– ARTICLE –

The Source, Composition and Typology of 'Limestone' Adzes from Eastern North Island, New Zealand

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ABSTRACT

Collections of stone adzes (*toki*) from the eastern North Island of New Zealand include a number of typologically early (Archaic) forms made from what has been previously described as 'siliceous or silicified limestone'. Seventy five finished adzes and preforms of this material were recorded in the present study. Their geographic distribution is primarily restricted to southern Hawkes Bay – Wairarapa, and they apparently originated from a single manufacturing centre at Owahanga, on the northern Wairarapa coast. Chemical and mineralogical analyses (by X-ray fluorescence, portable XRF, vacuum gasometry and X-ray diffraction) of two artefacts from Owahanga show they contain about 20–30 per cent $CaCO_3$ (as calcite), while samples of the presumed local source rock have a slightly higher carbonate content but comparable silica (quartz) and Rb concentrations. The rock type used in the manufacture of adzes was therefore not a true limestone but calcareous mudstone, compositionally distinct from siliceous limestones in southern Wairarapa and probably derived from the Whangai Formation. Possible reasons for the use of this stone material are discussed.

Keywords: adzes, chemical analyses, limestone, calcareous mudstone, New Zealand, typology.

INTRODUCTION

In contrast to the islands of central and eastern Polynesia, where stone adzes were made almost exclusively from basaltic rocks (e.g. Weisler 1997), a wide variety of lithic materials were utilised during the early prehistoric (Archaic) period in New Zealand. Most adzes (*toki*) were manufactured from metasomatised argillite (*pakohe*), basalt and greywacke, but some other rock types were also exploited on a limited scale, including limestone (Davidson 1984, Turner 2000). Limestone, though, is a relatively soft rock and would generally be considered an unsuitable material to fashion useable stone tools from, so it is rather surprising that a substantial number of early adzes from the south-eastern North Island were made from what has been described as 'siliceous or silicified limestone' (Fox 1982, Davidson 1984, Turner 2005). No detailed account of these adzes has been previously published.

This paper presents new information on the distribution, source, composition and typology of 75 adzes and preforms made from what is here referred to for convenience as the 'Owahanga limestone'. The majority of adzes (adze heads) are held by the Hawkes Bay Museum (MTG), Napier, and form part of the regionally important Simcox Collection.

ADZE DISTRIBUTION

The known distribution of adzes and chisels made from 'limestone' (or highly calcareous sedimentary rock) in the North Island of New Zealand is shown in Figure 1. So far they have been recorded only from the southern half of the island, almost entirely from coastal or near-coastal locations. The greatest concentration is in southern Hawkes Bay-Wairarapa, but one adze has been found at Nukuhakari on the west coast, and another two in the eastern Bay of Plenty, at Opotiki and Waimana (Moore 1977). In addition, some small adzes apparently made from limestone pebbles have been collected in the Wellington area where the stone was possibly known to Maori as *kohurau* (Keyes 1969, Best 1974: 37). There are also several chisels from Mahia, in northern Hawkes Bay (Tairawhiti Museum collection, Gisborne). Not all of these adzes are composed of the same kind of calcareous rock: that from Nukuhakari appears to be made from hard, fine grained limestone, perhaps originating from the Marlborough region in the north-eastern South Island; the adze from Opotiki is composed of sandy limestone; and that from Waimana consists of white crystalline limestone probably obtained from a local source (Moore 1977).

In the South Island the use of limestone for adzes was very limited, and apparently confined to the Marlborough

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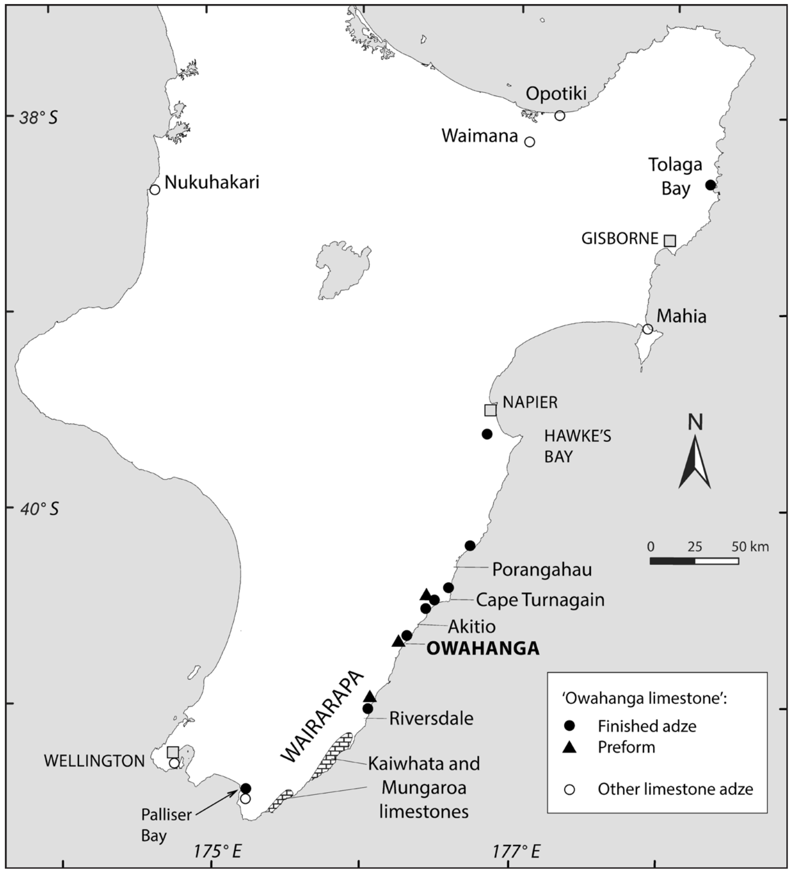

Figure 1. Distribution of 'limestone' adzes in the central-southern part of the North Island.

region where there is an abundant supply of hard siliceous Amuri Limestone. To date only a single finished example in this material has been recorded, from the Clarence River on the Kaikoura coast (Trotter & McCulloch 1979). On the remote Chatham Islands some adzes were made from dolomitic limestone (Sutton 1982).

Adzes composed of 'Owahanga limestone' are, as far as can be established at present, restricted to the eastern North Island (Figure 1). Finished adzes of this lithology have been recorded as far north as Tolaga Bay, and at least one example is known from Palliser Bay, at the southern end of the North Island (Leach 1977, 1979). The distribution of preforms is even more limited. Notably, there is no obvious association with outcrops of the hard, fine-grained siliceous Mungaroa and Kaiwhata limestones in south-eastern Wairarapa.

