explanations for the Variation Among Early New Zealand Adzes

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ABSTRACT

The influence of function on adze morphology has been little studied. A replication experiment in the manufacture of a small outrigger canoe was undertaken and the results compared with the analysis of 11,886 adzes from New Zealand museum collections and excavation assemblages. A functional typology was developed and compared with existing typologies such as that of Duff (1950). Six functional types were found to correspond generally to Duff's six types, but Duff's varieties were primarily influenced by different raw materials and manufacturing techniques. Within functional parameters, raw material quality and the technological solutions to working them explain much of the variability exhibited by adzes in New Zealand. The results of this research have implications for Polynesian adze studies and suggest directions for future research.

Keywords: ADZE FUNCTION, REPLICATION EXPERIMENTATION, ADZE TYPOLOGY, FUNCTIONAL TYPOLOGY, TECHNOLOGICAL SOLUTIONS, STONE QUALITY.

INTRODUCTION

The study of adzes has long been a focus of archaeological research in Polynesia but their potential value for providing information on human behaviour, while recognised, has not been realised. Furthermore, the preoccupation with adzes as 'type fossils' and 'markers of culture historic patterns' (Isaac 1977) continues as archaeologists persist in the use of formal adze typologies (e.g., Duff 1977) that were designed to address a limited range of questions.

Archaeologists are aware of the inadequacies of current typologies employed to study adzes and this has resulted in new approaches (Cleghorn 1984). The similarities shared by adze types throughout Polynesia have identified close culture historical relationships (Duff 1977; Green 1971; Skinner 1974). A clear chronological sequence of development and change among and within different island groups, however, particularly in East Polynesia, remains elusive.

Formal typologies provided a description of the standardised morphological adze forms present in Polynesia, where they were present or absent, and in what frequency, but did not adequately explain these observed patterns. Previous statistical analyses (Green and Dessaint 1978; Green and Purcell 1961; Groube and Chappell 1973; Law 1994; Park

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1972), while establishing certain significant dimensional correlations, ultimately failed to explain their significance. In recent years, as a consequence of these failures, it has become apparent that explanation may need to be sought in other areas relevant to the people who originally produced these artefacts, namely technology and function. While certain progress has been made concerning the manufacture and production of adzes (Cleghorn 1982; Jones 1984; Leach and Leach 1980; Leach and Witter 1987, 1990; Turner 1992; Turner and Bonica 1994), the results of technological studies (for example, the influence of raw material quality on final adze form) have yet to be fully incorporated into the analysis of finished adzes. Apart from Best's small but significant study on adze function (1975), the function and use of adzes have received scant attention from archaeologists. Because of a primary concern with the adze as an 'archaeological tool' for defining cultural relationships through time and space, the implications of the adze as an 'actual tool' have been almost completely neglected.

In New Zealand, adze studies have historically been related to two main questions. One of these is explaining the variability of the early period (*c*. A.D. 1200–1500) adze kit. This was characterised by a notable size variation from very large to very small, a wide range of cross-section shapes, and the presence of both tanged and tangless forms. From this range, Skinner (1943) identified ten different types, each with a number of varieties. Duff (1950) modified this typology to involve six basic types, each with at least four varieties. This latter typology is currently still in use. The other question relates to understanding changes over time for, some few hundred years after arrival from tropical East Polynesia, one type of adze had emerged as the dominant form, a tangless quadrangular-sectioned adze that Duff defined as '2B'. But it is difficult to explain change until conditions before change are established.

Possibly more importantly for archaeologists, artefact studies have the potential to articulate aspects of the relationship groups of people have with their environments and with each other (Torrence 1994). One way of achieving this is by understanding what particular artefacts meant to people and the behavioural strategies they employed to make and use the items they needed to aid and enhance survival and well being. New methodologies and approaches are needed to access this type of information, for example, the interaction of raw material, manufacture and function.

This paper focuses on providing explanations for the well documented (Duff 1950; Golson 1959) variation observed among early period adzes.

A combination of replication experiments and the examination of 11,886 archaeological adzes from museum collections, private collections and excavated assemblages was undertaken to examine, in particular, the influence of function and technology.

METHODOLOGY

REPLICATION EXPERIMENTATION

A programme of research has explored the influence of raw material and manufacturing techniques on adze morphology (Turner 1992; Turner and Bonica 1994). A major source of information during this research was a programme of replication experiments with stone tool expert Dante Bonica. Bonica has had 40 years' experience in stone adze manufacture and use. A long-standing familiarity with Maori stone tools was gained through work experience at various museums in both the South and North Island and on archaeological excavations. He has also long been concerned with questions regarding pre-European Maori adze design. In 1990, I began a five year programme of formal replication experimentation in the manufacture and use of stone adzes with Bonica. This included over 200 experiments in making adzes (documented in Turner 1992) and 49 adze and preform reworking experiments (documented in Turner 1992, Turner 2000: 243–244, Turner and Bonica 1994). The data from these experiments provided information on the relative qualities of the major raw materials favoured for adzes during the early period, the benefits and costs involved in making adzes, and how these influenced production and distribution strategies. A similar programme of replication experiments was undertaken to investigate the influence of function on early adze design. After some preliminary experimentation (for example Turner 1992: 11–13), three months were spent documenting Bonica making a small outrigger canoe from a felled kauri log (Turner 2000: 82–120). The experiment was aimed at addressing major questions, including what tasks these adzes were designed for, what morphological features were important in the functioning of each adze, their relative efficiency and durability, and whether functional requirements could adequately explain much of the variation seen in archaeological specimens. Another question concerned whether existing adze typologies (Skinner 1943; Duff 1950) used to analyse adzes in New Zealand were adequate for describing 'functional types' and whether the main attributes defining these typologies — primarily the shape of the cross-section and the presence or absence of a tang — had any functional validity.

In considering functional experimentation with stone adzes it was seen as necessary to choose an actual item for manufacture so that adze use, and the use of certain types of adzes, would arise from task requirements, not from preconceived archaeological assumptions about how different types of adzes were used. The construction of a small outrigger canoe was considered suitable in that it would probably require the greatest range of adzes involving the greatest variety of wood-working actions, as well as being a very important artefact characteristic of the early period in New Zealand for which archaeological examples exist (Adkin 1962; Barrow and Keyes 1966). More adzes were made and finished than were probably required in order to prepare for all possible eventualities (such as breakage), and to represent and test a range of raw materials known to have been important for the making of adzes in the early period. Sixteen of the preforms made during manufacturing experiments were completed. Most were made from Tahanga basalt, reflecting the dominant material used during manufacturing experiments (N = 10: three Type 1, one Type 2, two Type 4, two Type 3 and two Type 5). Four were made of Nelson/Marlborough argillite (two Type 2 and two Type 4, from both D'Urville Island and mainland sources). Another Type 4 adze was made from Otago basalt and one Type 2 was made of Motutapu greywacke. Thus the task was able to dictate the type of adze used, in order to identify adzes most suited to the task rather than those that had to be used to 'make do'.

During the outrigger experiment, Bonica hafted his adzes to one of three similar one-piece flat-soled hafts weighing 825 g, 640 g and 495 g respectively. As a general rule, the largest adzes were used with the largest haft. These were a Tahanga basalt Type 1 (313 mm long, 3025 g in weight), a Tahanga basalt Type 4 (315 mm, 2655 g), a Nelson/Marlborough argillite Type 2 (315 mm, 2130 g), and a Tahanga basalt Type 5 (210 mm, 940 g) (note that these weights do not include the haft) The rest of the adzes (between 270 and 156 mm long and between 1640 and 435 g in weight) were generally used either with the 640 g haft (N = 8) or the 495 g one (N = 4). There was some interchangeability, particularly between the two lighter hafts. The choice of using one or the other depended on the nature of the task — for example, the degree of force required. Because of the paucity of adze hafts recovered from archaeological contexts — especially for the early period — it is difficult to comment on the types and range of hafts used in the past. What can be said from experimental results is that three hafts were more than adequate for the sixteen adzes of various size and shape that were used, and for the range of tasks they performed. This suggests that much of the variability seen in early period adzes was exhibited by the stone portion. This situation may have changed over time, however, with some attributes being transferred from the stone piece to the wooden haft in the late period. This is discussed below.

THE ARCHAEOLOGICAL ADZE SAMPLE

An analysis was undertaken of 11,886 archaeological adzes from 34 museum collections and 14 private collections, including both surface and excavated assemblages in the North Island (26 museums) and South Island (8 museums) (see Turner 2000: 75–78, 464–466 Appendix B for more details of these). In relation to the functional experiment, this was a process of cross-tabulation between experimental and archaeological data. The largest and most accessible collection of adzes, in the Auckland Museum (N=3861), was analysed twice. The first study was undertaken with Dante Bonica before the functional experiment, partly to generate questions to be addressed by the experiment, to observe the range of variation in attributes and to identify those that might potentially be significant from a functional perspective. The second processing of the Auckland Museum collection and the analysis of the remainder of the sample took place after the manufacture of the outrigger, after some preliminary statistical analysis of the Auckland Museum sample and after a draft typology based on these two sets of results had been formulated.

Only early period adzes were included in the sample and a major focus was on North Island collections (N = 9711 adzes), in order to provide a representative sample for the study of distribution and possible trade and exchange patterns as well as the degree to which recycling was undertaken. A smaller sample of South Island adzes (N = 2175) was included because typological studies on New Zealand adzes (Duff 1950; Skinner 1974) have developed almost exclusively with reference to South Island collections and have been heavily influenced by them. As an important part of this study was to examine whether these typologies had functional relevance, it was necessary to include these collections in the analysis. Only adzes in original or near original condition ('primary' adzes, see below) were selected for the South Island.

The late period '2B' adzes made from coarse-grained rocks and adzes of pounamu (greenstone) were excluded. In the North Island, these adzes have not been recovered from any dated excavation of a pre-A.D. 1500 site. The definition of an 'early adze' was largely based on raw material and the nature of the technology. Flaking, the adze manufacturing technique imported from tropical Polynesia by the first settlers, was the main method of shaping adzes during the early period. But this technology placed major constraints on raw material selection. Raw materials had to be fine-grained and flakeable as well as tough enough to withstand use with considerable force and hard enough to create a durable cutting edge. Only a few raw materials fulfilled these criteria and many settlements in New Zealand during the early period were using adzes that originated from only a few locations or quarries, most notably the Nelson/Marlborough metasomatised argillite sources and, in the North Island, the Tahanga basalt quarry on the east coast of the Coromandel. For example, of a sample of 6414 finished adzes from the North Island, 76.3 percent are either Tahanga basalt (36.4%) or Nelson/Marlborough argillite (39.9%), with a further 13.3 percent made from the Tamaki source — Motutapu greywacke — making a total of 89.6 percent. The type of raw material, in particular, is a good indicator that the adzes were, at the very least, made and used during the early period, even though discard into the archaeological record may have been later for some (owing to the reworking strategy, see below).

There is also good chronological evidence that the quarries and sources from which the adzes derived had ceased production around A.D. 1500 (Leach 1990). Furthermore, as demonstrated by Turner and Bonica (1994), the early adze technology left a tell tale trail of debitage in the form of flakes from finishing and reworking broken adzes and preforms, recycled used tools made from these, and in the form of reject broken adze and preform pieces — debitage that is rarely recorded from North Island sites dated after A.D. 1500. This was largely due to the nature of the technology of the late period, a technology based on hammer-dressing and grinding that left no such debitage.

Finally, there is little dispute in the literature that the early adze forms are distinctive and that adzes of the later period are different in almost every way, including the technology employed to shape them, the raw materials used and the forms produced, particularly in the North Island (Golson 1959: 38–39, 48, 50; Duff 1950:140–197; Davidson 1984: 93– 95). Excavated and dated assemblages are further testament to the consistently distinctive nature of early period adzes (for example, see Duff 1950 for the range of adzes found at the moa-hunting site of Wairau Bar and Furey 2002 for the types of adzes found at the contemporary settlement of Mt Camel in the Far North). But while describing the nature of early period adze kits is relatively straightforward, explaining this distinctiveness and why this changed so dramatically has been more complex and difficult (for example, see Best 1975, 1977). The data collection for 11,886 adzes made of fine-grained hard tough materials and exhibiting some degree of flaking was designed to identify some of the possible reasons for change and if and how function may have been implicated.

Up to 42 pieces of data were recorded for each adze. Additionally, the outlines of 70 percent of all the adzes were drawn (examples can be seen in Figures 1 to 7). Nine pieces of information related to provenance, including where the adzes were found and under what conditions (excavation, surface collection), the environmental and cultural contexts, and their present location. One identified the raw material the adze was made of. Seven quantitative measurements were taken including length, maximum and minimum width and thickness, blade width and blade edge-angle. Five variables involved manufacturing details and related to the degree and nature of visible flaking, hammer-dressing and grinding. Six recorded details of the butt and poll, including the degree and type of tang and the treatment of the poll. Six provided information on the state and nature of the blade and bevel. Three recorded details on profile and shape, including the nature of the cross-section. The portion of the adze, for example, 'complete' or 'butt half', and the estimated percentage of the adze represented were also recorded. Another category concerned special features such as modern damage, fire damage or decorative features like notching. Two special categories were the functional type (outlined below) and the state the adze was in when it was discarded into the archaeological record.

One significant outcome of the initial analysis of the Auckland Museum adze collection was the observation that very few were in original or primary condition. Rarely were adzes discarded after damage or breakage. Instead, they were extensively repaired and reworked. This observation of intensive curation reflects a major problem with adze typologies to date. Of 6414 finished adzes analysed from the North Island, only 8.5 percent were in an original or near original primary state. The remainder had varying degrees of use, repair and modification, and 68 percent had seen breakage and subsequent reworking (or attempts at reworking) into smaller adzes. These curation processes, notably modification after major blade/bevel damage, and particularly reworking, generally changed the morphology, function, and value of the adze (see Turner 2000: 231–301 for more details on these processes). This paper focuses on identifying original functional designs. A practical typology that can be applied to all adzes (more useful from an archaeologist's perspective) is the subject of another paper.

Good examples of what can be considered as ideal primary designs can often be seen in preforms where shaping had been completed but grinding not yet started. Such a sample was found among the burial adzes at Wairau Bar. Primary preforms like these often make up caches (for example, the Mercury Bay cache made of Tahanga basalt in the Te Papa collection [Turner 2000: 471–479 Appendix D]). Primary finished adzes are also obvious in showing little sign of use, repair or major modification.

RAW MATERIAL SOURCES

Identification of stone type in the analysis of the archaeological sample was largely done macroscopically with the aid of a magnet and magnifying glass.

The major sources of stone used for early period adzes are fortunately quite distinctive in hand specimen. Museum visits were often combined with visits to local sources of adze-quality rock, usually under the guidance of local experts who also aided in the identification of museum specimens. The Nelson Museum has an extensive comparative collection of argillite samples from numerous quarries and sources from the Nelson/Marlborough region, which assisted in assigning adzes to specific quarries and particularly in distinguishing D'Urville Island sources from mainland sources (however, few D'Urville Island quarries can be considered distinctive, exceptions being the material from the large Mt Ears quarry, which provided a jet black stone, and the Ohana quarry, from which a light green veined material derived. But even at these quarries there is much variability in colour and pattern). A number of these quarries were also visited.

