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The Changing Proportions of Mayor Island Obsidian in New Zealand Prehistory

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ABSTRACT

New Zealand has about 18 sources of obsidian. The hypothesis that one of these, that on Mayor Island, was discovered first and that in the course of time the proportion of this type fell off as other sources were discovered, is widely accepted. Samples of obsidian from 65 New Zealand sites were evaluated to test this hypothesis. A new maximum likelihood regression model was devised to take account of variable errors in both dating of sites and the proportion of Mayor Island obsidian present. It was found that only 37 of the original list of 65 conformed to the regression model. There is no obvious culture-historical pattern in which sites do or do not conform to the regression relationship. It is concluded that while in general terms a correlation exists between age and proportion, in practical terms the proportion of Mayor Island obsidian in a site is not a useful guide to its age, and may be highly misleading. The idea that the Mayor Island source was discovered first cannot be substantiated on present evidence. The maximum likelihood regression model that was developed has wider potential applications in archaeology. It is argued that the earliest known archaeological sites suggest extensive geological knowledge by the 12th century A.D., and that this feature, coupled with recent evidence of a low net birth rate, indicates a lengthy period of settlement before this.
Keywords NEW ZEALAND, OBSIDIAN, REGRESSION, MAXIMUM LIKELIHOOD

INTRODUCTION

In 1964, on the basis of information collected from 29 archaeological sites, Green predicted that when more was known of the different obsidian sources in New Zealand, and a method for sourcing the archaeological material was perfected, a relative chronology of sites could be advanced based on seriation analysis. Furthermore, Green argued that "if a site is not too close to Mayor Island, one sign of an early date is a high proportion of Mayor Island obsidian" (Green 1964:139).

Since Green's paper appeared, great strides have been made towards the development of methods for sourcing obsidian in New Zealand (Green *et al.* 1967; Reeves *et al.* 1973; Armitage *et al.* 1972; Coote *et al.* 1972; Ward 1972, 1974a, 1974b; Leach 1977a, 1977b; Leach and Fankhauser 1978; Leach *et al.* 1978), and during the same interval many more archaeological sites containing obsidian have been excavated. These advances, however, have not been accompanied by widespread sourcing of obsidian artefacts, nor indeed by any re-evaluation of Green's original hypothesis. About 500 obsidian artefacts have been accurately sourced using such techniques as trace element analysis, and this work has disclosed the common sources that were being used by prehistoric man in New Zealand (Smith *et al.* 1977:176; Reeves and Ward 1976). These accumulated data are not sufficient to make New Zealand-wide comparisons of changes in source utilisation through time. Instead, a re-assessment of the hypothesis today must still rely on the original assumption that all green coloured obsidian derives from Mayor Island. This assumption is potentially hazardous since green obsidian is known from other obsidian sources. Nevertheless, so little of these kinds have been detected in archaeological assemblages (Leach and Anderson 1978) that it is reasonable to use this premise for the comparative purposes of the present study. When an archaeologist wishes to identify the full range of sources represented in an archaeological site, this assumption is not justified.

Green's obsidian sample consisted of 2,800 pieces from 29 sites and to this sample a further 11,778 artefacts from 26 new sites may be now added. The two largest samples comprise 3,525 artefacts from the Washpool Midden site (N168/22) and 3,150 from the site of Houhora (N6/4; Best 1975). Thus, information is currently available for 65 assemblages giving a combined total of 14,578 obsidian artefacts. The age of these assemblages and the proportion of green obsidian in each is documented in Appendix 1 and Table 1. A scatter plot diagram of age against proportion is shown in Figure 1. Visual inspection of this figure suggests some overall relationship along the lines originally proposed (ignoring for the moment distance from Mayor Island). Pearson's correlation coefficient is 0.70 with confidence limits of +0.11 and –0.15, $p = 0.05$ (Snedecor and Cochran 1967:185). On the whole, this confirms Green's hypothesis, but the question of whether this knowledge may be put to any useful purpose is not as simple to evaluate. For instance, archaeologists may wish to assess the age of archaeological sites on the basis of the amount of green obsidian. In order to see how feasible this is it is necessary to examine potential errors which may arise.