THE OWAHANGA SITES AND 'LIMESTONE' SOURCE

Many of the 'limestone' adzes (mainly preforms) were collected by Dr John Simcox, a local medical practitioner and farmer, at a site near the mouth of the Owahanga (or Aohanga) River in about 1950 (Figure 2) [Although Owahanga is the officially recognised name, Aohanga is still used by local people]. He described the site in his per-

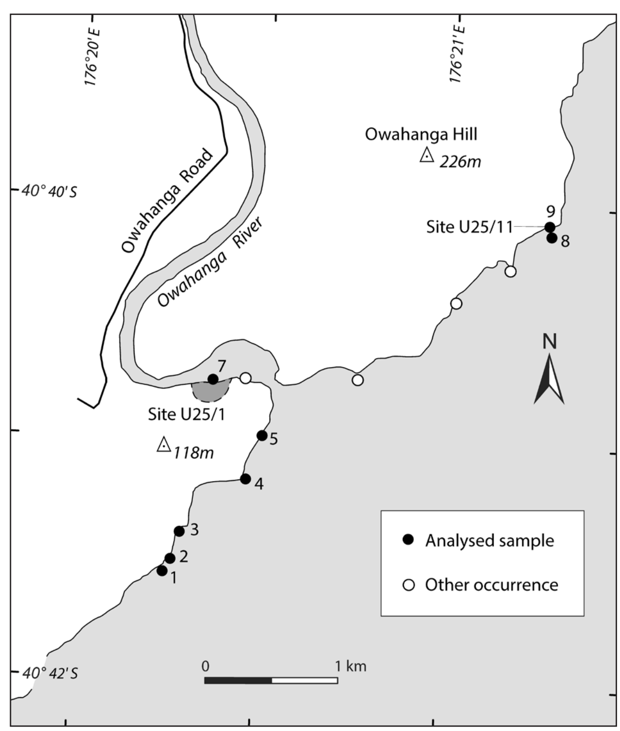

Figure 2. Map of the Owahanga area showing recorded archaeological sites and sample locations.

sonal notes as a 'small workshop' which had been exposed by wind erosion, containing 'many flakes, broken blanks, and several flaked adzes' of limestone (Millar 1993: 3). The exact location of this workshop is unknown, but it is presumed to have been situated near to or formed part of archaeological site U25/1, which was formally recorded by P.L. Barton in 1974 and classified as a possible habitation/ cooking area (source: *www.archsite.org.nz*). This site occupies an area of relatively flat land on the south side of the Owahanga River about 500 m from its mouth (Figure 3). Barton estimated the site may cover 1–2 acres (0.5–1 ha), though the basis for this is unclear. Several artefacts were collected at the time, including a small roughout chisel/ adze and two flakes, apparently all of chert, and another flake off a polished adze, but none made of limestone. Some additional chert flakes were found in March 2014 (personal observation) near the western end of the flat area, eroding out of greyish brown sand exposed in a 30 cm deep hole.

In March 2014 a second site (U25/11) was identified by PRM on the coast about 2.5 km northeast of the Owahanga River mouth, on a low promontory (Figure 2). Here a single broken preform (part of the blade only) was found on the ground surface among a group of large rocks. The nature and extent of the site are uncertain, but adzes were clearly being manufactured at this location. Boulders of the same lithology as the preform are relatively common along the adjacent foreshore.

The actual origin of the 'limestone' used in the manufacture of adzes at Owahanga has, until now, remained something of a mystery. This can be attributed in part to the lack of a reliable description or analysis of the rock, and also to some rather misleading information in the literature. Simcox referred to it as a siliceous limestone, but did not record how that was determined. He did write, however, that the limestone 'occurs in some coastal areas as the mother rock' (Millar 1993: 3), and thus seems to have been thinking of the prominent outcrops of Mungaroa Limestone in the White Rock-Tora area much further south (Figure 1). Several authors have also attributed the source to 'Akitio' (e.g. Leach 1977, Prickett 1979, Davidson 1984), a small coastal settlement about 10 km northeast of Owahanga, although the Simcox Collection does not include any limestone adzes or preforms from this location. Further uncertainty was introduced by Fox (1982: 64) in stating there were 'bands of silicified limestone ... used for adze manufacture' south of Cape Turnagain. This gave the impression (like Simcox) that such limestone actually outcropped somewhere along the coast between Akitio and Owahanga, and was similar in character to the Mungaroa and Kaiwhata limestones of south-eastern Wairarapa.

Detailed geological mapping has not resulted in the location of any significant outcrops of siliceous limestone in the area (Moore 1988a, Delteil et al. 1996, see also Lee & Begg 2002), although Neef (1992) identified some units of indurated calcareous mudstone inland, constituting part

Figure 3. View of the Owahanga River mouth and archaeological site U25/1 (centre). Vehicle for scale.

of the Whangai Formation. Turner (2000) regarded the source as detrital, and reported that high quality material ('silicified limestone') was distributed a considerable distance along the coast north and south of the river, much of it in the form of small cobbles and pebbles. She did not speculate on where the limestone had come from.

In a brief survey of the coastline in March 2014 cobbles and boulders of hard, light grey, creamy weathering calcareous mudstone were found at least 1.5 km to the south and 2.5 km to the north of the Owahanga River mouth (Figure 2). They are relatively uncommon, except in a few places such as near site U25/11. Many of the cobbles exceed 20 cm in size, and some of the boulders are >50 cm across. A few larger blocks >1 m were also recorded. One of these, about 2 m in length, consisted of individual layers (beds) up to 10 cm thick. A number of the cobbles and boulders showed evidence of boring by marine organisms (Figure 4).

The distribution of these rocks seems to coincide with the outcrop of well-bedded strata along the shore platform to the north and south of the river mouth, which are of Oligocene (Moore 1988a) or early Miocene age (Delteil et al. 1996, cf. Neef 1992). This stratified unit includes lenses of coarse sedimentary breccia containing clasts up to 2 m across of a variety of rock types, many of which appear to be derived from the Late Cretaceous-Paleocene Whangai Formation. It is likely that the cobbles and boulders of 'Owahanga limestone' have been eroded out of the breccias, and indeed one clast (*c.*15 cm diameter) of similar lithology was found *in situ* within a breccia outcrop north of the river mouth. The breccia-bearing unit is unusual and appears to be restricted to a thin strip along the Owahanga coast (Moore 1988a, Delteil et al. 1996), though given the complexity of the geology in southern Hawkes Bay and Wairarapa (Lee & Begg 2002) similar breccias might occur elsewhere in the region. We cannot, therefore, completely rule out the possibility that some of the adzes were manufactured from the same rock type but at other locations.

LITHOLOGIC DESCRIPTION

Fresh samples of the 'Owahanga limestone' are light to very light grey in colour (Munsell notation N7 to N8), while weathered surfaces vary from pale yellow (2.5Y 8/4) to yellow (10YR 8/6), pink (7.5YR 8/3) and reddish brown (Figure 4). Broken faces invariably show vague to distinct 'blotches', indicative of burrowing (bioturbation) of the original sea floor sediment by soft-bodied organisms, and some pieces display weak parallel lamination. Some also contain very thin dark to medium grey veinlets and/or lighter coloured calcite veins. Under a binocular microscope it is possible to discern fine sand-sized grains of quartz, rare mica and glauconite, spherical radiolarians, very rare organic material, and in a few samples, aggregations of tiny pyrite crystals. In terms of grain size the rock can be classed as a mudstone or sandy mudstone. Testing

Figure 4. Split block of 'Owahanga limestone' (circa 27 cm across) at locality # 1, showing interior (left) and rough, bored exterior (right) surfaces.

with 10 per cent HCl indicated it is calcareous but not necessarily a limestone.