I have undertaken detailed surveys of the Tahanga basalt quarry (Turner 1992) and the Motutapu greywacke sources (Turner 2000: 44–47). Tahanga basalt is potentially the most difficult to distinguish from other basalts which had minor importance in several areas (for example, Waikato, Northland, Otago). Sources of these materials have been located and samples collected and comparisons made. A magnet proved useful for separating volcanic rocks from sedimentary ones. It was also useful for distinguishing Tahanga basalt from other basalts, as the former is strongly magnetic because of its high iron content. Familiarity gained from many months spent flaking, grinding and hammer-dressing adzes made from these various materials and the initial examination of almost four thousand archaeological adzes in the Auckland Museum resulted in an experienced and discerning eye. The use of a Munsell colour chart (especially for the Nelson/Marlborough argillite sources) proved unreliable given the variable light conditions of Museum storerooms. There is always the possibility that some sources of adze stone have not been relocated but it is unlikely that they were of major importance. For example, in order for a source to have been a major supply it not only has to be of a certain quality but there had to be plenty of it, and such a source is likely to be highly visible in the archaeological landscape, with accessibility also playing a role both in the past and in the present.

RAW MATERIAL QUALITY

Quantitative engineering tests on raw material quality (flakeability, toughness and hardness) were trialled (for example, Turner 1992: 223–229) but none proved sensitive enough to reflect the real differences experienced during experimental manufacture and use of adzes made from these materials. It is reasonable to suggest that the experimental results reflect differences experienced by early New Zealand adze makers and users also. Archaeological data are consistent with these findings. For example, adzes of the highest quality materials, as tested in replication experiments, were distributed over much wider areas than those found to be of lesser quality. A detailed outline of the raw materials is given in Turner (2000: 33–58), including availability and accessibility, abundance and density, the influence of raw material form and the influence of local materials used as hammer stones and grinding stones. These influences are discussed below where relevant.

A FUNCTIONAL TYPOLOGY

The functional experiments highlighted certain quantitative variables that proved functionally important and readily observable:

1. Length and weight = size.
2. Edge-angle (see Fig. 1).
3. Edge curvature.
4. Blade width.
5. Thickness relative to length and blade width.

In these experiments, large heavy thick tools with high blade edge-angles were ideal for the task of chopping and roughing out the log. Thinner wide-bladed adzes with low blade edge-angles were, in contrast, best suited to trimming timber. Archaeological specimens were then examined to discover if these adzes exhibited a consistent combination of these variables and if a set of functional types could be identified.

The results of this analysis showed that the combinations of functional variables outlined above occurred consistently. The six distinct functional adze types identified in functional experiments were also observable in the archaeological record. An interesting finding of this research was that Duff's six types (1–6), with some important adjustments, generally correspond with the six functional types described below, despite the finding that cross-section shape and the presence or absence of a tang have only minor functional significance. His varieties, however, are mainly variations on a theme, reflecting more the influence of the raw materials and manufacturing techniques employed. The good news, therefore, is that for ease of description (given the archaeological profession's familiarity with them) Duff's basic terminology can be retained with the bonus of now being able to explain the distinctions between the different types.

Tables 1, 7 and 8 include the subset of adzes where original function was preserved (N = 3993). The majority of these adzes had seen some degree of wear and tear and episodes of repair. These tables also include preforms that are well formed at an advanced stage of manufacture. These tables look at the frequencies of functional types and the stone materials they are made of. But in order to understand what were considered design ideals, only those adzes and preforms in a complete and primary state are included in Tables 2–6 and 9–11.

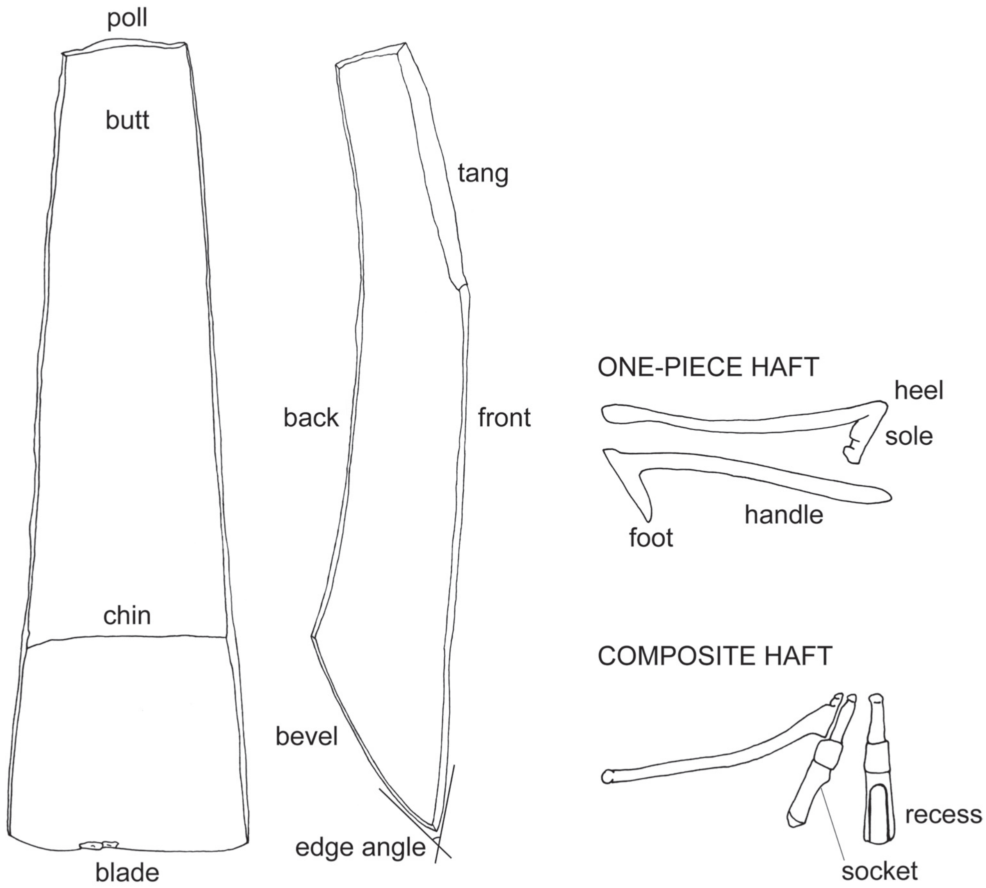

Figure 1: Features of adzes and hafts. Type 1 adze from Waitaki River Mouth, back (b) and side (s) views. Haft drawings after Wallace (1982).

TABLE 1
FUNCTIONAL TYPE FREQUENCIES

Type	**N**	**%**
Type 1	962	24.1
Type 2	1218	30.5
Type 3	439	10.9
Type 4	799	20.1
Type 5	90	2.2
Type 6	485	12.1
Total	**3993**	**99.9**

The six primary functional types are discussed and outlined below. Following this, the combined influences of function and technology on final adze form are examined and the behavioural strategies suggested are discussed.

TYPE 1 (Tables 1–11 and Figs 1, 2f, 3a, 4e)

Type 1 adzes were the second most common type of adze after Type 2 (24.1%; see Table 1). These adzes are generally large (average 280–290 mm long; Table 2) thick (49 mm average; Table 3) and heavy (average 1.7 kg; Table 4) with wide blades (average 75 mm wide; Table 5) and steep blade edge-angles (average 50 degrees; Table 6). Actions involve chopping and splitting at a high angle of attack with considerable force for the fast removal of excess wood. Wood-working operations include tree felling and the roughing out stage of big projects like shaping large logs/boards for canoes and other large wood-working projects — possibly houses (though the archaeological record is unclear regarding the general size and nature of these for the early period). Bonica generally used these adzes in tandem with large Type 4 adzes (see below).

There are high raw material constraints, with toughness a major criterion. In the archaeological record, the majority of Type 1 adzes are rendered in the toughest materials: Nelson/Marlborough argillite and Tahanga basalt in the North Island (for example, while Tahanga basalt and Nelson/Marlborough argillite adzes account for 73.4 percent of all North Island early adzes, they make up 91.5 percent of Type 1 adzes; see Table 7), and Nelson/Marlborough and Southland argillite in the South Island (see Table 8). Nelson/Marlborough argillite, especially the material from D'Urville Island, can be seen as reflecting the ideal raw material for the form. In manufacturing and functional experiments, this material emerged as being the hardest and toughest material as well as the most flakeable. Archaeological specimens are significantly longer than other functional types, have significantly wider blades and have the greatest symmetry (Tables 2 and 5). All these features improve functional operations as well as durability.

The toughness of Tahanga basalt probably explains its prominence among Type 1 North Island adzes. In contrast, the type is rare in more brittle materials like Motutapu greywacke. Outcrops of good quality material are common on Motutapu Island; at the Pig Bay site, close to these outcrops, large quadrangular broken preforms bear witness to attempts to make them, yet finished Type 1 adzes numbered very few in the archaeological data. Even in the Auckland area where Motutapu greywacke adzes were common, almost all Type 1 adzes are made of Tahanga basalt or Nelson/Marlborough argillite (Turner 2000: 122).

Duff's description of his Type 1A as "broad-bladed, quadrangular in section, and with a marked 'tang' or 'grip', thick and massive …" with sharp intersecting sides and with the front always wider than the back (Duff 1977: 146, 148, 151) basically describes a Type 1 adze made of Nelson/Marlborough argillite of the kind common at Wairau Bar. But while some of these features relate directly to function, others do not.

Butt modification was obviously aimed at increasing hafting security and there was a definite trend in the archaeological data for larger heavier adzes to have more pronounced butt modification. However, much variation in the type and degree of butt modification was exhibited on archaeological specimens; for example, frontal reduction, side reduction (shoulders), offsetting at an angle instead of reduction and hammer-dressing of corners in the butt area (see Table 9). The degree of butt reduction and the nature of butt modification appear to be related to raw material and manufacturing constraints and not to size. The same can be said regarding lugs, another feature that aids hafting security. These projections

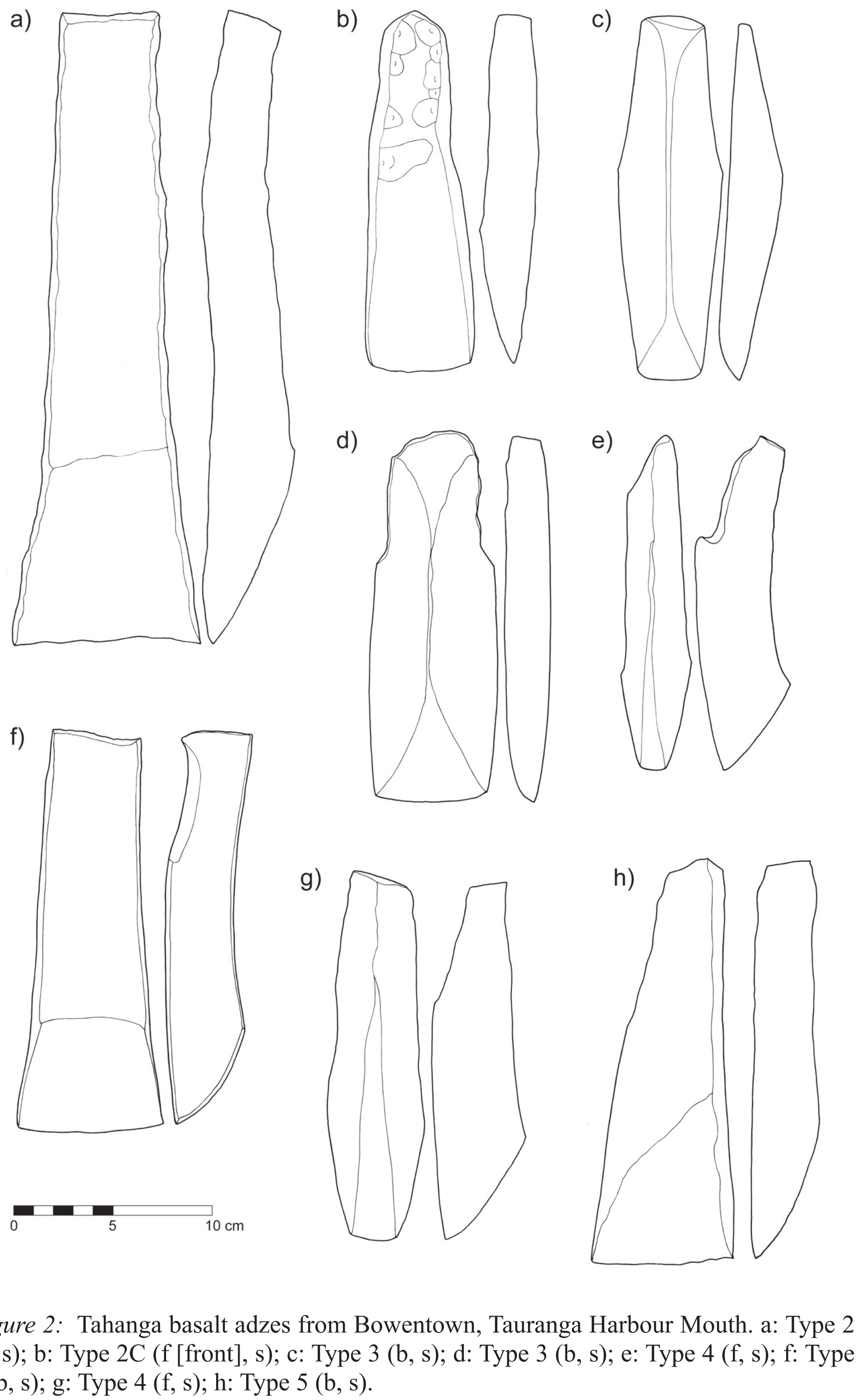

Figure 2: Tahanga basalt adzes from Bowentown, Tauranga Harbour Mouth. a: Type 2 (b, s); b: Type 2C (f [front], s); c: Type 3 (b, s); d: Type 3 (b, s); e: Type 4 (f, s); f: Type 1 (b, s); g: Type 4 (f, s); h: Type 5 (b, s).