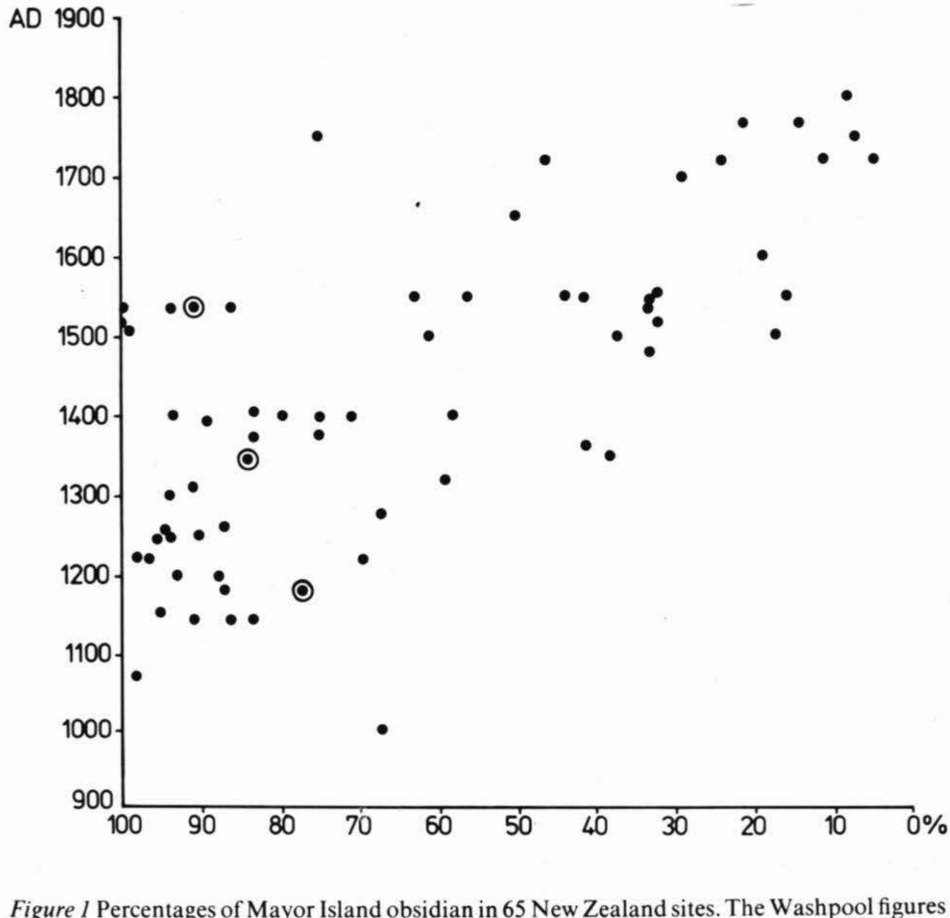

Figure 1 Percentages of Mayor Island obsidian in 65 New Zealand sites. The Washpool figures are circled.

TABLE 1
LIST OF FIGURES USED FOR THE TIME-TREND ANALYSIS

N.B.1 Supporting data are given in Appendix 1, which should be read in conjunction with this table.

N.B.2 The distance to the Mayor Island source was calculated with spherical trigonometry using latitudes and longitudes. The distances therefore are greater circle paths.

N.B.3 The first 29 samples are those used in Green's (1964) study.