One geological sample (from locality 8, Figure 2) was thin-sectioned, and shows that the rock is completely dominated by an extremely fine-grained dark matrix containing a few scattered coarse silt-sized grains of detrital quartz, feldspar and/or glauconite, rare pyrite, and isolated tests of siliceous and calcareous microfossils.

The adzes/preforms in the Hawkes Bay Museum have a very similar macroscopic appearance. Less weathered surfaces are predominantly light grey in colour (2.5Y 7/1–8/1) and more rarely grey (2.5Y 6/1), and tend to have a finely specked texture. The outer weathered cortex is generally white to pale yellow, and commonly finely pitted. A significant proportion of the adzes (at least 30 per cent) show faint to distinct bioturbation, and vague to distinct lamination is evident in about 20 per cent of them. At least 16 (35 per cent) contain thin grey veinlets and, in some cases, complex vein networks. Given these attributes, we are confident that the adzes are made from the same lithology as the geological samples collected from Owahanga.

ANALYSIS

No complete chemical analyses of the 'Owahanga limestone' have been previously published. However, semi-quantitative data for some indurated limestones were obtained by B.F. Leach in 1976 using a low-power XRF analyser at Oxford (Leach 1977). His pilot study included analyses of four flakes from 'Akitio' (provided by Hawkes Bay Museum) as well as an adze and flake recovered from the Washpool site S28/49 (N168/22) in Palliser Bay, and several reference samples. The results clearly indicated that the 'Akitio' flakes had a very different composition to that of the Amuri-type limestones in south-east Wairarapa, including a markedly lower Ca content. On this basis the adze from Palliser Bay was confidently attributed to the 'Akitio' (= Owahanga) source, while the flake was 'obviously derived from White Rock' (Leach 1977: 11).

Methods

Nine samples from the Owahanga area were selected for chemical analysis as part of the present study: seven of the probable source material (# 1- 4, 4A, 5, 8) and two artefacts, one a large flake (# 7) found beside the Owahanga River adjacent to site U25/1, the other a broken preform (# 9) from site U25/11 (Figure 2). These were the only two 'limestone' artefacts found in March 2014. A representative sample (# 10) of the hard, fine-grained, white Mungaroa Limestone from Tora, in southeast Wairarapa, was also included for comparison. This sample was obtained (*in situ*) from a coastal location, and therefore subject to a similar weathering regime. The main purpose of the analyses was to determine if the rock type used for adze manufacture at Owahanga was actually a limestone (i.e. contained >50 per cent $CaCO_3$), and whether the two artefacts were definitely made from local, not imported, stone material. No artefacts from museum collections were analysed as we wanted to test the suitability of both destructive and non-destructive analytical methods on material of known context.

The chemical and mineralogical composition of the Owahanga samples was determined by five different methods (see Tables 1–5):

1. Major and trace element analysis of whole rock sample surfaces by non-destructive, energy dispersive XRF (pXRF) using a portable Delta 50 kV Premium Exploration Analyzer at the University of Waikato. Samples were run for 60 seconds on Geochem Mode. The results for all ten samples are presented in Table 1.
2. Major and trace element analysis, using the same instrument, of a representative selection of six powdered samples (*c.*10 g) in plastic cups covered with a polyester film, chosen on the basis of the rock surface results as in (1). Powdered samples were obtained from less significant parts of the two artefacts (# 7, 9) by use of a drill with diamond-impregnated bit (8 mm diameter). The diamond bit was used in order to avoid any elemental contamination. The pXRF analyses of the six powders are recorded in Table 1.
3. Major oxide and selected trace element analysis of the same six powdered samples in (2) using the University of Waikato SPECTRO X-LAB 2000 polarising energy-dispersive X-ray fluorescence spectrometer. These XRF results are recorded in Table 2, along with those for the international limestone BCS-CRM 393 and Green River Shale SGR-1b standards.
4. An acidification vacuum-gasometric system at NIWA, Wellington, was used to determine the calcium carbonate content of the same six powdered samples (in (2) and (3)), following the procedure described by Jones & Kaiteris (1983). Results of two runs are given in Table 3, along with those for an Analar grade calcium carbonate sample.
5. X-ray diffraction (XRD) was used to determine the mineralogical composition of the Owahanga samples. Unoriented powder mounts were run on the same six samples used in (2) and (3) above, scanned from about 3–40°2θ on the University of Waikato's Philips X'PERT and Panalytical Empyrean Series 2 instrument, supported by X'PERT HighScore software. Qualitative results of mineral abundance are given in Table 4, based on the relative intensities of key diffractogram peaks along the lines described by Nelson & Cochrane (1970). Uniquely, each scan generates a pie chart giving an estimated amount of SiO_2% and $CaCO_3$% in samples. The latter can be compared with values obtained from the vacuum-gasometric runs in (4), as well as the theoretical values of $CaCO_3$% calculated from the pXRF and XRF Ca and CaO contents of samples analysed in (1), (2) and (3) above (Table 5).

Table 1. *pXRF analyses of rock surface and powdered samples for the major elements Si and Ca, and selected trace elements (Ba, Sr and Rb). Not shown here, but the measured pXRF value of Ca in the international limestone standard BCS-CRM 393 powder was 42%, equivalent to about 58% CaO, which compares well with its certified value of 55.4% CaO. The reported Si content for this standard is only 0.3%, below the limit of detection by pXRF. n=no. of analyses per sample (for n>1 average values are given).*

Sample	#1	#2	#3	#4	#4A	#5	#7	#8	#9	#10
Rock	n=1	n=1	n=1	n=1	n=1	n=1	n=4	n=1	n=2	n=1
Si%	23	24	19	21	21	26	39	22	46	8
Ca%	16	16	18	18	15	12	2*	13	0.3*	28
Ba (ppm)	1336	1337	1096	1177	1626	1448	2542	1007	895	614
Sr (ppm)	248	288	313	206	177	258	121	199	115	549
Rb (ppm)	13	19	12	13	9	26	14	14	21	7
Sr/Rb	19	15	26	16	20	10	9	14	5	78
Powder	n=3			n=2			n=3	n=2	n=2	n=2
Si%	27	–	–	25	–	–	42	30	39	9
Ca%	22	–	–	23	–	–	23	20	20	35
Ba (ppm)	1074	–	–	998	–	–	1894	927	620	635
Sr (ppm)	361	–	–	327	–	–	285	318	276	747
Rb (ppm)	18	–	–	19	–	–	23	25	26	9
Sr/Rb	20	–	–	17	–	–	12	13	11	83

* Unusually low Ca values for artefacts considered to be due to surface weathering and leaching of calcite

Table 2. *XRF analyses of major oxides and selected trace elements (Ba, Sr and Rb) compared to international limestone (Lst) and shale (Shl) standards. Tr = trace (<0.05%), ND = not detected, meas = measured. LOI = loss on ignition at 1050 °C.*