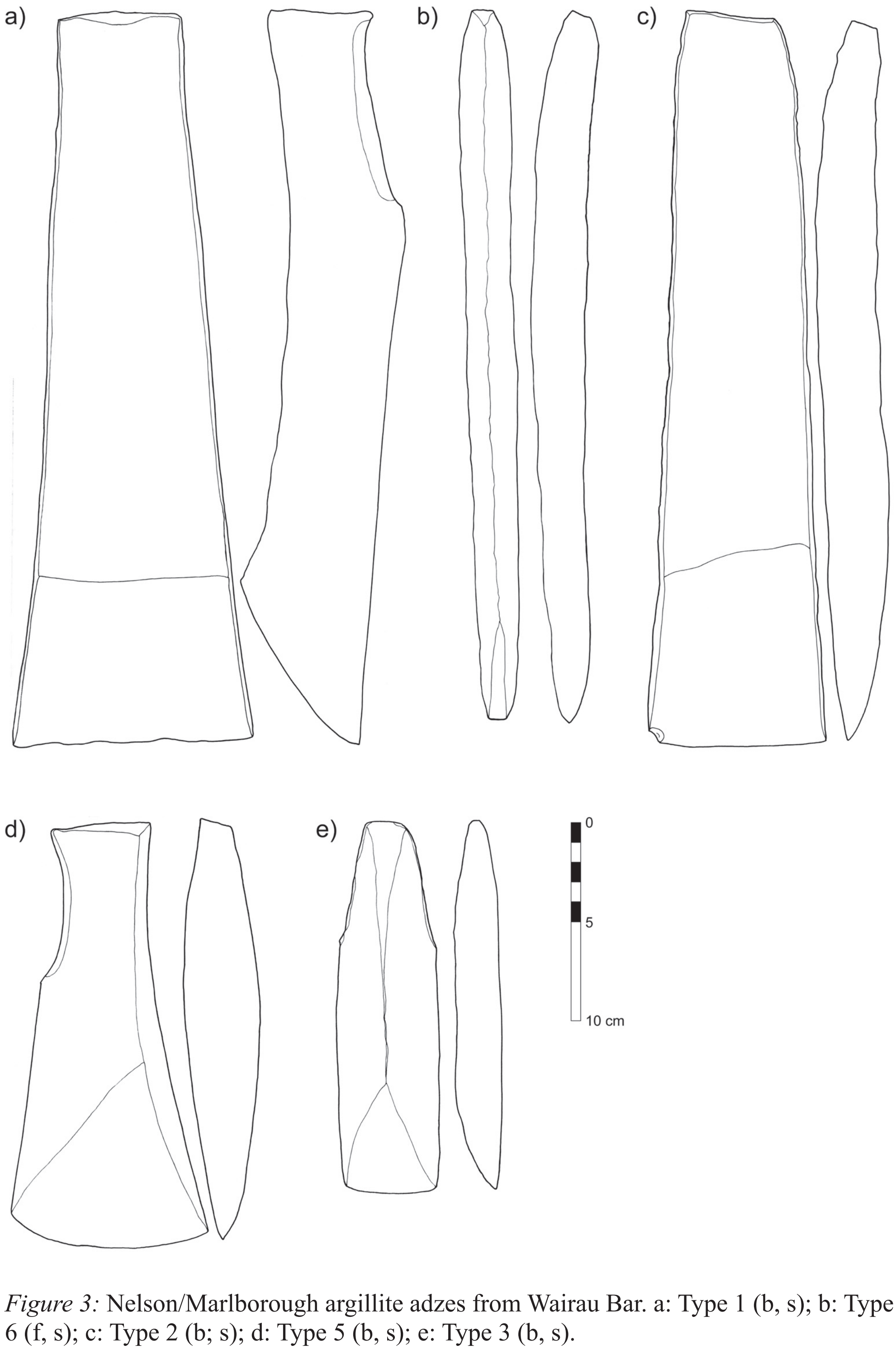

Figure 3: Nelson/Marlborough argillite adzes from Wairau Bar. a: Type 1 (b, s); b: Type 6 (f, s); c: Type 2 (b; s); d: Type 5 (b, s); e: Type 3 (b, s).

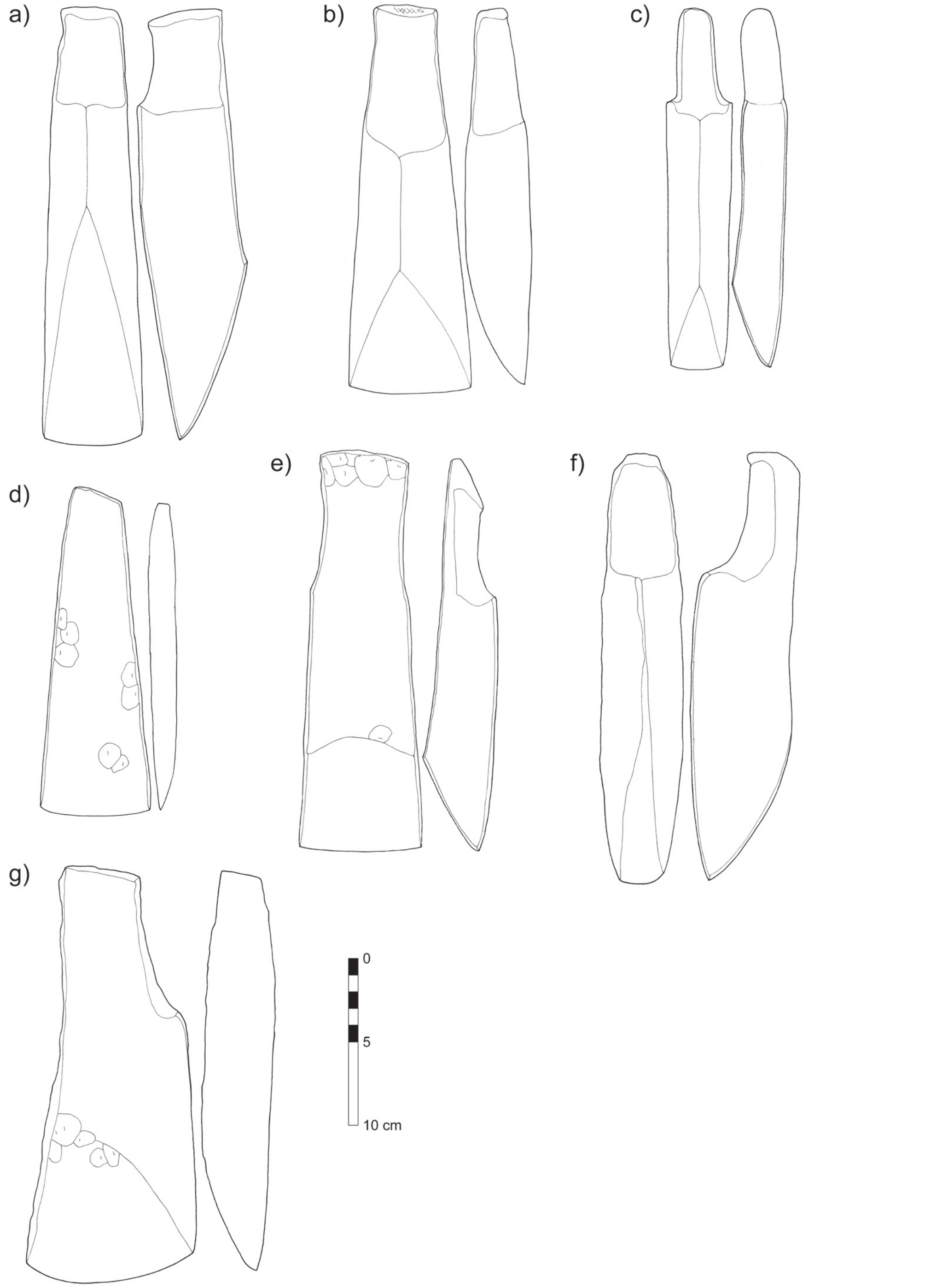

Figure 4: Adzes from Waitaki River Mouth. a: Type 4 (f, s); b: Type 3 (b, s); c: Type 3 (b, s); d: Type 2 (b, s); e: Type 1 (b, s); f: Type 4 (f, s); g: Type 5 (b, s).

TABLE 2
LENGTH OF PRIMARY ADZES*

Functional Type & Stone Type	**N**	**Mean mm**	**Range mm**	**Standard Deviation**	**Standard Error**
1 South Island all	84	292.0	141–420	64.8	4.7
1 North Island all	63	285.8	172–430	49.9	5.1
1 Tahanga basalt	48	281.1	184–363	32.7	4.7
1 D'Urville Island argillite	66	296.6	184–430	54.4	6.7
1 Nelson/Marlborough argillite	19	275.5	172–375	53.7	12.3
1 Southland stone	27	291.8	168–416	64.6	12.2
1 with lugs	30	314.0	174–450	63.5	11.6
1D all	29	363.0	213–465	52.4	9.1
2 large all*	72	321.9	205–566	87.9	10.0
2 large Tahanga basalt*	12	288.7	207–415	55.8	16.1
2 large D'Urville argillite*	49	328.4	205–566	72.2	10.3
2A all	95	178.1	110–249	35.7	3.6
2A Tahanga basalt	13	173.7	133–231	28.7	7.9
2A D'Urville Island argillite	39	185.8	117–249	36.3	5.8
2A Nelson/Marlborough argillite	19	176.1	122–250	33.4	7.6
2A Motutapu greywacke	11	162.5	112–209	31.5	9.5
2C all	50	168.4	115–253	30.1	4.2
2 Chin Ridge all	27	273.3	191–451	56.1	10.7
3A all*	31	225.8	114–376	67.3	12.1
3B all*	54	221.3	115–367	63.9	8.7
3C all*	20	203.4	136–254	31.8	7.1
3D all*	30	172.8	103–260	34.2	6.3
4A all	128	242.9	146–364	47.7	4.2
4A Tahanga basalt	27	217.0	140–301	45.6	8.8
4A D'Urville Island argillite	49	251.2	161–332	45.0	6.4
4A Southland stone	20	245.5	97–364	48.1	10.7
4B all	21	204.2	156–268	26.8	5.8
6 all	33	192.8	129–300	41.9	7.4
5 all*	44	210.6	141–338	37.5	5.6
5 Tahanga basalt*	16	194.6	140–245	29.4	7.3
5 Nelson/Marlborough argillite#	19	222.6	146–338	32.5	7.4

* well formed preforms added to increase sample

\# includes D'Urville Island sources

TABLE 3
MAXIMUM THICKNESS OF PRIMARY ADZES*

Functional Type & Stone Type	N	Mean mm	Range mm	Standard Deviation	Standard Error
1 all	177	49.0	32–69	6.8	0.5
1 Tahanga basalt	48	50.3	37–69	7.4	0.8
1 D'Urville Island argillite	66	47.9	35–68	7.4	0.9
1 Nelson/Marlborough argillite	19	45.8	32–60	6.7	1.5
1 Southland stone	27	47.1	32–62	7.9	1.5
1 with lugs	30	48.8	36–70	9.6	1.7
1D all	29	55.0	32–72	9.8	1.6
2 Large all*	72	36.2	22–59	8.0	0.9
2 Large Tahanga basalt*	12	38.3	31–47	4.8	1.4
2 Large D'Urville Is argillite*	49	35.6	22–49	8.0	0.9
2A all	95	25.2	11–47	6.1	0.6
2A Tahanga basalt	13	29.3	18–47	8.3	2.3
2A D'Urville Is argillite	39	23.6	11–35	5.3	0.8
2A Nelson/Marlborough argillite	20	24.4	12–34	5.5	1.2
2A Motutapu greywacke	11	27.7	18–40	5.5	1.6
2C all	50	27.0	15–41	6.1	0.8
2 Chin Ridge all	20	34.9	24–54	6.7	1.4
3A all*	31	37.0	17–60	9.3	1.6
3B all*	54	33.6	20–57	6.7	0.9
3C all*	20	28.0	17–46	7.1	1.5
3D all*	30	23.4	11–37	5.8	1.1
4A all	128	56.9	34–82	10.3	0.9
4B all	21	44.3	29–69	7.1	1.5
5 all*	44	37.9	20–56	7.7	1.2
6 all	33	32.9	23–46	6.1	1.1

*well formed preforms added to increase samples

or knobs are generally located at or near the front corners of the poll. Although they are present on some of the largest and heaviest adzes observed, they are rare, and are absent on the majority of Type 1 adzes, including those of similar or greater size.

The presence of lugs and pronounced butt reduction is a feature more common to South Island adzes and adzes made of raw materials localised to the South Island (see Table 9). The reason for this can be related primarily to the availability of an extremely effective hammer-dressing material — hydrogrossular garnet or 'lime garnet'. This very strong material is found as water-rolled cobbles and pebbles in Nelson/Marlborough

TABLE 4
WEIGHT OF PRIMARY ADZES*

Functional Type & Stone Type	**N**	**Mean g**	**Range g**	**Standard Deviation**	**Standard Error**
1 all	177	1751	505–5560	713	53
1 Tahanga basalt	48	1639	545–3350	653	94
1 D'Urville Island argillite	66	2186	622–5560	905	111
1 Nelson/Marlborough argillite	19	1790	505–3455	784	180
1 Southland stone	27	1595	320–3535	1050	202
1 with lugs	30	2475	675–5405	1258	238
1D all	29	2373	540–3680	709	121
2 large all*	72	2145	405–5450	1364	161
2A all	95	459	100–1240	244	25
2C all	50	431	130–1485	261	37
2 Chin Ridge all	20	1684	500–4100	95	21
3A all*	31	1007	110–2385	679	122
3B all*	51	919	145–1850	449	63
3C all*	20	375	125–1135	161	36
3D all*	30	236	87–556	109	20
4A all	128	1022	232–2870	502	44
4A Tahanga basalt	25	798	232–1800	473	94
4A Nelson/Marlborough argillite	56	1112	235–2150	377	50
4A Southland stone	19	1139	230–2870	657	151
4B all	21	806	470–1151	232	50
5 all*	40	896	245–2515	432	68
6 all	31	309	81–905	181	32

*well formed preforms added to increase samples

and Southland rivers and beaches. The equally common presence of features like raised chin ridges, hollowed bevels and grooved tangs on South Island adzes — particularly Southland adzes — can also be attributed to the effectiveness of lime garnet hammer-dressing. Duff's variety 1C is distinguished as such by marked lateral tang reduction (Fig. 6). Both heavy high edge-angled quadrangular forms and thinner rectangular low edge-angled forms are included by Duff in this category but here would be included as Type 1 and Type 2 respectively. In North Island collections, Nelson/Marlborough argillite adzes have notably more tang reduction than Tahanga basalt adzes — again reflecting use of lime garnet hammer stones which, as tested in experiments, leave a distinctive pattern; a deep pitting to the surface rather than just bruising. The one disadvantage with lime garnet is that there is a higher risk of breakage during hammer-dressing. Nelson/

TABLE 5
BLADE WIDTH OF PRIMARY ADZES*

Functional Type & Stone Type	**N**	**Mean mm**	**Range mm**	**Standard Deviation**	**Standard Error**
1 all	177	74.9	42–128	11.5	0.9
Tahanga basalt	48	70.1	52–97	9.3	1.3
1 D'Urville Island argillite	66	86.9	55–128	15.1	1.8
1 Nelson/Marlborough argillite	19	73.7	44–104	13.5	3.1
1 Southland stone	27	65.3	42–87	12.9	2.4
1 lugs	30	89.0	60–137	19.9	3.6
1D all	29	55.0	35–94	12.2	2.1
2 large all*	72	89.6	61–137	15.1	1.7
2 Large Tahanga basalt*	12	81.6	65–98	10.7	3.1
2 Large D'Urville Island *	49	91.9	68–137	16.1	2.3
2A all	95	58.2	39–89	11.8	1.2
2A Tahanga basalt	13	57.0	45–80	11.3	3.1
2A D'Urville Island argillite	39	60.7	45–89	12.1	1.9
2A Nelson/Marlborough argillite	20	55.3	40–77	9.9	2.2
2A Motutapu greywacke	11	54.1	40–65	8.9	2.7
2C all	50	52.3	37–87	9.2	1.3
2 Chin Ridge all	20	99.4	42–142	24.3	5.4
3A all*	31	63.6	36–105	20.1	3.6
3B all*	54	69.0	39–125	19.4	2.6
3C all*	20	37.1	25–54	8.8	1.9
3D all*	30	32.4	17–55	9.1	1.6
4A all blade width	128	21.4	01–60	9.1	0.8
4A all maximum width	128	50.2	28–76	9.9	0.8
4B all	21	43.8	29–63	7.4	1.6
5 all*	44	81.8	50–126	14.3	2.1
6 all blade width	33	11.9	03–28	5.1	0.9
6 all maximum width	33	28.3	15–42	5.4	0.9