Sample	#1	#4	#7	#8	#9	#10	Lst Std*	Lst Std*	Shl Std*	Shl Std*
Wt%	n=1	n=1	n=1	n=1	n=1	n=1	meas	actual	meas	actual
SiO2	57.1	54.70	60.2	62.6	63.4	21.0	0.8	0.70	23.2	28.20
TiO2	0.1	0.10	0.1	0.1	0.1	Tr	ND	Tr	0.2	0.25
Al2O3	1.8	1.70	0.8	1.9	1.5	1.0	0.3	0.10	5.1	6.50
Fe2O3	1.2	1.10	0.8	0.8	1.3	0.6	0.1	Tr	4.0	3.00
MnO	Tr	0.10	Tr	Tr	Tr	0.1	Tr	Tr	Tr	0.30
MgO	0.5	0.60	0.1	0.8	0.2	0.1	Tr	0.15	4.8	4.40
CaO	24.9	26.00	16.7	21.3	14.2	45.4	57.1	55.40	7.6	8.40
K2O	0.3	0.30	0.3	0.4	0.4	0.2	0.1	Tr	1.5	1.70
P2O5	0.1	0.10	0.1	0.1	0.1	Tr	ND	ND	0.3	0.30
LOI	20.0	21.14	14.9	17.6	13.4	35.1	ND	43.20	ND	44.30
Ba (ppm)	318	273	342	237	114	169	51	51	249	290
Sr (ppm)	306	286	175	247	191	703	150	161	388	420
Rb (ppm)	14	13	13	17	16	6	1	–	81	83†
Sr/Rb	22	22	14	15	12	117	–	–	–	–

* Measured and actual oxide wt% in international limestone (BCS-CRM 393) and shale (SGR1b) standards. The measured values in these standards for the two main oxides reported here, CaO and SiO_2, are within 5% of their accepted values, while the values for the trace elements are mainly similar.
† Recommended (uncertified) value.

Table 3. *$CaCO_3$ (wt%) content of samples from acidification vacuum-gasometric analyses.*

Sample	#1	#4	#7	#8	#9	#10	Lst Std*
Run 1	40.4	42.4	27.8	33.5	23.5	74.2	97.3
Run 2	39.9	42.8	27.8	34.6	23.1	74.0	97.9
Average	40.2	42.6	27.8	34.0	23.3	74.1	97.6

*Limestone standard is AnalaR grade calcium carbonate

Results

The pXRF analyses indicate that Si and Ca are the only significant major elements (constituting >20–30 per cent) in all of the Owahanga samples, for both rock surfaces and powders (Table 1). The only other consistently detected elements were K and Fe, both in tiny amounts (< 0.4 per cent); notably, Al was not detected in most samples. This suggests that the dominant minerals in all samples are

Table 4. *Mineralogy of samples from XRD analysis, and estimates of SiO_2 and $CaCO_3$ content.*

Mineral/sample	#1	#4	#7	#8	#9	#10
Quartz	A	A	VA	A	VA	M
Calcite	C	C	M	C	M	VA
Feldspar	R	–	–	R	R	–
Illite/mica/glauconite	R	R	–	R	R	–
Calcite type	LMC	LMC	LMC	LMC	LMC	LMC
SiO_2% estimate*	65	62	83	71	86	23
$CaCO_3$% estimate*	35	38	17	29	14	77

Relative abundances: VA = very abundant; A = abundant; C = common; M = moderately common; R = rare. LMC = low-Mg calcite.
*Rough estimates from XRD software pie charts.

Table 5. *Comparison of $CaCO_3$ content from different analytical techniques.*

Sample	pXRF rock	pXRF powder	XRF*	XRD	Acid digest
#1	40	54	45	35	40
#2	40	–	–	–	–
#3	45	–	–	–	–
#4	44	57	47	38	43
#4A	36	–	–	–	–
#5	31	–	–	–	–
#7	5‡	59	30	17	28
#8	32	50	38	29	34
#9	1‡	49	25	14	23
#10	69	89	81	77	74

‡Low values for pXRF surface analyses of artefacts # 7, 9 considered to be due to weathering and leaching of calcite.
* All CaO attributed to $CaCO_3$.

quartz and calcite, an inference confirmed by XRD (Table 4).

The combined pXRF data for Si and Ca (from Table 1) are plotted in Figure 5, which shows three distinct groupings: (1) a high Ca/low Si group (Ca 25–35 per cent, Si <10 per cent) represented solely by sample # 10, from the Mungaroa Limestone; (2) a moderate Ca/moderate Si group (Ca 10–20 per cent, Si 20–30 per cent) represented by all geological samples collected from the Owahanga coast; and (3) a low to moderate Ca/high Si group (Ca 0–20 per cent, Si 40–45 per cent) represented by the two analysed artefacts, samples # 7 and 9. Despite the similar trends shown by the data, a notable difference is the much lower Ca content of the artefacts # 7 and 9 in the rock surface compared to the powder samples. We suggest that this results mainly from factors relating to analysis of outer rock surfaces, particularly weathering and leaching of carbonate. There are also some clear differences in Si content between the geological samples and artefacts. Nevertheless, tight clustering of the seven geological samples indicates there is limited variation in the overall composition of the 'Owahanga limestone'.

The more reliable quantitative XRF analyses (Table 2) also emphasise the dominance of SiO_2 and CaO in the Owahanga powdered samples, which together comprise between about 75 and 85 weight per cent. In addition, compared to the pXRF results the XRF data show the persistent occurrence of small quantities of Al_2O_3 (*c.*1–2 per cent), Fe_2O_3 (*c.*1–1.5 per cent), MgO (up to 0.75 per cent) and K_2O (*c.*0.3 per cent), as well as tiny amounts ($\leq$ 0.13 percent) of P_2O_5, TiO_2 and MnO (Na_2O was not detected in any of the Owahanga samples). The high SiO_2 and CaO values are consistent with the dominance of quartz and calcite in the Owahanga samples, while the small amounts of the other metallic elements support the co-occurrence of minor feldspar and phyllosilicate (clay) minerals that were identified in some samples by XRD (Table 4).

A plot of SiO_2 versus CaO (Figure 6) displays a generally similar trend for the Owahanga samples as seen in the

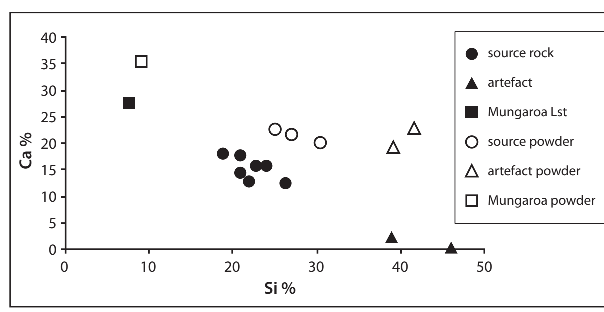

Figure 5. Plot of Ca versus Si for whole rock (solid symbols) and powdered (open symbols) samples determined by pXRF. Data from Table 1.