*well formed preforms added to increase samples

Marlborough argillite and Southland argillite are tough enough to withstand lime garnet hammer-dressing with relatively low levels of damage/breakage risk. The same cannot be said of many weaker materials. For example, the only Type 1 Motutapu greywacke adze made in experiments (Turner 1992: 218–220) broke during tang reduction using lime

TABLE 6
EDGE ANGLES OF PRIMARY ADZES*

Functional Type & Stone Type	N	Mean degrees	Range degrees	Standard Deviation	Standard Error
1 all	177	50.0	41–58	3.0	0.45
1 Tahanga basalt	48	51.3	44–58	3.4	0.22
1 Nelson/Marlborough argillite	66	49.2	40–57	3.5	0.49
1 Southland stone	27	49.8	40–58	4.0	0.43
1 with Lugs	28	49.4	43–58	3.5	0.77
1D all	29	50.0	43–60	4.3	0.66
2 large all	65	38.9	29-48	4.2	0.52
2 large Tahanga basalt	12	37.3	35-45	2.7	0.75
2 large D'Urville Island argillite	47	36.4	29–46	4.3	0.62
2 Chin Ridge all	20	38.9	27–42	3.9	0.87
2A all	61	40.4	29–46	4.0	0.51
2A Tahanga basalt	13	35.8	33–45	3.4	0.95
2A Nelson/Marlborough argillite*	32	42.1	28–43	3.1	0.55
2C all	47	42.1	31–52	4.5	0.65
2C Tahanga basalt	32	43.9	36–52	4.0	0.7
3 all	43	37.8	28–50	5.1	0.6
4A all	71	61.3	53–73	4.2	0.5
4B all	21	61.1	50–75	6.5	1.43
5 all	28	42.4	36–49	3.5	0.76
6 all	33	49.2	40–56	4.3	0.67

*includes D'Urville Island argillite

garnet. Care needs to be taken with Tahanga basalt also. Although a small number of lime garnet hammer stones have been identified in North Island collections, extensive hammer-dressing is uncommon on Tahanga basalt Type 1 primary adzes and correspondingly, tangs are generally less pronounced, with some having little or no reduction at all (see Tables 9 and 10). Angulation, in contrast, is frequently observed where flaking is the dominant manufacturing method and is a common design feature of Tahanga basalt adzes (see Fig. 2). It is far less common where hammer-dressing plays a major part in overall manufacture (that is, not just restricted to the butt).

This was the case with Southland adzes. Southland materials, including argillite and other sedimentary and volcanic materials, were generally very tough and difficult to flake. A distinctive characteristic of Southland adzes is that lime garnet hammer-dressing was a major manufacturing method (see Table 10). Flaking appears to have been used in the initial flaking out of the blank to remove excess weight but, equipped with lime garnet hammers, it was probably faster, more efficient and safer to use hammer-dressing for

TABLE 7
FUNCTIONAL TYPE BY STONE TYPE FOR NORTH ISLAND ADZES (%)

Type	**N**	**Tahanga basalt**	**D'Urville Island argillite**	**Nelson Marlborough argillite**	**Motutapu greywacke**	**Northland basalt**	**Waikato basalt**	**Taranaki argillite**	**Silicified Limestone**	**Other**
1 all	494	47.5	30.5	13.5	0.8	3	0.2	0.8	0.2	3.2
2 large	86	14.1	61.1	15.2	4.7	3.5	0	0	0	1.1
2A	339	27.7	30.7	21	13.8	2.1	0.3	0	0	3
2C	193	67.9	5.8	4.2	9.6	6.9	3.2	0	0.5	1.6
2 Chin Ridge	13	0	20.7	63.8	0	0	0	7.6	0	7.6
3A	41	12.1	56.1	7.3	12.1	7.3	2.4	0	0	2.4
3B	67	49.2	20.8	11.9	10.4	4.4	0	0	0	2.9
3C	7	42.8	57.1	0	0	0	0	0	0	0
3D	11	18.1	54.5	9	9	0	0	0	0	9
4A	336	45.4	14.6	9.7	15.2	6.7	2.4	0.3	1.5	3.9
4B	55	63.6	12.7	1.8	5.4	9	1.8	0	3.6	1.8
Type 5	38	71	18.4	0	5.2	0	5.2	0	0	0
Type 6	197	47.5	24.5	9.6	10.1	2.1	2.1	0	1	1.6
6 Reworked	373	40.5	23.2	15.8	10.9	0.8	0.2	0.5	2.2	5.4
Total	**2250**	**821**	**552**	**348**	**299**	**67**	**25**	**48**	**17**	**74**
% of total		**36.4**	**24.5**	**15.4**	**13.3**	**2.9**	**1.1**	**2.1**	**0.7**	**3.3**

Note: Includes finished adzes only

TABLE 8
FUNCTIONAL TYPE BY STONE TYPE FOR SOUTH ISLAND ADZES (%)

Type	**N**	**D'Urville Island argillite**	**Nelson Marlborough argillite**	**Southland argillite**	**Basalt & volcanic**	**Pounamu**	**Greywacke**
Type 1	145	46.8	9.6	29.6	12.4	0	1.3
1C quadrangular	13	0	0	46.1	15.3	7.6	30.7
1D	35	0	0	60	0	0	40
2 large	71	40.8	23.9	22.5	2.8	8.4	1.4
1C rectangular	7	14.2	0	71.4	0	0	14.2
Chin ridge	26	34.6	46.1	3.8	0	3.8	11.5
2A	192	46.8	17.1	19.2	10.4	6.2	0
2C	38	26.3	10.5	39.4	23.6	0	0
3A	38	42.1	13.1	34.2	7.8	2.6	0
3B	27	55.5	25	15	5	0	0
3C	21	66.6	4.7	28.5	0	0	0
3D	20	55	25	15	5	0	0
4A	155	47	5.8	23.8	14.1	1.9	7
4B	11	27.2	27.2	27.2	9	0	9
Type 5	28	59.2	7.4	25.9	3.7	3.7	0
Type 6	120	48.3	15.8	9.1	12.5	11.6	2.5
Total	**947**	**418**	**129**	**225**	**97**	**39**	**39**
% of Total		**44.2**	**13.7**	**23.7**	**10.2**	**4.1**	**4.1**

Note: Includes finished adzes only

much of the shaping process. This was also the case during the later period in the Nelson/Marlborough region, when poorer-flaking mainland river argillite was commandeered for adze making.

Duff's type 1D and 1C adzes (Figs 5 and 6) are Southland forms shaped predominantly by hammer-dressing and exhibit features typical of the technique: marked tang reduction, raised chins, and a rounded cross-section (see Tables 9 and 10).

Similarly, on South Island adzes and Nelson/Marlborough argillite adzes in the North Island, lugs tend to be well defined 'knobs' achieved by hammer-dressing. Lugs on Tahanga basalt adzes, in contrast, tend to be 'incipient' and characterised by sharp corner projections left by flaking and then often ground smooth (see Turner 2000: Appendix F for list of lugged adzes).

In New Zealand, Type 1 cross-sections are often close to square (defined here as quadrangular where the width at mid-section is similar or equal to thickness). While this lends a certain functional advantage in balance and symmetry, the functional criteria could just as easily (probably more easily from a manufacturing perspective) have been

TABLE 9
BUTT MODIFICATION OF PRIMARY ADZES (%)

Type and Stone	N	Slight rough / rounded	Angulation only	Minor front reduction	Moderate front reduction	Marked front reduction	Lateral & front reduction	Lateral reduction only	Marked grooving	Well defined lugs	Not modified
Type 1 all	177	13.1	16.4	16.4	58.2	2.9	2.9	0	0	14.1	0
Type 1 Tahanga basalt	51	11.8	33.3	11.7	43.1	0	0	0	0	3.9	0
Type 1 D'Urville argillite	72	1.5	10.2	14.7	73.5	0	0	0	0	26.6	0
Type 1 Nel/Mar argillite	18	6.6	0	33.3	53.2	17.8	6.6	0	0	23.5	0
Type 1 Southland sources	26	0	0	11.8	56.1	34.4	14.2	0	0	7.1	0
Type 1D all	29	0	0	3.4	24.1	0	24.6	0	0	3.4	0
Type 1C all	15	0	0	0	0	0	86.6	0	13.3	20	0
Type 2 large all	72	12	10.6	52	21.3	0	4	0	0	4.1	0
Type 2A all	96	28.2	9.5	0	0	0	0	0	0	0	62.2
Type 2C all	51	19.5	4.7	0	0	0	0	0	0	0	75.7
Type 2 chin ridge all	20	35.2	0	0	0	0	0	0	0	0	64.7
Type 3 all	81	16	0	0	0	0	13.5	35.8	2.2	0	34.5
Type 4A all	134	7.1	14.1	14.1	56.7	5.1	0	0	0	5.9	0
Type 4A Tahanga basalt	46	1.1	41.3	13.7	37.9	6.9	0	0	0	0	0
Type 4A D'Urville argillite	39	1.1	10.6	14.8	72.3	2.1	0	0	0	10.6	0
Type 4A Nel/Mar argillite	14	0	0	35.7	64.2	0	0	0	0	7.1	0
Type 4A Southland sources	16	0	5	5	50	25	0	0	15	10	0
Type 4A Motutapu greywacke	19	8.9	33.5	24.6	32.9	0	0	0	0	0	0
Type 4B all	21	2.4	2.7	9.3	66.6	14.2	0	0	4.7	4.7	0
Type 5 all	44	0	0	0	0	0	0	99.9	0	0	0
Type 6 all	33	1	48.3	41.9	8.7	0	0	0	0	3.2	0

TABLE 10:
HAMMER-DRESSING ON PRIMARY ADZES (%)

Type/Stone	N	None	Minor	Moderate	Extensive	Butt only
1 all	177	10.1	11.2	20.7	13.4	44.3
1 north North Island all	50	21.1	18.7	7.5	0	52.2
1 south North Island all	43	0	11.5	30.7	7.6	50
1 north South Island all	41	3.4	6.8	48.2	10.3	31
1 south South Island all	43	0	0	32.2	58.8	11.7
1 Tahanga basalt	51	34	20	8	0	38
1 D'Urville argillite	72	1.3	8.3	23.6	5.5	61.1
1 D'Urville argillite Nth Nth Island	20	1	13.5	0	0	75.4
1 D'Urville argillite Sth Nth Island	27	4	10.7	28.5	0	56.7
1 D'Urville argillite Sth Sth Island	25	0	0	40	12	37.9
1 Nelson/Marl argillite	18	0	10.5	42.1	0	47.3
1 Southland sources	26	0	0	28.5	60.7	11.1
1D all	29	0	0	0	100	0
1C all	15	3.4	0	27.5	37.9	31
2 Large all	72	17.6	22.2	10.2	4.4	45.5
2A all	96	49.4	38.9	7.3	4.2	0
2C all	51	56	40	4	0	0
2 Chin Ridge all	20	12.8	5.1	38.4	43.5	0
3A all	29	0	3.4	10.3	10.3	75.8
3B all	26	75.8	21.8	6.2	0	0
3C all	11	61.5	7.6	15.2	0	15.2
3D all	15	64.2	28.5	7.1	0	0
4A all	134	10.4	6.7	21.6	15.6	45.5
4A Tahanga basalt	46	38	19	2.3	0	40.4
4A D'Urville argillite	39	10.6	7.5	10.6	4.5	66.6
4A Nelson/Marl argillite	14	0	21.7	30.4	8.6	39.1
4A Southland sources	16	0	0	36	52	12
4A Motutapu greywacke	19	28.5	28.5	0	0	42.8
4B all	21	9.5	14.2	14.2	14.2	47.6
6 all	33	40.6	15.6	0	0	66.6
5 all	44	6.9	0	17.2	0	72.7

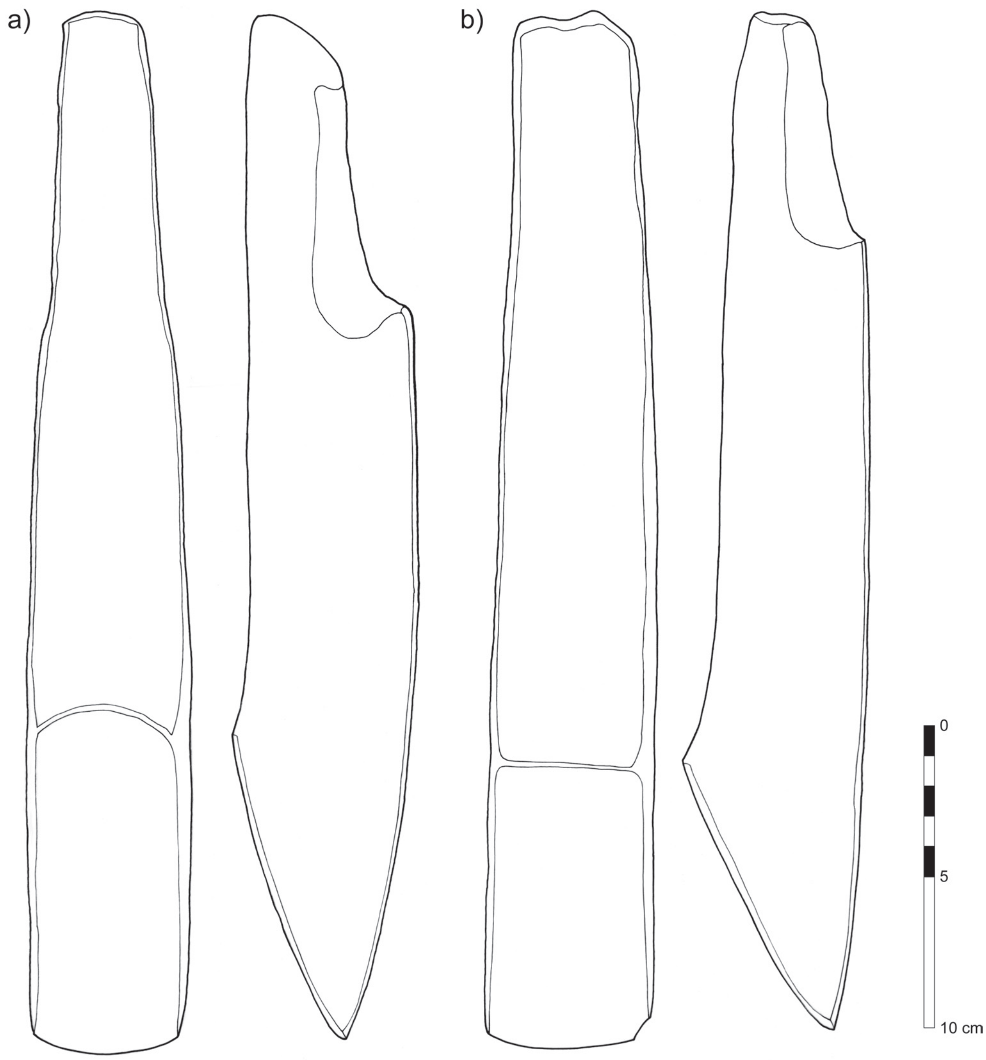

Figure 5: Southland 1D adzes: back and side views.

met by triangular, plano-convex, trapezoidal or any other cross-section shape as long as it was thick relative to width.