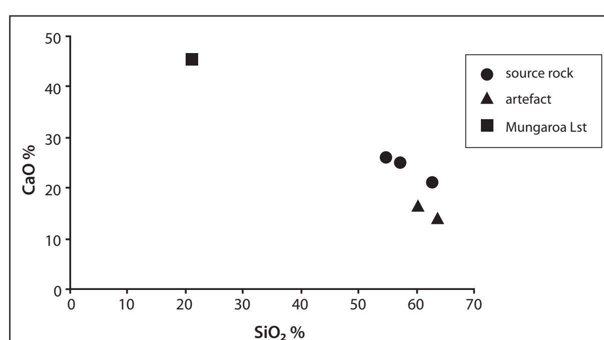

Figure 6. Plot of CaO versus SiO_2 determined by XRF. Data from Table 2.

pXRF plot (Figure 5), with distinct separation of the high CaO-low SiO_2 Mungaroa Limestone sample (# 10) from all others. However, unlike the clear separation seen in the pXRF plot based on Si content between the artefacts (# 7, 9) and geological samples (# 1, 4, 8), this distinction is far less obvious in the XRF SiO_2 versus CaO plot, although the artefacts do have somewhat lower CaO values (average *c.*15 per cent) than the geological samples (average *c.*24 per cent). They also contain less MgO (Table 2).

The precise $CaCO_3$ contents determined by the acidification-gasometric technique (Table 3) are plotted in Figure 7. These support the XRF CaO values and trend shown in Figure 6. Mungaroa Limestone (# 10) has by far the highest $CaCO_3$ content (average 74 per cent), the Owahanga geological samples (# 1, 4, 8) range from 34–43 per cent, and the artefacts (# 7, 9) contain 23–28 per cent $CaCO_3$. Significantly, the sample closest in $CaCO_3$ (and SiO_2) content to the artefacts is # 8, which was collected near site U25/11, where the preform # 9 came from (Figure 2).

Some of the XRD spectra show a small clay peak at about 10Å, indicating the presence of illite/mica and/or glauconite. In all spectra the position of the main calcite peak (e.g. see Chave 1954) indicates it is low-Mg calcite with <2 weight per cent $MgCO_3$, consistent with the known mineralogy of the main carbonate microfossils typically found in fine-grained, deep-water sedimentary rock facies, namely planktic foraminifera and nannofossils. While silt and clay-size detrital quartz probably accounts for much of the SiO_2 content in the Owahanga samples, undoubtedly a proportion will also have been contributed from scattered siliceous microfossils (e.g. radiolarians, diatoms) in the same facies, which have undergone recrystallisation from opaline silica to microquartz.

The only trace elements that appear to be of value in characterisation of 'Owahanga limestone' are Sr and Rb,

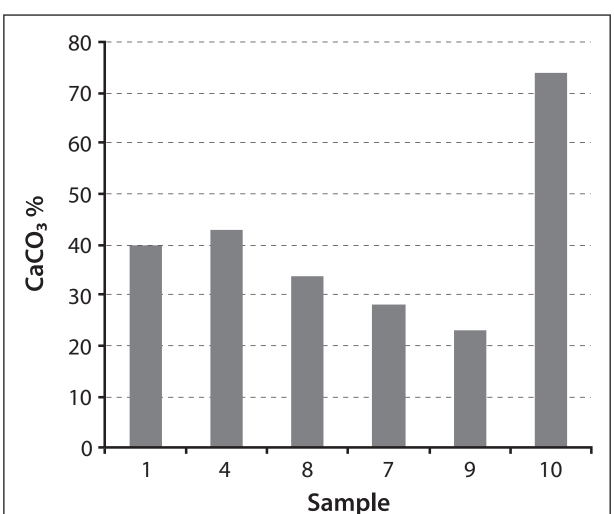

Figure 7. $CaCO_3$ content of powder samples determined from vacuum-gasometric analysis. Data from Table 3.

both of which can be measured with relatively high precision by pXRF. Limits of detection for these elements are <5 ppm. Analyses of rock surfaces by pXRF indicate that the two artefacts have the lowest Sr content, corresponding to their very low Ca percentage, though this is less evident from the powder samples (Table 1). This would suggest that while the low Sr values are mainly due to the leaching of calcite, there could be a slight difference in the composition of the artefacts, which is also supported to some extent by the Ba values. On the other hand Rb levels remain relatively constant across all analyses. Of particular note are the very high Sr and low Rb concentrations in the Mungaroa Limestone (# 10), resulting in a significantly higher Sr/Rb ratio than the 'Owahanga limestone'.

In terms of rock nomenclature, only the Mungaroa Limestone sample is a true limestone (>50 per cent $CaCO_3$); it could also be called a siliceous limestone. It is not argillaceous. All other samples are dominated by SiO_2 (55–63 per cent) with subordinate $CaCO_3$ (23–43 per cent), and compositionally can be classified as calcareous siliceous mudstones. However, the XRD spectra and low Al_2O_3 values indicate they contain little argillaceous material, so the clay and silt-sized material (i.e. mud) forming the 'matrix' must be represented primarily by crypto- to micro-crystalline quartz (dominant) and calcite. Thus the name 'Owahanga limestone', while convenient, is clearly inappropriate.

Comparison of the $CaCO_3$ results obtained by the five different methods (Table 5) shows that the values from pXRF analysis of whole rock surfaces are remarkably close to those determined by acid digestion, except where samples are weathered (# 7, 9). The pXRF results for powder samples, however, are consistently high, and in the case of the two artefacts about twice that of the true $CaCO_3$ value, which may be due to matrix effects associated in particular with slightly weathered material. In contrast, the XRF values are in good agreement (bearing in mind that all CaO was attributed to calcite), while the XRD estimates are also quite similar, apart from the artefacts. Values for the Mungaroa Limestone are reasonably consistent across all methods.

The carbonate content of the Owahanga geological samples and artefacts is very similar to that of the calcareous Porangahau Member of the Whangai Formation, which is typically about 20–40 per cent (Moore 1988b). This supports the initial visual identification of the rock samples as likely being derived from the Whangai Formation. In comparison, previous analyses of the hard siliceous Kaiwhata and Mungaroa limestones in southeast Wairarapa indicated they contain between 66 and 83 per cent $CaCO_3$ (n = 9), and average about 75 per cent (Moore 1976), which is in good agreement with the value (74 per cent) obtained by acid digestion for the one sample of Mungaroa Limestone analysed in the present study.

In summary, the chemical and mineralogical analyses indicate the two artefacts are sufficiently close in composition to the geological samples collected from Owahanga to accept they were manufactured from the local 'Owahanga limestone' (which in reality is a calcareous mudstone). Differences in Ca, Si and Sr concentrations in particular can probably be attributed mainly to surficial weathering and leaching of carbonate from the artefacts, as well as to matrix effects associated with pXRF. However, we cannot exclude the possibility that some artefacts were made from cobbles or blocks of calcareous mudstone of slightly different composition.

Figure 8. Type 4 adze from Makaramu, southern Hawkes Bay. Simcox Collection, Collection of Hawke's Bay Museums Trust, Ruawharo Tā-ū-rangi, 66/135. Adze is 22 cm in length.

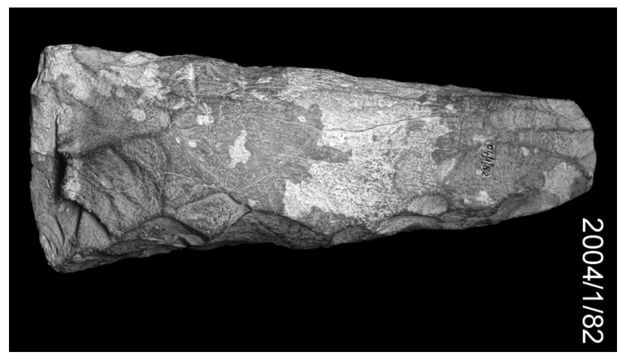

Figure 9. Type 3 preform (front view) from Whareama River, Wairarapa. It has a smooth transverse depression between the blade and butt (lighter coloured area) which may have resulted from hafting. Collection of Hawke's Bay Museums Trust, Ruawharo Tā-ū-rangi 2004/1/82. Adze is 19 cm in length.

SIZE AND TYPOLOGY OF ADZES

Altogether 75 'Owahanga limestone' adzes and preforms were recorded in museum collections. The majority of these are held by the Hawkes Bay Museum, and a further five (from 'Aohanga') by the Whanganui Museum. Another four adzes in the Hawkes Bay museum have no provenance but were almost certainly found in Hawkes Bay and are therefore included in this study. Of the total, 29 (39 per cent) are finished or near-complete adzes, and 46 (61 per cent) are preforms, collected mainly from Owahanga. Two examples are shown in Figures 8 and 9. Details of 26 finished adzes in the Hawkes Bay Museum collection are provided in Table 6.

Size and technology

The lengths of both finished adzes (and chisels) and preforms are illustrated graphically in Figure 10. They show a considerable size range, though the majority of finished adzes are between 75 mm and 150 mm in length (predominantly 100–125 mm), with very few of larger size. In contrast, most preforms are <100 mm long. Thus the production of larger adzes >150 mm in length was quite limited, and the greatest success in conversion of preforms into finished adzes was in the 100–150 mm size range. One of the larger preforms (66/181) weighs about 2.3 kg.

The adzes were produced by flaking followed by complete or partial hammer-dressing, particularly on the butt. Generally only the bevel and all or parts of the blade were polished. Examination of the preforms indicates some were made from elongate slabs (e.g. 66/182), while others were manufactured from large flakes (e.g. 66/184, 69/136).

Typology

The typology of the adzes and preforms was determined with reference to the classification system established by Duff (1956) and subsequently modified by Turner (2005). Most of the finished adzes are of the rectangular-sectioned Type 2 (n = 11) and triangular-sectioned Type 4 (n = 8). There is only one Type 3 adze (95/37), which is a relatively rare form in general (Turner 2005). None of those classified as Type 2 can be reasonably regarded as being of the 'late' 2B variety. The only other category certainly represented is Type 6, which comprises chisels and gouges. Interestingly, just one definite Type 1 adze (66/165) has been recorded (cf. Turner 2000). Although Fox (1982: 65) referred to the existence of a Type 1A adze with lugs (66/156) in 'local limestone' from Porangahau, Simcox (Millar 1993: 5) considered this example was possibly made of quartzite, and in the Hawkes Bay Museum catalogue it is tentatively recorded as argillite. Re-examination of this adze revealed that although it is of Type 1A form, it is composed of metasomatised argillite.

Only about 16 of the 48 preforms (35 per cent) could be confidently assigned to types. A further 12 were tentatively included under specific types, but 14 (30 per cent) were not able to be placed in any group. Seven, including the one from site U25/11, were broken. In many cases typology was based solely on the rough shape of the cross-section, which was generally either rectangular to sub-rectangular or triangular to sub-triangular. Those in the former category were probably intended to become Type 2 adzes, whereas the final form of the latter would almost certainly be Type 3 or Type 4. Only those with undoubted reverse triangular sections (i.e. apex facing to the back)

Table 6. *Dimensions (mm) and typology of 26 finished 'limestone' adzes held by Hawkes Bay Museum.*

Museum no.	Locality	Type	Length	Width	Thickness	Blade width
37/976	Hastings	2A	167	66	33	64
38/403	Mangaheia (Tolaga Bay)	2	115	31	24	37
66/134	Makaramu	4	137	42	45	*c.*27
66/135	Makaramu	4A	224	56	66	23
66/138	Orui (Riversdale)	4A	164	35	35	12
66/139	Blackhead	4	146	29	28	11
66/142	Pakuku (Herbertville)	1A/4A	138	42	36	38
66/143	Pakuku	4	123	34	29	28?
66/144	Pakuku	4	120	30	32	12
66/163	Blackhead	2	105	41	28	50
66/165	Burnview	1B	92	47	20	50
66/171	Owahanga	2	86	25	11	25
66/172	Waimata	2	80	26	12	34
66/173	Burnview	2	75	22	13	26
66/174	Oruhi	2	76	27	19	27
66/178	Pipibank station	6	74	14	14	10
66/202	Owahanga	2	105	40	21	39
67/514	Whangaehu	2	nd	–	–	36
67/652	Owahanga	2	111	55	27	nd
85/76	Owahanga?	1?	>118	50	33	55
2002 /9/1	Taikura (Blackhead)	4A	231	57	73	36
2002 /9/10	Taikura	2	79	33	16	39
377	?	1 or 2	247	73	51	65
53/168	?	6	nd	–	–	–
60/150	?	4	155	30	32	16
95/37	?	3	155	42	28	*c.*45