Again, cross-section shape may be more influenced by raw material quality and manufacturing techniques. For example, common among Tahanga basalt Type 1 adzes and entirely absent among adzes of Nelson/Marlborough argillite is the back-wider-than-front form that has the effect of turning blade corners inward slightly and narrowing the blade. Had Duff been familiar with this form he might have identified it as another variety. On Tahanga basalt adzes this feature reflects raw material form (rough rounded cobbles), a less than ideal flakeability (makes acute angles difficult to achieve) and the need to protect blade corners on softer materials.

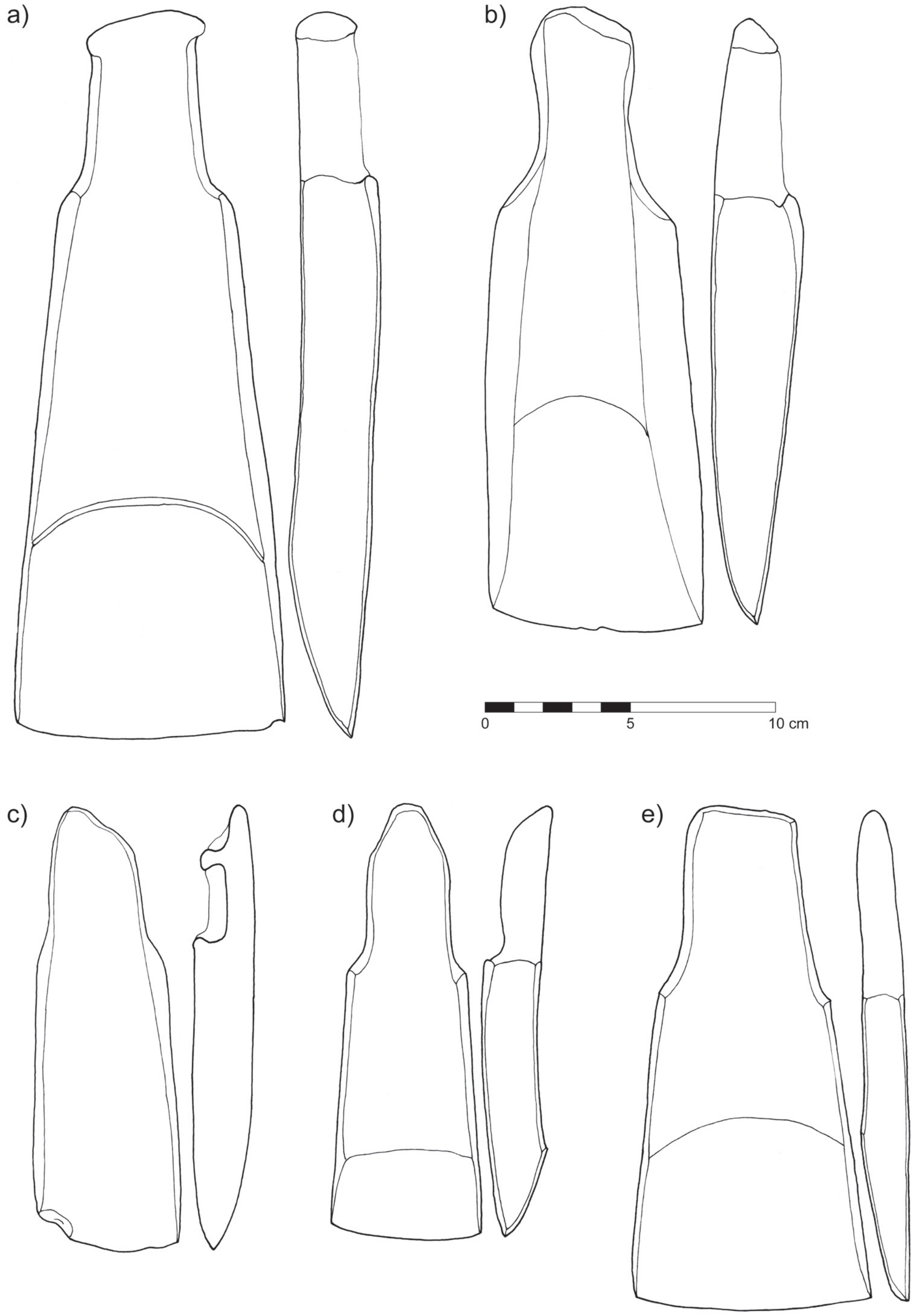

Figure 6: Southland Type 2 adzes with pronounced or grooved tangs: back and side views.

The degree of blade curvature (Table 11) and blade flaring on Type 1 adzes may also reflect raw material quality. It is likely that the softer the material and the greater the blade curvature, the narrower the blade becomes; both are methods of protecting the most vulnerable part of the blade — the corners. Nelson/Marlborough argillite adzes had significantly wider blades than Type 1 adzes of other materials (Table 4) and the lowest degree of blade curvature and this may be correlated with the experimental observation that this was the hardest material of those tested in experiments.

TABLE 11
BLADE EDGE CURVATURE OF PRIMARY ADZES (%)

Type/Stone	N	Quite Straight	Slight Curvature	Marked Curvature	Blade Corners Rounded
1 all	177	86.1	13.8	0	0
1 Tahanga basalt	51	83.3	18.6	0	0
1 D'Urville Is argillite	72	93.4	6.5	0	0
1 Nelson/Marl argillite	18	93.3	6.6	0	0
1 Southland sources	26	87.5	12.4	0	0
1D all	29	10.4	59.5	30	0
1C all	15	50	49.9	0	0
2 large all	72	91	8.9	0	0
2A all	96	90	9.9	0	0
2C all	51	85.6	14.3	0	0
2 Chin Ridge all	20	15.4	65.6	9.9	0
3 all	81	0	3.8	96.1	0
4A all	134	80.9	8.5	0	6.6
4B all	21	72.2	22.2	5.5	0
6 all	33	84.7	5.2	0	10
5 all	44	0	27.6	72.3	0

TYPE 2 (Tables 1–11 and Figs 2a, 2b, 3c, 4d)

Type 2 adzes are the most common type of adze, accounting for 30.5 percent of the sample (Table 1). They are wide bladed, thin, low edge-angled adzes of varying sizes depending on task requirements. They are used with a low angle of attack with a true follow-through adzing stroke and with a relatively low impact compared to Type 1. Their primary function is for surface timber dressing and trimming. In New Zealand, primary specimens have rectangular cross-sections (as defined in this paper — where thickness is generally half the width at mid-section).

The major difference from Duff's description of his type is the inclusion here of large rectangular adzes as Type 2 (Figs 3c and 2a). Compared to Type 1, they are significantly thinner and longer with wider blades and significantly lower edge-angles (average 320 mm long, 90 mm blade width, 37 mm thick, 38.9 degrees edge-angle) but similar in weight (average 2 kg due to their greater size and width — a different weight distribution). Duff and Skinner included these large Type 2 adzes in Type 1, mainly because of their size and the presence of a tang.

These large forms are, however, quite uncommon compared to smaller ones, being more specialised — probably reserved for tasks like cleaning down large planks or the outer surfaces of large canoes. The specimen made by Bonica for the outrigger experiment was generally too large to be useful in this particular experiment, though it was used briefly for testing purposes.

Hardness was the most favoured quality for these adzes. Moderate manufacturing constraints exist except for the large specimens where, because of the thin cross-section relative to length and width, constraints were probably higher than for Type 1. This may explain why the majority of all large forms are made of Nelson/Marlborough argillite, notably D'Urville Island sources (for the North Island sample: 61.1 percent were made of recognisable D'Urville Island sources [the Ohana and Mt Ears quarries], 76.3 percent all Nelson/Marlborough argillite — see Table 7).

The more common smaller forms have average dimensions of 178 mm length, 58 mm blade width, 25 mm thickness, 459 g weight and 40 degrees average edge-angle (Tables 2–6). Duff's main varieties are 2A and 2C. His other varieties, 1B and 2B, are not included here as, for the early period, these types (without exception in the large adze sample of 11,886 examined) are reworked forms with a different function and history (Turner 2000: 272–285).

The major distinction Duff made between these two rectangular tangless varieties is that Type 2A has the front wider than the back, while Type 2C has the back wider than the front (Fig. 2b). Although there is no functional significance, this difference does have some historical relevance. The 2C is the dominant standardised form in Samoa comprising "…over ninety percent of all adzes recorded from Samoa…" and has thus become known as the "Samoan Type" (Duff 1977: 168; Skinner 1974: 107). According to Duff and Skinner, the 2C is uncommon outside the immediate area of Samoa.

Among those classified as 2A by Duff at Wairau Bar are what I have alternatively identified as small flake adzes, a distinctive form that had a very different technological history and function. Basically they are very rough and made on small flakes opportunistically scavenged from the by-products of finishing primary preforms or reworking broken preforms and adzes. In contrast to adzes that reflect a curated technology, these adzes are quickly made, apparently used only for a short period for some minor task, and then discarded. They bear almost no morphological resemblance to primary, well-crafted rectangular tangless specimens.

Among the medium-sized forms, Duff's varieties 2A and 2C, a greater range of materials are utilised than for Type 1 and the large-sized Type 2. For example, Motutapu greywacke adzes are more frequent among these smaller lighter forms in the North Island sample (Table 7). This is probably due to lower production and use constraints.

There are, however, marked differences in raw materials between the two Duff varieties. In the North Island, Tahanga basalt is poorly represented among 2A adzes but overwhelmingly dominant among 2C adzes (Table 7 and Fig. 2b). Other basalts, both in the North and South Island, also have a strong showing among 2C adzes (Tables 7 and 8). The reverse is the case for Nelson/Marlborough argillite, where Type 2C is rare. Because Nelson/Marlborough argillite is the most commonly utilised adze material overall, this might explain why 2A adzes are more common than 2C, particularly in sites like Wairau Bar, where 80 percent of the adzes are Nelson/Marlborough argillite (Turner 2000: 152–153). It is interesting to speculate, therefore, that had fine-grained basalt been the dominant or only stone material available in New Zealand, 2C adzes might have emerged as the most common rectangular form, reflecting the situation in Samoa.

The significance of the Duff 2A and 2C distinction, however, is not related to function and relates more to solving raw material and manufacturing problems. Furthermore, it can be a distinction that, in practice, is difficult to make. When my own analysis of the Wairau Bar assemblage is compared with Duff's, several problems in the practical application of his typology become apparent. For Duff, the Type 2A classification appeared to have served as a 'catch-all' for adzes that did not fit any other of his type/variety descriptions. It is interesting to note that with the Wairau assemblage, particularly, it is very difficult to discern whether the front is wider than the back or vice versa — the difference is often less than several millimetres. This is a characteristic of the Nelson/Marlborough argillite adzes that dominate the assemblage. The faces and sides of quadrangular and rectangular argillite adzes generally intersect at sharp, well defined right angles so that the back and front of the adzes are approximately the same width. Therefore, trying to determine whether an adze is a 2C or a 2A on the basis of this feature is a time-wasting and ultimately fruitless exercise, at least for Nelson/Marlborough argillite adzes.

It appears that, because Duff had the Samoan 2C adze to use as a model, he classified as 2C only those adzes approximating this shape and distinctive 'style'. All other tangless and four-sided adzes were lumped in with the 2A variety, even though very few of these adzes have the front noticeably, or even marginally, wider than the back.

In summary, in the Wairau Bar assemblage and others where Nelson/Marlborough argillite dominates, the distinction between 2A and 2C cannot, given Duff's criteria, be made. The reason for observing this distinction in this research is largely due to the observation that while Type 2C is rare in Nelson/Marlborough argillite, it is a notably common primary form in Tahanga basalt and other basalts, though they are often morphologically distinct from the Samoan type. This might be significant if it were not for the observation that adzes of the 2A type had fronts clearly wider than their backs for these stone types also. It is evident from replication experimentation and from confirmation in the archaeological record that Tahanga basalt and most other raw materials did not allow for the finely controlled flaking that enabled the sharp angles on Nelson/Marlborough argillite adzes. The "generally crude workmanship" (Duff 1977: 170) of the Samoan 2C adzes may indicate that the basalt used there also imposed technological limitations that influenced final adze form. Interestingly, the 2C Type specimen from Wairau illustrated by Duff (1977: 169, Fig. 37) is made of basalt — possibly even Tahanga basalt — and Skinner stated from his study of Otago Museum adzes that "All examples observed are of basalt" (1974: 107). Most of the adzes identified as 2C in the Wairau assemblage were also made of basalt.

Butt modification on Type 2 adzes was generally minor except on large ones where there was a greater need for hafting security given the length and weight of these adzes (Table 9). Probably because they were not used with as much force, butt modification is not as pronounced as it is with Type 1. Most of the smaller Type 2 adzes have no butt reduction, though some have hammer-dressed front corners. Southland adzes are an exception; even when relatively small in size, many commonly had well defined tangs. Adze-makers took advantage of the fine cross-sections on Type 2 adzes to reduce, by lime garnet hammer-dressing, not only the front of the adze but usually the sides as well (see the examples in Fig. 6 [Duff type 1C] and Tables 9 and 10). Again, butt reduction sometimes took the form of grooving (Fig. 6c), a feature readily accomplished by hammer-dressing.

From comparisons between my analysis of the Wairau Bar adze assemblage and Duff's, it is apparent that Duff did not adhere strictly to his own type definitions and had problems in defining when a tang was not a tang. The distinction between his Type 1A and Type 2A proved to be particularly problematic. Ten adzes and preforms, which I classified as Type 2 on the basis of functional attributes, were classified as 1A by Duff. Almost without exception these adzes were medium-sized (under 200 mm in length), with thin rectangular cross-sections and low edge-angles, and with varying degrees of butt angulation (though not marked in any case), but with no specimens exhibiting actual butt reduction. The difference may be explained by the emphasis I placed on size, cross-section thickness and edge-angle as functional criteria, while Duff placed a major emphasis on butt reduction or angulation, regardless of how well defined it was.

Chin ridge form (Fig. 7)

Challis (1978) has also classed as 2A a distinctive standardised rectangular adze form seen most frequently in Nelson/Marlborough argillite and common to that region. It has been associated stratigraphically with late rather than early occupation from at least one site in the area (Rotokura). Challis distinguishes this type as '2Aii' and suggests that it developed from the earlier 1A form. The 2Aii adzes differ in being "… much shallower in cross-section … broader bladed, and have no grip" (Challis 1978: 71). Skinner included this adze form with his Type 2B (1974: 107). The most distinctive features of this type of adze are a raised chin ridge and lack of any butt modification. The nature of the cross-section and edge-angle, however, firmly places this form of adze in the functional category of timber dressing adzes.

A pronounced raised chin ridge is another feature readily achieved on adzes where hammer dressing is the predominant shaping method, as is evident on these adzes. Leaving a raised ridge to indicate where the bevel is to start assists in keeping the shape in proportion during hammer dressing. Removing it when the adze is shaped to its final form would actually increase, not decrease, time and effort costs. Evidence of the process of leaving this ridge to demarcate the bevel during surface reduction can commonly be seen on chin-ridge performs, otherwise known as 'humpback' in the Nelson/Marlborough area (for illustrations see Challis 1978: 67, Fig. 39b; Barber 1994: 444).

Many of these adzes appear to be made from river cobbles of tougher argillite (Turner 2000: 149, 164). Butt modification/reduction is entirely lacking; instead haft polish on the poll is a common feature. This seems to reflect changes in hafting methods — possibly from flat-soled one-piece hafts to recessed and/or composite hafts, indicating that the hafting mechanism of the adze has been transferred from the stone to the wooden component, a characteristic of late period adzes.