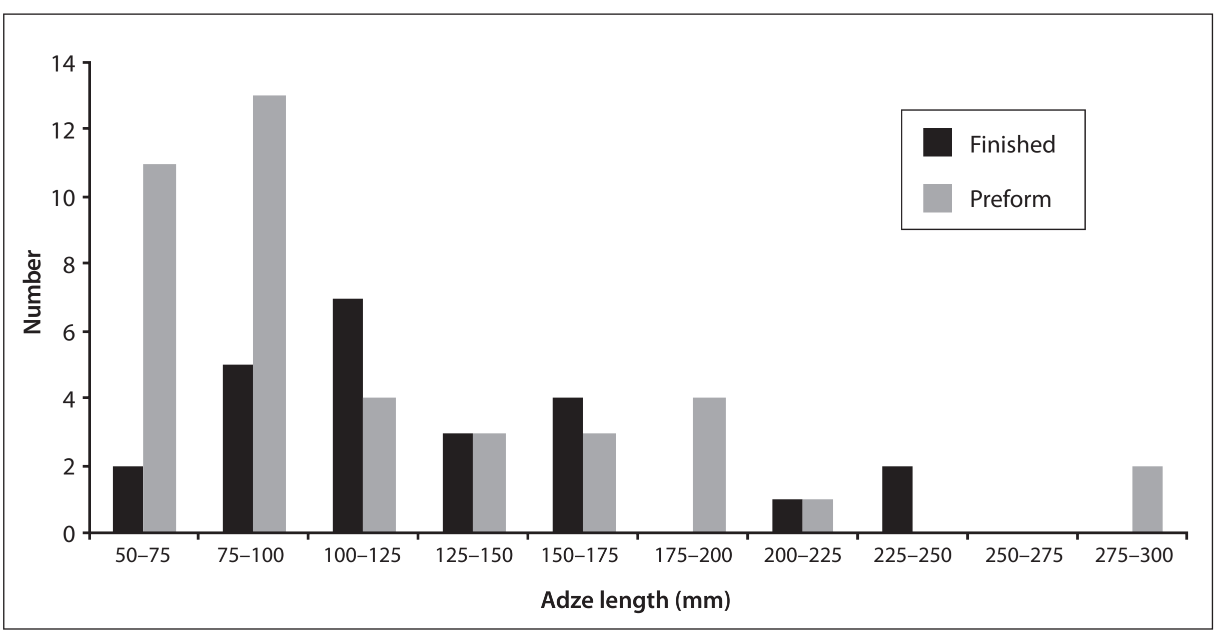

Figure 10. Size of 'limestone' adzes and preforms (n = 65). See also Table 6.

were assigned to Type 3 (Figure 9). None appeared to be of the side-hafted Type 5.

It is useful to compare the proportions of different types of finished adzes and preforms, despite uncertainty over the typology of many of the latter (Figure 11). Although Type 2 is clearly the most common form among finished adzes, it does not appear to have been the dominant type produced at Owahanga, where preforms with triangular cross-sections (Types 3 and 4) are slightly more numerous. The majority of these seem destined to have become Type 3 adzes, yet only one finished Type 3 was recorded, which is in good agreement with Turner (2000: table 5.4). In contrast, while Type 4 preforms make up only about 10 per cent of the Owahanga assemblage, this type is well-represented among the finished adzes. The differences in the relative proportions of types between preforms and finished adzes are unlikely to be related to collection bias, and suggest that while there was relatively good success in producing Type 2 and Type 4 adzes, there was a high failure rate among Type 3 forms, some of which may have been reworked into chisels or gouges (Type 6). The very low number of Type 1 preforms and adzes may reflect a difficulty in producing this particular form in 'Owahanga limestone', as Type 1 adzes made of metasomatised argillite are relatively common along the southern Hawkes Bay coast (Hawkes Bay Museum collection).

It is worth noting the differences in typology of primary finished limestone adzes recorded by Turner (2000, 2005) from the Hawkes Bay-Wairarapa region (Table 7). In her PhD thesis (Turner 2000), the figures for most adze types are in reasonable agreement with those determined in this study, except for Type 2 and Type 6 (chisels). However, in Turner's later publication (Turner 2005, her table 7), in which typology was based on adze function, it seems that most Type 2 adzes were considered to be chisels, and predominantly reworked forms.

Of other adzes collected from Owahanga two are Type 3 forms, one made from metasomatised argillite (and probably reworked) and the other of Tahanga basalt (66/147, 66/149). Another, in the Whanganui Museum, is a large preform of grey-black argillite, probably a Type 1 or 2. There are also three small argillite chisels, one of which is a preform (1941.39.1). These provide good evidence that adzes of other materials were being imported in finished form, and possibly also manufactured, at Owahanga.

Adze function

Observations were made on the degree of damage to the cutting edge on 21 of the finished adzes. It is assumed the damage is the result of use prior to discard or loss of the adze, but in some cases might have occurred during collection or subsequent storage and handling. Only about 12 (50 per cent) showed some chipping of the edge, although this was severe on two examples (66/174, 67/652). At least 10 (40 per cent) had no indication of damage, which suggests that a significant proportion of the adzes were unused, or more likely that the cutting edge had been reground. Edge angles were measured on four adzes, all of Type 2. This varied from 55° to 65° (average 60°), which is unusually high compared to the values (29–46°) reported by Turner (2005: table 6) for Type 2A adzes, and tends to support the idea that many cutting edges had been rejuvenated. On one of the finished adzes from Owahanga

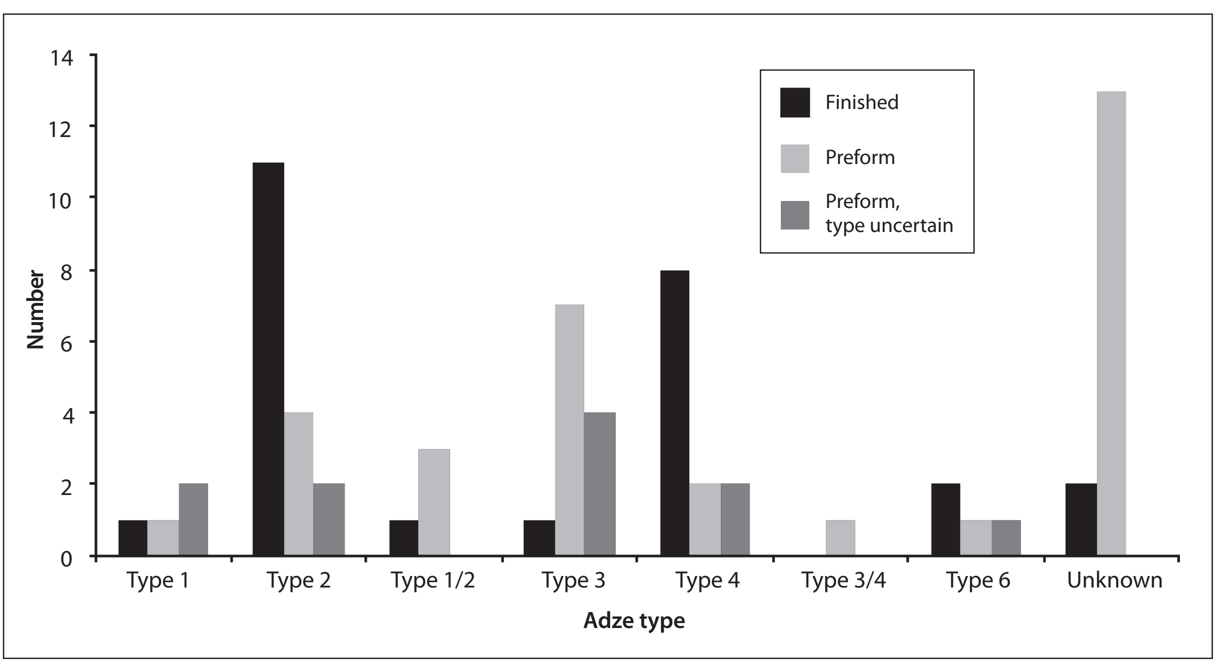

Figure 11. Proportion of 'limestone' adzes of different typology.

Table 7. *Typology of finished 'limestone' adzes according to Turner (2000, 2005) and this study.*

Typology	Type 1	Type 2	Type 1/2	Type 3	Type 4	Type 6	Unknown	TOTAL
This study	1	11	1	1	8	2	2	26
Turner (2000)	0	6	0	1	8	6	0	21
Turner (2005)	1	1	0	0	7	10	0	19

(66/202), which has an edge angle of 55°, the blade had obviously been reground.

It is not clear what the 'limestone' adzes were used for, as the relatively soft nature of the rock would not make them particularly effective on hard materials. Turner (2005) considered that primary Type 2 adzes were used for dressing and trimming timber, while the heavier, narrow-bladed Type 4 was employed in scarfing, gouging, splitting and making v-shaped cuts into wood. In the absence of any experimental studies involving this material it is difficult to know how well the adzes would have performed in the working of timber.

PERIOD OF EXPLOITATION

Although no excavations have been undertaken at Owahanga, some indication of age is provided by the style of adzes produced (see Duff 1956, Davidson 1984). Based upon the predominance of preforms with triangular cross-sections, and the number of finished Type 4 adzes, the 'limestone' was clearly exploited during the early (Archaic) period of settlement, before about 1500 AD. Early occupation at Owahanga is also supported by the collection of two other adzes from the area, both of which are Type 3 forms. The one made of Tahanga basalt (66/149) was found 'near the site of the supposed Moa-hunter workshop' (Millar 1993: 15), and thus most likely at or close to site U25/1. The lack of any definite Type 2B adzes suggests that the Owahanga source was not utilised during the later 'Classic Maori' period.

So far only one limestone adze has been recovered through well-controlled excavation, at Palliser Bay. The adze, a small Type 2? probably made of 'Owahanga limestone' (Leach 1977), was obtained from the lowest stratigraphic level of the Washpool Midden site S28/49. This level was originally dated to the late 12th century (Leach 1979), but considering that initial settlement of New Zealand is now thought to have occurred in the late 13th century (Wilmshurst et al. 2008), such an early date seems unlikely. Another limestone adze, found at site S28/52, is broken but probably also a Type 2 (Leach 1979 fig. 12F). However, this site was not excavated and there are no published details concerning the context of the adze. Prickett (1979) also recorded flakes and pieces of 'silicified limestone' from a further four sites in Palliser Bay, though whether any of this material originated from Owahanga is unknown.

Additionally, flakes of 'white limestone' have been reported from a number of other sites along the eastern Wairarapa coast (McFadgen 2003: appendix 1). The type of limestone is uncertain, and it is not known if these flakes represent debitage from the manufacture/reworking of adzes or intentional flake tools. At one site (U26/24) near Mataikona about 15 km south of Owahanga, containing unspecified limestone artefacts, the lowest cultural layer probably dates to the 15th century (Cairns & Walton 1992).

There is a reasonable indication then that the 'Owahanga limestone' was exploited sometime between the late 13th and 15th centuries. It may have been utilised only for a very short period.

DISCUSSION

Although a number of authors have referred to the 'limestone' adzes of southern Hawkes Bay – Wairarapa (Prickett 1979, Fox 1982, Davidson 1984, Turner 2000), no consideration has been given to why a relatively soft rock would be used to make such essential stone tools. Two possibilities come to mind: (1) a desire to determine if local rock was suitable (i.e. experimentation), and/or (2) difficulty in obtaining finished adzes from elsewhere. Both of these options would perhaps imply a degree of isolation of the Owahanga community.

We might assume that the 'Owahanga limestone' was utilised simply because it was easily worked, but although the rock flakes reasonably well it is brittle and not particularly durable. The large number of preforms of indeterminate type found at Owahanga also suggests there was a high failure rate during the initial flaking stage. In particular it seems to have been difficult to produce larger adzes, especially of the quadrangular-sectioned Type 1. Nevertheless, an attempt was made to produce almost the full range of early adze forms, other than the side-hafted Type 5.

Experimentation with the 'Owahanga limestone' may be at least partly attributable to the scarcity of other suitable materials in the south-eastern North Island from which to manufacture adzes, apart from greywacke. Certainly the only rock types that are sufficiently hard and fine-grained to be easily worked by flaking techniques are chert and the siliceous limestones of south-eastern Wairarapa. However, chert seems to have been more suited to chisels and flake tools, and although there was some use of 'siliceous limestone' at Palliser Bay (Prickett 1979), there is no indication it was utilised for adzes.

The exploitation of 'Owahanga limestone' seems to have gone well beyond the point of mere curiosity. The production of at least 29 finished adzes and chisels, and probably far more than 45 preforms, suggests there was a necessity to make useable tools from this material, even if it meant having to frequently rejuvenate the cutting edges. This might indicate some difficulty in acquiring superior metasomatised argillite adzes, due perhaps to limited involvement in exchange networks operating in the eastern North Island at the time. Yet many argillite adzes have been found along the southern Hawkes Bay – Wairarapa coast, particularly at early sites north of Owahanga (Fox 1982). Communities at Palliser Bay also seem to have had ready access to argillite adzes, although notably many were reworked (Prickett 1979). A demand for adzes made from inferior local materials could also be generated by an increase in population, the development of more permanent but isolated settlements, and a greater focus on agriculture.

None of these options on its own satisfactorily explains why this particular lithology was exploited. But the fact that the 'Owahanga limestone' occurs in a coastal situation, in the form of easily worked cobbles and boulders, at an ideal place for settlement, may have been important. Similar reasons are inferred for the small-scale utilisation of isolated occurrences of basalt and andesite in the north-eastern North Island, in relatively close proximity to the major Tahanga basalt source (Moore 2014).

CONCLUSIONS

This study has confirmed that adzes made of 'siliceous limestone' are largely restricted to the south-eastern North Island. Most if not all originate from a small manufacturing centre at Owahanga, on the northern Wairarapa coast, where an attempt was made to produce a range of typical East Polynesian adze forms. The main types produced were Duff Type 2 and Type 4. Although limited damage on the cutting edges of finished adzes would suggest that few were actually used, the edges were almost certainly rejuvenated. The adzes may have been best suited to lighter wood-working tasks.

Chemical and mineralogical analyses of two artefacts (a broken preform and large flake) collected at Owahanga indicate they are not actually composed of limestone but calcareous mudstone containing 20–30 per cent $CaCO_3$ (as calcite), probably derived from the Whangai Formation. These artefacts have a lower carbonate content than that of the probable local source rocks (30–45 per cent $CaCO_3$), which can be attributed mainly to weathering and leaching of calcite. The silica (quartz) content of artefacts and source rocks is similar (55–63 per cent SiO_2), as is their K_2O and Rb concentration and Sr/Rb ratio. In contrast, the Mungaroa Limestone in south-eastern Wairarapa has a much higher $CaCO_3$ and Sr content, and therefore was not the lithology used in the manufacture of adzes at Owahanga. The results also demonstrate that while complete quantitative XRF analysis of fine-grained calcareous rocks is preferable, portable non-destructive pXRF can provide useful 'ball-park' values as long as weathering is minimal.

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