In summary, as with Type 1, Duff and Skinner's varieties reflect technological problem-solving strategies involving different types of raw materials, not direct functional ones.

TYPE 3 (Tables 1–11, Figs 2c, 2d, 3e, 4b, 4c)

Type 3 adzes are quite rare (10.9%; Table 1) compared to Types 1 and 2, reflecting the relatively specialised tasks they performed. Duff's varieties 3C and 3D are even rarer than side-hafted adzes, especially in the North Island (see Tables 7 and 8).

These adzes were designed for shaping curved surfaces such as those found on canoe hulls and bowls. They were generally used with a low angle of attack in a follow-through adzing stroke with moderate force. Distinctive characteristics, which relate to their specialised

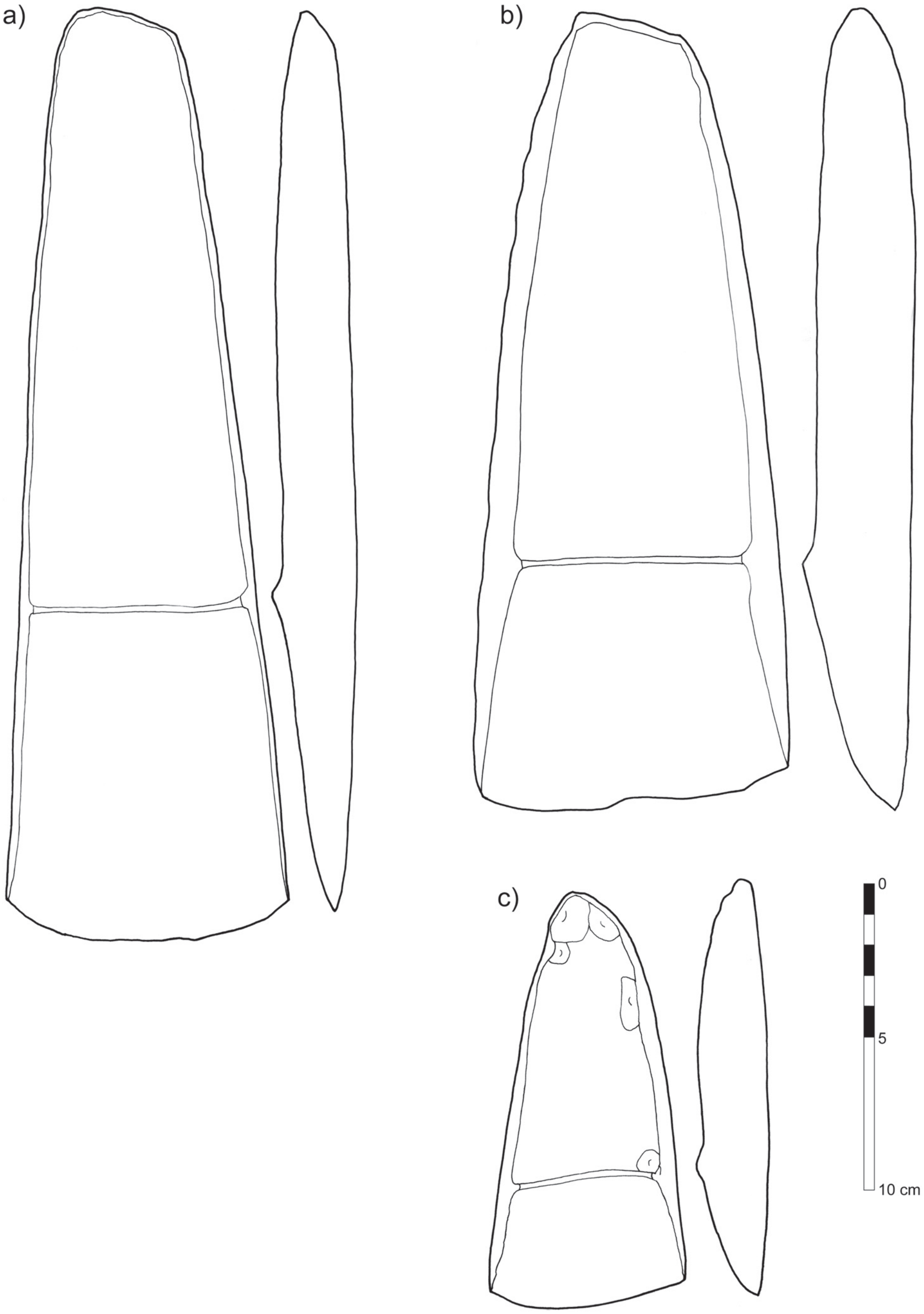

Figure 7: Nelson/Marlborough chin-ridge Type 2 adzes: back and side views.

function, are frontal convexity and a scooped curved blade. Edge-angles range from low to moderate (Table 6). Hardness was probably the most valued stone quality for clean cutting. Measurements vary according to the nature of the task, depending on whether a large or small amount of curved surface needed to be cleaned down or whether this was required in a wide or narrow space. Duff's varieties are all described as triangular or sub-triangular and differences are related to the width of the blade and the presence or absence of a tang (1977: 170), but all shared the similar functional attributes listed above. One exception is the small narrow-bladed chisel and gouge forms Duff includes as 3D. These are functionally different from the type of adze described here and are discussed later (see Type 6 below).

The very rare examples observed of Duff's variety 3E, both in the South and the North Island (N=3), are indeed 'accidental products' (Duff 1977: 176) and none can be regarded as primary adzes. This is in marked contrast with the elaborate forms more frequently found in Pitcairn Island, Tubuai and Easter Island, to which only a very tenuous resemblance can be noted. All of the very small New Zealand sample, including the one small, unfinished sample from Wairau, have been reworked from the blade portions of large rectangular adzes.

Duff suggests that "… the New Zealand examples … are ancestral forms or prototypes" (1977: 170). That is, the form was incipient at the time of migration to New Zealand and thereafter developed in Central Polynesia in a more elaborate form. Skinner also noted the resemblance of his Type 1C — the thick rounded hammer-dressed Southland form — to what he called the "Cook Island type" (1974: 104–105). Duff, however, does note that the New Zealand forms have "thinner blades" (1977: 172).

From my examination of a large number of Type 3 adzes in both the North and South Island, the differences between New Zealand and Central Polynesian Type 3 adzes appear to be so marked as to suggest that the ancestral relationship postulated by Duff (1977: 1970) is very unlikely. In functional terms, the Central Polynesian Type 3A, with its commonly thick cross-section and high edge-angle (see Duff 1974: 129–135 and Figueroa and Sanchez 1965: Figs 65–71), would be classified as Type 1 in this study. Nor can it be accepted for the New Zealand Type 3 that they represent a 'prototype'. The majority of New Zealand forms are thin-sectioned more fragile tools, morphologically similar to Type 3 forms found in other marginal East Polynesian Islands, for example, Hawai`i and the Marquesas Islands.

Furthermore, for both the South Island and North Island forms, the section can rarely be called triangular or even sub-triangular; rather, the cross-section of primary Type 3 adzes is more commonly lenticular (83.6%; Turner 2000: 168). From a purely technological perspective, it is also unlikely that triangular-sectioned adzes would develop from quadrangular-sectioned adzes, as the latter are the most difficult form to flake, and therefore, to make.

The distinction Duff made between his varieties 3A and 3B, and 3C and 3D was chiefly one of the presence/absence of a tang. The tanged forms (3A and 3C) were somewhat larger than the untanged forms (see Table 2) but generally size does not appear to have influenced the decision to modify the butt. Again the influence of stone type may be implicated here, with the smaller Tahanga basalt adzes dominating the tangless 3B sample and Nelson/Marlborough argillite and Southland materials most strongly represented among the larger tanged 3A adzes, on which lime garnet again is well employed (Tables 7, 8 and 10).

Wide-bladed forms were generally larger, with some specimens over 300 mm (Table 2); a predictable observation given that these adzes were probably used to clean the curved areas of large canoe hulls. In functional experiments the length served to increase the length of the adze stroke and to enable a better reach into the lower recesses of the canoe hull.

It might be assumed that the often rounded contours of Type 3 adzes would lend them some instability if set on to a flat-soled haft. At Huahine, a number of haft soles were recessed and grooved and would have been ideal for triangular, plano-convex or lenticular adzes (Sinoto 1982: 176). Bonica preferred to set his Type 3 adzes on to a flat open sole if only to avoid having to modify a haft specifically for an adze form that would not be used as often as others like Type 1 and 2, thereby restricting the use of the haft to that form. Wrapping the adze head in fibre padding provided adequate hafting security for Type 3 adzes where the amount of force used was not severe.

TYPE 4 (Tables 1–11, Figs 2e, 2g, 4a, 4f)

Type 4 adzes are the third most common type of adze in the North Island sample (20.1%; Table 1). The average dimensions of Type 4 adzes are 247 mm length, 25 mm blade width, 50 mm maximum width at the mid-section, 57 mm thickness, and just over 1000 g weight (Tables 2–6).

These adzes are heavy, large narrow-bladed tools with the steepest edge-angle of all adze types (Table 6). The design is a robust one with a very thick cross-section. They are used with a high angle of attack and with a high level of force. Actions include scarfing, gouging, splitting and making deep V-shaped cuts into wood to allow wide-bladed tools like Type 1 adzes access to split and chop out large chunks of wood during operations such as tree felling and roughing out items like canoes.

The weakest point on other adze types is the mid-section but with Type 4, thickness is equal to or greater than width at this point; thus toughness is less of a necessity than would normally be the case given the type of work these adzes were involved in. There is also not a great need for hardness; rather, blade edge strength is required to withstand heavy impact. This is again imparted by the adze design in the manner by which the sides curve into a narrow blade well protected by a high edge-angle. The archaeological sample (Tables 7 and 8) shows that the widest range of materials was used for this form, reflecting the robust nature of the Type 4 design, which enabled even fairly weak rocks to be viable for use. In the North Island, among minor stone sources, Type 4 is the most frequent form represented (Table 7) along with slender hogback gouges (see Type 6 below). For example, Northland basalt, Waikato basalt and Wairarapa silicified limestone adzes have very similar Type 4 frequencies. Frequencies of Type 4 adzes are also high for Motutapu greywacke. In comparison, the frequency of Type 4 among Nelson/Marlborough argillite primary adzes found in the North Island is very low. This is probably because local rocks could be utilised for this form.

Additionally, in replication experiments, Type 4 adzes were not difficult to manufacture. Shaping can generally be accomplished by low-angled trilateral flaking. Type 4 proved an adaptable form when problems roughing out blanks for Type 1 adzes occurred. Because of their narrow form, asymmetrical blanks could be readily reshaped into Type 4 adzes.

In the archaeological sample, Type 4 adzes were usually well formed and finished but not generally to the standard seen with Type 1 and large Type 2 adzes. This reflects the relative ease of manufacture of Type 4 and the lesser importance of symmetry given the robust nature of the form.

Again, in his classification of Type 4, Duff's preoccupation with cross-section led him to include varieties of small gouges (Type 4C and 4D, though the latter was later incorporated into the Type 6A class), which were probably more commonly used in conjunction with a mallet. In practice the extensive variability of cross-section shape among small chisels and gouges made the application of Duff's typology difficult and ultimately irrelevant for this class of adze. This was particularly the case when field observation revealed that most were the outcome of reworking. All these small chisel (straight blade) and gouge (curved blade) forms have been assigned here to Type 6 (see below). Another form both Skinner and Duff included as a variety of Type 4 were long narrow slender gouges with lower edge-angles. These would have been reserved for finer gouging work, probably for gaining access to corners in deep excavations, like the apex of canoe prows and bows where the slenderness and length of these adzes would have been an advantage, if not a necessity. Skinner adds that they have also been used "for cutting slots and grooves" (1974: 108). Because they function in a very different way from robust Type 4 adzes and have more in common with smaller gouges, these adzes are included with Type 6 below.

Functional experiments suggested different though related uses for 4A and 4B, the 4B adze being a compromise between the deep gouging action of the 4A and the shallow shaving action of broad-bladed types. This was probably a task that could be performed by other types of adzes and this may explain the relative infrequency of the 4B form compared with 4A. Primary 4B adzes were rare (Fig. 4a) and most are modified and reworked 4A adzes. The outcome of repairing blade damage on Type 4A adzes is a wider blade.

All Type 4 adzes observed had some form of butt modification, reflecting the need for hafting security (heavy tools used with great force). Again Nelson/Marlborough argillite adzes and Southland adzes, in particular, had more pronounced and elaborate tangs reflecting the use of lime garnet hammer stones (Tables 9 and 10). Some of these latter adzes also had lugs or projections at each end of the tang.

TYPE 5 (Tables 1–11, Figs 2h, 3d, 4g)

Type 5 adzes are the least common adze form, accounting for only 2.2 percent (Table 1).

These adzes were laterally-hafted excavation tools for working in confined spaces (for example, in canoes and bowls). They were used with a follow-through adzing stroke with a moderate to low angle of attack and moderate force. There is a need for frontal convexity and blade curvature, especially toward the driving corner, in order to shape curved surfaces and to protect the blade corner that takes the initial impact.

Butt modification is essential if no specially designed or modified foot (recessed) is incorporated into the haft design. This is achieved by lateral reduction on the opposite side to that in contact with the haft. The side lashed against the haft foot needs to be flat to increase stability.

Side-hafted adzes were fairly robust tools (average dimensions 210 mm length, 81.8 mm blade width, 38 mm thickness, 900 g weight, and 42.4 degrees edge-angle; Tables 2–6). Aside from lateral hafting, another characteristic of Type 5 adzes is their wide blades relative to length. These blades are significantly wider than other adze forms except large Type 2 adzes. Much of the hollowing out process would have been accomplished by these adzes and the wide blade enabled a wider surface area to be covered with each stroke. The steeper edge-angle compared with other timber-dressing adzes would also have contributed to the fast removal of wood. The need for a wide blade would have placed some constraints on blank type — as was experienced in manufacturing replication experiments.

The cross-sections of the majority of side-hafted adzes observed in this study are triangular and relatively robust compared with the majority of Type 2 and Type 3 adzes. Almost all Type 5 adzes share with Type 3 rounded profiles including frontal convexity and marked curvature of the blade (Table 11), features designed for trimming the concave inner surfaces of canoe hulls.

Tahanga basalt and Nelson/Marlborough argillite were the favoured materials for Type 5 adzes (Tables 7 and 8). There is also a marked preference in the North Island for Tahanga basalt. This choice may reflect the desire for a relatively tough sturdy tool. In the North Island, Nelson/Marlborough argillite Type 5 adzes are, in contrast, quite rare and mainly confined to the southern half of the island.

Type 5 adzes are regarded as the most rare and specialised adze form (Duff 1977; Moore *et al.* 1979). Yet a prevailing problem exists in that while the Type 5 adze appears to have served a special and vital role in the excavation of deep narrow hulls characteristic of Polynesian canoes, its actual occurrence in the archaeological record is rare, both within New Zealand, and in tropical East Polynesia in particular. This suggests that alternative methods of excavating deep narrow confined spaces must have been in existence. Both Duff and Skinner suggest the possibility of affixing a rotatory sleeve to the haft, enabling 'normal blades' to be used in a side-hafted manner as was done elsewhere in the Pacific including Polynesia (Duff 1977: 186; Skinner 1974: 113; Moore *et al*. 1979: 53).

The rarity of the form in New Zealand may be overstated by Duff, however. Since the first publication of his finalised adze typology in 1950, the number of side-hafted adzes recorded has increased significantly, especially in the North Island (Moore *et al*. 1979). A number of previously unrecorded specimens are included in my research (see Turner 2000: Appendix C) but still their frequency remains low.

One observable cause for this in the data is that, unlike other adze forms, once a Type 5 adze broke or suffered major blade damage, the distinguishing characteristics of the type were quickly obliterated by subsequent repair and reworking. Nor was it possible as a rule during manufacturing experiments to rework broken pieces of other types of adzes into a Type 5 form. The major problem encountered was that few broken pieces were large enough to provide the broad cutting edge or the length required for a side-hafted adze. No reworked specimens were observed in the present study though three specimens were broken pieces where reworking attempts had failed. Breakage and bad damage probably made Type 5 adzes redundant for their former tasks and it is possible that they were often reshaped for other purposes. The reshaping of a broken Type 5 adze would probably involve extensive reflaking of the apex side to form a more symmetrical bevel and cross-section for normal hafting and use. A rounded quadrangular or plano-convex cross-section would probably result. Some Type 5 adzes may have been reworked or modified into Type 3 adzes. Of note is that several specimens recorded in Moore *et al*.'s 5A list (1979: 60–73) have bevels and functional features more consistent with Type 3 (for example the Pig Bay adze and Crosbie's Settlement adze) than Type 5.

Thus the majority of specimens identified in this study were generally complete and either primary forms, well formed preforms or adzes where repair has been minor. Type 5 preforms can prove difficult to identify unless they are well formed. This is particularly problematic with specimens found at quarries. For example, I regard as dubious the specimens listed by Moore *et al*. (1979) which were found at the Tahanga quarry and nearby at Opito Bay; also the preforms rendered in chert. Personal observation revealed these to be in a rough ill-formed condition and their resemblance to Type 5 may be fortuitous.

In conclusion, the relative rarity of the Type 5 adze may be real but it is exacerbated by the rapid disappearance of the form once damage or breakage occurred. Additionally, the form could only be acquired by working new material; thus replacement would necessitate a return visit to the quarry or communication with exchange partners. Difficulty in replacement may have stimulated alternative solutions such as the rotatory sleeve at a quite early date in areas distant from raw material sources (Keyes 1971: 92). This may provide another explanation for their rarity.

Right-sided forms are markedly more frequent than left-sided forms. Of 90 Type 5 adzes recorded during this research, only 21.1 percent were left sided. For the functional experiments Bonica made both left- and right-sided forms and found that he favoured the left-sided adze. A probable explanation is that Bonica is left-handed.

TYPE 6 (Tables 1–11, Fig. 3b)

Chisels and gouges were very common but over half of the sample were reworked forms (not included in Table 1). Average dimensions of primary forms were 193 mm length, 112 mm blade width, 28 mm maximum width at mid-section, 33 mm thickness, 309 g weight, and 49 degrees edge-angle (Tables 2–6).

These tools were used for a wide range of generally detailed intricate tasks. The main action was gouging and chiselling. Tasks would have included surface decoration (carving), grooving, lashing holes/perforation and grooves, as well as shaping corners and apexes in objects like canoes, bowls and boxes.

Although Duff defines Type 6 adzes as tangless gouges and chisels of circular cross-section (1977: 190), the archaeological record demonstrates a wide variety in terms of size, cross-section thickness and shape, butt modification and edge-angle. All the small specimens were reworked forms and the majority were under 100 mm long.

Basically these were narrow-bladed tools with either a curved cutting edge for gouging or a straight cutting edge for chiselling. Their size and hafting facility were relative to the size and type of task. In New Zealand adze collections, they are generally small. The exception is the primary form — the long slender hogback gouge, which may have a specialised function in canoe making. These are quite rare in the archaeological record, reflecting their specialised role and greater vulnerability to breakage (after which they became smaller reworked chisels and gouges — some of the in-line type). They were common preforms at Wairau Bar, including two exceptionally long thin (350 mm long, 30 cm thick and wide; Fig. 3b) finely flaked, unground examples from Burial 39. The dominant material, both at Wairau and elsewhere, is D'Urville Island argillite, both for large primary examples and small reworked types (a further indication that small forms were reworked from larger ones).

Almost all slender gouges were back-wider-than-front forms with triangular cross-sections, the exceptions being two rounded specimens. As well as being significantly narrower, thinner and lighter that the robust Type 4, these slender gouges had significantly lower edge-angles.

Another distinctive type was the small, short deep-bodied gouges and chisels that could be slotted into in-line hafts and hammer-driven with a mallet. These forms needed robust cross-sections and edge-angles to withstand the impact of hammer blows for making lashing holes and deep grooves. Many resemble Type 4 in design because they were used in similar tasks but on a much smaller scale. One difference would be the manner of hafting. Mallet-driven gouges were, from ethnographic examples, slotted into recessed handles, and have less butt modification and more poll modification or/and evidence of haft polish on the poll from rubbing against the haft. In the archaeological record, many of these tools were broken and so lacked the diagnostic evidence to identify the nature of hafting. Bonica has demonstrated, however, that these adzes can be hafted in different ways depending on task requirements.

A range of other small, thin-sectioned, low edge-angled forms would probably be adequate for surface detail and decoration, and were probably hafted in the normal manner.

For mallet-driven gouges and chisels there is a need for particularly tough materials in order to withstand the considerable stresses imparted. For operations requiring a relatively high angle of attack (e.g., making lashing holes) blade corners are particularly vulnerable. One solution is to round off the corners completely so that no corner exists. Because of their vulnerability to breakage, long slender hogback gouges are also likely to be made of tough materials. Hardness is also valuable for these precision tasks, so we might expect a preference for highest quality materials.

From replication experimental results and from observations in the archaeological record, the majority of small chisels and gouges were the outcome of reworking larger primary forms like Type 4 or the slender hogback gouges. Reworking had a higher success rate and was a faster method of production than primary manufacture and was, thus, a viable method for producing these small forms. The nature of the hogback form also constrains its reworking flexibility so that little else but smaller gouges can result. This practice also freed adze-makers at quarries to concentrate their time and energy on the manufacture of large adzes that could not be produced from reworking. Also, small flakes, often the by-products of adze manufacture and reworking, were suitable for thin-sectioned chisels and gouges.

DISCUSSION

Drawing from considerable experience in studying Australian stone hatchets as well as making and using them, Dickson (1981: 99) states:

> Good workmanship is making an implement so that it will be well suited for its purpose without undue waste of effort… . There is wide scope for variation and compromise so many of the traits that can be distinguished and even measured have no meaning for the toolmaker… . It is necessary to look for essential design features, those that determine the suitability of the tool for its intended purposes.

This paper has demonstrated that while combinations of functional attributes remain consistent enough to identify a tool kit comprising six primary functional types, there is considerable morphological variation. Much of this variation can be related to the qualities of the raw materials used — including those used to make the adze — and how these raw materials influenced manufacturing techniques.

The East Polynesian immigrants brought with them an adze-manufacturing technology based on the flaking of fine-grained tough materials. But adze makers in New Zealand were confronted with a much wider variety of raw materials than they had hitherto experienced, thereby providing them with a greater range of technological choices. The technology they were familiar with, however, influenced the choices that were initially made regarding raw material selection, and generally saw a continuation of the adze production strategies that had been practised in the home islands. But experience with new materials, including new manufacturing materials, may have seen quite rapid adjustments, even supposing functional requirements remained the same. For example, a task requires removal of excess wood so a thick, heavy, high edge-angled adze with a secure hafting device is needed. Standardised adze types such as quadrangular 1A, central East Polynesian 3A and Southland 1D would all fulfil these functional requirements, yet they exhibit considerable morphological variability. These morphological differences primarily reflect technological adaptations to raw material constraints. The technological repertoire that developed in Southland, one that resulted in forms like Duff's 1D and 1C, was responsive to two major factors, the generally variable flaking quality of the stone materials available and the availability of an extremely effective hammer-dressing material — hydrogrossular garnet.

In Southland, there was therefore a strong motivation to convert from a flaking technology to one based on hammer-dressing, even for materials where the potential to flake adzes to shape existed. But flaking was not dismissed entirely from the repertoire. It was retained where it was effective and viable; for example, in the breaking up of large parent forms and in roughing out blanks to remove excess material quickly. Southland may thus prove to be an example that documents quite rapid changes in adze technology from the time of initial settlement. The influence of the hammer-dressing technology was evident on almost all the adzes made in Southland materials, including adzes from early stratigraphic contexts at sites like Waitaki River Mouth, Shag River Mouth, Pounawea and Papatowai. Indeed, it is possible that while adze-makers in the rest of the country were busily flaking their adzes to shape, the Southland artisans had already discovered the potential of lime garnet and were using it to advantage. The effectiveness of lime garnet is expressed by the degree of elaboration on Southland adzes; for example, deep tangs, chin ridges and large-sized adzes.

Lime garnet was also present in the Nelson/Marlborough area, but the availability of exceptionally high flaking quality D'Urville Island argillite saw the continuation of the flaking technology. The results were some of the largest and most finely made adzes in Polynesia. Lime garnet was not ignored, however, but again used to best advantage to provide a secure hafting device. Later, as use of the D'Urville Island quarries declined, lime garnet provided a solution to the problem of working the very tough, poor flaking, yet very accessible, river argillite and produced distinctive adzes like the chin-ridge form.

It is likely that the variability exhibited among adzes from other Polynesian island groups may reflect similar differences in raw material quality, including the nature and quality of manufacturing tools like hammer stones. For example, in Hawai`i where the use of hammer-dressing was rare and flaking the primary shaping method, Type 1 adzes have characteristically angulated profiles with offset tangs and steep sides (Brigham 1902: Plate LVI). In contrast, in Central East Polynesian islands like the Societies, Cooks and Austral Islands where hammer-dressing became the predominant method of shaping, features like raised chin and shoulder ridges, heavily reduced, well-defined tangs and hollow-ground bevels are common and often elaborately rendered. In his description of Southern Cook Island adzes, Duff makes frequent mention of hammer-dressing as the method by which these features were created (1974: 125–139). The distribution of lugged or 'horned' adzes also shows a strong correlation with island groups where hammer-dressing was the primary shaping method (Duff 1974: 125–130; 1977: Fig. 32, 153). Another outcome of hammer-dressing is the difficulty of achieving right angles, so that adzes with the front notably wider than the back prevail. This was a feature of Southland adzes, and the emergence of the triangular Duff 3A form in Central East Polynesia is probably not unrelated to the method by which they were manufactured. The often thick cross-sections, size and high edge-angles on these adzes suggest their suitability for performing tasks undertaken by quadrangular Type 1 adzes in New Zealand and Hawai`i (see Figueroa and Sanchez 1965: Figs 66, 71; Duff 1977: 173, Fig. 39 for illustrated examples).

We might, therefore, predict that in Central East Polynesia, raw material suitable for making adzes was of limited flakeability and was relatively soft, and/or that the adze-makers in these islands possessed a superior hammer-dressing material. Indeed, from geochemical analysis, Sheppard (pers. comm.) describes the basalt from the Cook Islands as being relatively soft because of a low silica content.

Equally, variability in adze kits may reflect different functional requirements that may relate to environmental factors such as the nature of the timber available for wood working. For example, some small islands in East Polynesia may have had limited timber resources (relatively small trees and/or a finite supply of them) that did not allow the manufacture of canoes in one piece. As in the Tuamotu Archipelago, canoes made of many planks may have been the solution (Haddon and Hornell 1936). The specialised adze kit with a dominance of large wide-bladed adzes in New Zealand may have a direct correlation with the availability of large, good quality trees in abundance and also the need for large sailing canoes to sail around New Zealand and possibly further afield. This may explain a startling characteristic of Pitcairn adzes. The very large collection at Auckland Museum, which I am currently analyzing, is characterised by a wide variety of narrow-bladed adzes (with a few notable exceptions!) — a major contrast to adze kits from early New Zealand. Such a tool kit, designed for a range of intricate specialised tasks like timber joinery, might be expected where canoes and other large items could only be made from multiple carefully fitted pieces (Bonica pers. comm.). Though the functional and manufacturing quality of the Pitcairn basalt is as yet unknown, the range of objects made from it, the adze forms, and the high quality and high angled flaking exhibited on many of the specimens suggest a material that may have been similar to D'Urville Island argillite. In support of this probability, Pitcairn basalt has the highest silica content of all the basalts found in Polynesia (Sheppard pers. comm.). Though this has yet to be substantiated by further research, it is a possibility that functional rather than manufacturing constraints could explain this notable aspect of Pitcairn adzes.

In New Zealand, it might also be possible that the hammer-dressing technology, which became the main shaping technique throughout the country in the late period, developed in the South Island first. While Classic Maori artefacts (in the terminology of Golson 1959) from the South Island are generally considered as an intrusion from the North Island, at least one author has considered that the reverse might also be the case (Davidson 1993: 251). Certainly it is possible that the Southland 1D adze was the first fully hammer-dressed adze form made from coarse-grained stone to be developed in New Zealand. The advantages of marrying such a technique to this type of stone would have become well known throughout the country, though it may not necessarily have been adopted until changes in social or/and environmental circumstances prompted responses to new conditions and solutions to new problems. The flaking technology involved high costs and placed high constraints on raw materials. It was therefore probably very vulnerable to adverse changes such as the depletion of high quality material at source areas (which may have led to critical increases in searching time), and disruptions in communication and distribution networks. The advantages of hammer-dressing were low risk, low skill, and low waste of material; adze-makers need not be tied to long periods at quarries as required by the flaking technique. Additionally, the hammer-dressing technology allowed the use of previously under-utilised raw materials. Of major significance, the hammer-dressing of coarse-grained tough materials was a much faster and more economic method of adze manufacture (as tested in replication experiments; Turner 2000).

There are also indications in the archaeological data that raw materials and adze designs were matched to maximise the valued qualities of each in terms of functional performance. In the North Island, local rocks that lacked the toughness of Nelson/Marlborough argillite and Tahanga basalt could be pressed into service for Type 4 adzes, a robust design more resistant to breakage and damage than others. Motutapu greywacke was probably valued for its hardness, a quality important in producing a particularly sharp cutting edge for cleaning down and shaving wood, an action that does not require excessive force, and this may explain why Type 2 is the most common form rendered in Motutapu greywacke. The heavy work undertaken by Type 1 adzes required them to be made of particularly tough materials, and this provides a reason why they were so scarce among Motutapu greywacke adzes, yet very common among adzes of Tahanga basalt and Nelson/Marlborough and Southland argillite.

The criteria employed by Duff to define his types were primarily the presence/absence of a tang and the shape of the cross-section. The results above suggest that while these criteria may be related to the functioning of the adze in general they do not define different functional types. Rather, again, both features reflect more the nature of the raw material and the manufacturing tools available.

The decision to modify the adze butt rather than the wooden helve to aid hafting security appears to have developed in East Polynesia, hence the importance Duff attached to it (Green 1971; Duff 1977). The finding of this research, that tangs are most commonly present on large adzes, may be more significant for understanding what motivated such a development. For in East Polynesia, adzes also became larger and longer (Leach 1993), possibly as a consequence of achieving higher levels of flaking skill due to the availability of higher quality raw materials (e.g., the Mauna Kea quarry in Hawai`i and the Tautama quarry on Pitcairn) and driven by functional requirements (for example, the need to improve and optimise canoe manufacture for increasingly difficult and challenging voyages of exploration and colonisation). Large adzes generally had functional benefits and improved durability — an important aspect with highly curated technologies (Turner 2000: 231–303). Butt modification may, therefore, have developed in response to the hafting difficulties posed by large adzes, and higher quality materials and increased flaking skill would have facilitated such a development.

The flaking technique and the tang feature were well developed by the time the East Polynesians colonised New Zealand, as was the trend toward large adzes. The tang feature retained its importance to scholars of New Zealand prehistory because, by the late period, tangs had all but disappeared, the role of providing hafting security having been transferred to the wooden helve. It was probably not a coincidence that adzes also decreased in size. Notably, distinctive late period forms that did retain tangs, for example, some Hawke's Bay adzes, were also large heavy quadrangular Type 1 forms.

Thus butt modification is not directly linked to specific task requirements. Rather, where a task requires the use of a large adze and high levels of force, the adze is more likely to be tanged. As demonstrated above, the type of tang and the degree of modification were generally guided by the nature of the adze materials and the tools used to shape them.

The shape of the cross-section is also of secondary functional importance. Of primary significance is the thickness of the section relative to length and blade width. The shape of the cross-section may be influenced more by raw material quality and manufacturing techniques than it is by function. Thus the Central East Polynesian triangular-sectioned 3A adze probably performed the same sorts of tasks as the quadrangular-sectioned adzes in Hawai`i and New Zealand, despite the difference in cross-section shape. Similarly, very narrow quadrangular forms could fulfil the same functional role as Type 4 if thickness-to-width ratios and edge-angles were comparable. The profiles showing the thickness and edge-angles on a variety of four-sided Hawaiian adzes (Brigham 1902: 408, Fig. 74) demonstrate a range of edge-angles from very robust (at least 60 degrees) to very low (less than 40 degrees). Low edge-angles are also matched consistently to thin rectangular cross-sections, as are thick quadrangular cross-sections to robust edge-angles. Notably, the largest adze thus far recovered from Hawai`i (555 mm long) is a thin rectangular low edge-angled Type 2 form (Brigham 1902: Plate LVII). Central East Polynesian triangular-sectioned adzes show similar variability in thickness and edge-angle with a consistent correlation between the thickness of the cross-section and the degree of edge-angle (Duff 1974: 129–135, Figs 62–67; Figueroa and Sanchez 1965: Figs 65–71). The focus on adze standardisation as reflected by cross-section shape has drawn attention away from the variability evident in functionally significant features. This has caused some problems for scholars who feel that changes in function must have accompanied changes from the variable 'Archaic' adze kit to the simplified 'Classic' 2B adze kit (Best 1975, 1977), or otherwise assert that different adze forms or 'types' do not represent different functional forms (Leach 1981: 168). Certainly the Type 5 adze is absent from the tool kit in later times and a change in canoe hull design may well be the reason (Best 1975, 1977; Moore *et al*. 1979). Replacements for adze forms like Type 4 and Type 3 remain unclarified, yet, judging from Classic period wooden artefacts, such adzes would still have been needed. However, it is likely that among the numerous tangless, four-sided adzes classified as 2B, considerable variability in size, blade width and curvature, cross-section thickness and edge-angle will be found that may well reflect the functional range of tools defined for the early period. Nor should we forget that a number of functional features seen on the stone blade in the early period were transferred to the wooden haft in the later period, for example, the hafting attachment. A composite haft would also provide significant length and weight to the stone piece. Furthermore, the use of coarse-grained rocks and the major technique used to shape these — hammer-dressing — generally places limitations on shape and size (the exception being when lime garnet is used).

The implications of these results suggest that the use of adze types to trace ancestral connections and culture-historical relationships, as Skinner and Duff attempted to do, is unlikely to be successful. Similarly, we can dismiss evolutionary models where one adze type is said to develop from another (for example, Duff 1977: 161, 176). Polynesian island groups shared an ancestral technological repertoire but this was probably very sensitive to new conditions, especially to the qualities of the raw materials available (stone and wood). The evident differences in adze morphology between Polynesian island groups closely related in time probably reflect rapid adjustments to raw material quality and availability.

There is also no need to require cultural isolation for differences to develop. We need only to look at the differences in New Zealand adzes owned by people obviously in close contact, for example, Southland and Nelson/Marlborough groups. At the Waitaki River Mouth site, which is centrally located between these two regions, adzes rendered in Nelson/Marlborough argillite and Southland materials were present in similar frequencies. The morphological distinctions evident in adzes imported from these regions reflected the different raw materials they were made of and the different techniques employed to make them (see Fig. 4, where equal numbers of adzes in Southland materials and Nelson/Marlborough argillite are illustrated). This may also explain morphological similarities between adze assemblages of different materials from sites hundreds of kilometres apart. For example, the Tahanga basalt adze assemblage from Bowentown at the mouth of the Tauranga Harbour in the North Island (Fig. 2) has close parallels to the Wairau Bar assemblage from the South Island, which is composed mainly of D'Urville Island argillite adzes (Fig. 3). Both assemblages contain adzes shaped predominantly by flaking and where hammer-dressing was generally limited to butt modification. One notable difference is the smaller size of the Tahanga basalt adzes, reflecting the superior flaking quality of D'Urville Island argillite. In contrast, the relative dearth of hammer-dressing on northern North Island primary adzes compared to their Southland counterparts produces marked morphological differences. Functional features were consistent, however, and the Southland 1D adze and the Tahanga basalt back-wider-than-front Type 1 adze would have performed the same sorts of tasks; the differences in form can only be explained by raw material variability and the properties of manufacturing tools.

Adzes were primarily designed to fulfil utilitarian roles. It is possible that adze-makers were only likely to persist in making adzes in the old way if the technological system continued to work, environmental conditions remained static, and costs stayed within manageable limits. But with tool efficiency and reliability as major goals, they would also have been motivated to make improvements in the management of costs, be it by adjusting or/and improving design, by finding a faster, safer more economic method of manufacture and/or by using a better material. It is likely that similarities in adze design and finish between Polynesian island groups will suggest a similarity in raw material quality (stone and timber); a close cultural relationship need not be invoked to explain this phenomenon.

Raw material quality also ultimately dictates manufacturing techniques. Understanding how raw materials operated in use and during manufacture, therefore, provides the means by which to account for much of the observed variability in Polynesian adze design.

Given these findings, and the emergence of raw material as an important factor in explaining adze morphology, we also need not invoke the rise of high-status specialists and high-ranking consumers to explain the event of major quarries and mega-adzes (Leach 1993: 41). Major quarries were major because of an abundance of high quality, flakeable raw material. Adze size, standardisation and distributional range reflect the benefits in manufacture and use of these high quality materials in which design ideals could be optimised.

Additionally, explanations wherein large adzes developed as "symbols of a community specialization" or "… constituted a new and desirable fashion" or were the exclusive property of high-ranking, high-status individuals or families (Leach 1993: 41) should be viewed with caution. Undoubtedly they were valuable and expensive but this should not be stressed at the risk of ignoring the most fundamental aspect of an adze — that they were tools, that they were designed as solutions to wood-working problems, and that with high quality materials these problems could be solved with maximum benefit (for example, the successful discovery and colonisation of new homelands). Functional experiments have shown that large adzes would have reduced the time and effort involved in large wood-working projects (like canoe building) to a significant degree. Increasing or maximising size can be considered as having important functional benefits and as possibly allowing wooden items to be built on a grander and more innovative scale. From adze distribution patterns (Turner 2000: 405–451) it is apparent that people were prepared to go to extra efforts to obtain these materials and the adzes made from them.

Status and mana would be more likely to result from the special wood-working abilities of adzes made of high quality major raw materials like D'Urville Island argillite. Southland 1D adzes would surely comply with Leach's criteria for identifying adzes from important major quarries — very large, standardised and with design extras like elaborately rendered tangs and chins — and could readily qualify as ceremonial high-status adzes. The same could be said of the elaborately hammer-dressed Central Polynesian 3A adzes, but in both cases, there is no known association with major quarries. The reason for this is that they reflect a different technology that produced little in the way of by-products, unlike flaking where, from replication experimental evidence, huge amounts of debitage can be generated in a very short space of time. It is not the 'major quarry' that is significant but the plentiful supply of high quality raw materials at these quarries.

While some were side-lined as burial goods, and some may have attained 'ceremonial' or heirloom status over time, many of the largest adzes recorded in New Zealand, for example a broken and modified Type 1 adze from Grovetown and a Type 2 adze from Patea with a damaged blade (see Turner 2000: 162), both over 500 mm long and over 5000 g in weight, had most definitely been used, and with a vigour that goes beyond ceremonial and ritual use.

Herein lies another explanation for the variability in adze morphology, the observation that only a small percentage of the total number of adzes examined in this research were in original or primary condition. From this small sample, the influences on primary adze design have been discerned, but the majority of adzes have seen considerable use, modification and reworking. Major changes in adze morphology were the outcome, especially after an adze had suffered transverse fracture and the pieces were subsequently reworked. Once this had occurred it was unlikely that adzes could be used in the tasks they were originally intended for. Critical loss of length, weight, blade width and edge-angle were problems that would have constrained use options. A problem with existing typologies is that they treat all adzes as being in primary condition, as original designs. Yet it is possible that some adze types were solely the outcome of reworking (for the early period these include many adzes often classified as Duff's Type 1B and 2B). Some design elements like flaring blades on wide-bladed adzes may have served not only to improve adze performance but also to facilitate repair of blade corner damage. Likewise, maximising length may have served to extend use-life.

Manufacturing methods and raw material quality may continue to be influential during the use-life of adzes. Flaking allows for effective and quick rejuvenation and reshaping but has the disadvantage of being wasteful. With length and blade width already critical on broken pieces, more conservative reshaping methods may have been desirable. Adzes made of high quality imported raw materials might have had higher rates of curation, and a greater range of reshaping options might have existed for adzes made of highly flakeable raw materials. As a result of being tougher and harder, adzes of D'Urville Island argillite, for example, may have had longer use-lives and retained their original form and function for longer. This would have further increased their value.

The implications of ongoing modification and reworking throughout the use-life of an adze pose problems for researchers formulating and applying typologies and classification systems to adzes. For example, at what point does a Type 1 adze cease to function as a Type 1 adze? At least two situations will immediately change the function of the adze: when it has snapped in half and is no longer big enough for tree felling or for work on large projects, and when the blade has suffered major corner damage so that it has to be flaked into a much narrower or shorter tool. The problem is a complex one and for adzes, at least, any workable typology needs to recognise both the functional status of the adze and the state (the degree of use and modification) it was in at the time of discard into the archaeological record. The state of the adze as a result of these curation processes also has a major influence on the value and status of the adze and how and in what context it might eventually be discarded in the archaeological record. For example, it is likely that primary adzes, particularly the more specialised forms (such as Type 3 and 5) might have spent significant periods in storage and been used only for specific and/or special projects. The felling of a tree for a large canoe using Type 1 and Type 4 adzes was probably not an everyday event. Once an adze was broken or badly damaged and developed the loss of symmetry that often accompanies repair and reworking, it may have been relegated to everyday tasks like firewood chopping or scrub clearing.

Recognising the state and function of an adze also has implications for understanding site function, even in the absence of any other evidence of the site itself (common with the many specimens in Museum collections). For example, the finding of primary adzes at a site immediately has at least two implications. One is that they represent a place where canoe building or other major wood-working took place, or, more likely, a place where adzes were stored — most probably in houses at permanent or semi-permanent settlements. Another possibility is that the adzes were recovered from burials, as well attested by the prominence of primary adzes and preforms from the burial grounds at Wairau Bar (Turner 2000: 238).

Very few purely decorative features were observed on adzes during this research; that is, features that did not serve or enhance any functional aspect of the adze. One rare example was the notching on the side corners of a very small number of adzes from the Far North (N = 6). The adzes with this feature were large Type 1 and 2 adzes — all but one (Tahanga basalt) made of Nelson/Marlborough argillite. At least two had suffered quite major blade damage, indicating that they had been used quite extensively.

But can it otherwise be said with confidence that adzes are the sum total of functional and manufacturing influences? More research of this nature needs to be conducted in other areas of Polynesia to explore and answer this question properly. An example is cross-section shape. In any given island group there does appear to be a selection for certain functional types to be given standardised cross-section shapes or for this to become standardised over time. In New Zealand, for example, both Type 1 and Type 2 adzes are consistently four-sided. While this shape does lend certain functional advantages to wide-bladed adzes, it is not a crucial operational element. Moreover, four-sides adzes generally pose a greater flaking challenge, often requiring difficult high-angled quadrilateral flaking. Yet, despite the documented wide variability in raw material quality and manufacturing techniques and constraints, this cross-section shape remains a consistent one throughout the country. It is possible that the functional advantages imparted by this shape and the greater manufacturing skill exhibited gave a certain edge to these products, many of which were involved in trade and exchange systems, thereby setting established standards of, and limits on, design.

Other design features that go beyond functional necessity are more obviously related to technological advantages. An obvious example is butt modification. Southland adzes can be said to be ‘over-designed’ with respect to hafting security, most exhibiting pronounced, extensively reduced and occasionally grooved tangs. The design feature illustrates (advertises?) the major technological advantage of the region — possession of a superior hammer-dressing material. But, together with other hammer-dressing elaborations like raised chin ridges, the design features also act as ‘badges of identity’ for the region; in other words, a distinctive regional ‘style’ of adze.

CONCLUSION

The six primary functional types outlined in this paper were standardised in terms of functional features such as length, thickness, blade width and edge-angle. Archaeological data were consistent with experimental results, confirming that within functional parameters, much of the variability in adze morphology and finish reflects solutions to different raw material and manufacturing problems.

Function dictated what features and dimensions were required but raw material and manufacturing techniques determined how these features were to be actualised. With the highest quality materials (superior flakeability, hardness, toughness) like D'Urville Island argillite, functional requirements could be optimised (for example, increases in length and blade width, lower edge-angles) and design ideals realised. Lower quality materials had weaknesses that needed to be compensated for. Problems may have been related to functional qualities or to difficulties producing the form required. Weak but hard materials like Motutapu greywacke imposed limits on size and on the amount of force used. In contrast, tough but relatively soft materials like coarse-grained greywacke were likely to have narrower blades and more blade curvature to provide greater protection to blade corners. Materials like the Southland and Nelson/Marlborough river argillite were impressively hard and tough but lacked the fine flaking qualities to enable this use potential to be realised in optimal form using traditional techniques like flaking. Technological adjustments involving an increase in hammer-dressing during the shaping process solved the problem. The Tahanga basalt adze-makers did not have this option and had to persist with the flaking technique. Where raw material qualities were optimal, we see elaboration of design elements, for example, grooves, ridges and knobs, with lime garnet hammer-dressing, and marked angulation and length with high quality flaking materials.

This paper has attempted to identify and describe functional and technological influences on adze form or type and how, together, they can explain much of the variability exhibited by early period adze kits. This paper also illustrates the importance of first isolating these influences before any discussion of style and fashion or of cultural relationships can take place with any degree of validity. Similar studies need to take place in other Polynesian island groups to clarify these issues further.

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