Sample	No. of Flakes	Date AD	95% Limits	% Mayor Is	95% Limits	km to Mayor Island
1†	500	1536	100	99.2	0.9	33
2†	46	1536	200	93.5	8.2	33
3	8*	1200	200	87.5	29.2	33
4†	462	1400	200	93.5	2.4	26
5	35	1550	200	62.9	17.4	70
6†	11	1143	114	90.9	21.5	70
7†	6*	1143	114	83.3	38.2	70
8†	134	1550	200	15.7	6.5	70
9	79	1400	200	79.7	9.5	70
10	84	1220	200	96.4	4.6	70
11	4	1400	200	75.0	54.9	70
12	11*	1310	100	90.9	21.5	70
13†	55	1071	100	98.2	4.4	43
14	180	1550	200	56.1	7.5	92
15	110	1400	200	70.9	8.9	92
16†	36	1220	200	69.4	16.4	92
17	511	1300	200	93.9	2.2	92
18	171	1600	200	18.7	6.1	126
19†	13	1719	100	46.2	30.9	126
20	114	1250	200	89.5	6.1	126
21	12	1400	200	58.3	32.1	122
22	31	1500	118	61.3	18.8	118
23†	17	1320	200	58.8	26.3	118
24†	3*	1100	200	66.7	70.0	118
25	21	1720	200	23.8	20.6	124
26	69	1550	200	31.9	11.7	124
27	20*	1720	200	5.3	12.7	121
28	9*	1720	200	11.1	26.1	115
29	60	1220	200	98.3	4.1	133
30	231	1550	200	40.7	6.6	52
31†	347	1500	100	37.2	5.2	52
32†	604	1350	100	38.2	4.0	52
33†	648	1518	140	99.9	0.4	472
34†	12	1500	200	16.7	25.3	127
35†	36	1800	100	8.3	10.4	900
36	7	1700	200	28.6	40.6	100
37†	115	1395	100	88.7	6.2	699
38†	66	1516	100	31.8	12.0	881
39†	117	1508	106	99.2	2.1	1058
40	14*	1750	100	7.1	17.1	910
41†	566	1361	140	41.3	4.1	444

Table 1 continued

Table 1 cont...

Sample	No. of Flakes	Date AD	95% Limits	% Mayor Is	95% Limits	km to Mayor Island
42	56	1765	142	14.3	10.1	117
43†	132	1765	142	21.2	7.4	117
44†	3150	1154	112	94.9	0.8	341
45†	83	1538	100	90.4	7.0	410
46	1975	1345	100	83.5	1.7	410
47†	1467	1180	100	77.4	2.2	410
48†	222	1538	100	86.0	4.8	410
49	4*	1375	142	75.0	54.9	410
50	6*	1375	142	83.3	38.2	410
51	3*	1480	140	33.3	70.0	410
52	3*	1539	152	33.3	70.0	410
53	6	1650	200	50.0	48.3	410
54	6*	1404	100	83.3	38.2	410
55	3*	1538	100	33.3	70.0	409
56†	150	1180	100	86.7	5.8	410
57	16*	1250	200	93.8	15.0	404
58†	4*	1750	100	75.0	54.9	420
59†	7*	1147	108	85.7	33.1	420
60	3*	1273	100	66.7	70.0	420
61	117	1200	200	93.2	5.0	415
62	42	1249	100	95.2	7.6	415
63	15	1261	132	86.7	20.5	417
64	17	1250	200	94.1	14.1	415
65	122	1550	100	43.4	9.2	317

* Implies that one flake was arbitrarily added to the figures to compensate for zeros (see text).
† These assemblages were found to be outliers from the observed overall trend through time in the proportion of Mayor Island obsidian.

ERRORS IN PROPORTION AND AGE

In his pilot study, Green did not fully discuss the highly variable errors either of the suggested age for the sites or of the true proportion of Mayor Island obsidian. Some of the samples used were very small and the estimated proportions are therefore highly suspect. The first task of the present study, therefore, was to assess the probable errors associated with each assemblage. In the case of the dates, radiocarbon ages were used wherever possible. These are based on the old half life without secular correction. Where useful comparative artefacts existed without a ^{14}C date, an estimate was made, and with the exception of a few very late sites, an error of ± 100 years was allowed. The 95% confidence limits shown for all ages in Table 1 are twice the ranges given in Appendix 1. In the case of proportions, the confidence limits are related to both the calculated proportion and the sample size and were determined following Snedecor and Cochran (1967:210 ff.) as:

$$C = K.(P.(1-P)/N)^{0.5} + 1/2N$$

C is the confidence limit, P is the sample proportion, N the sample size, and K is a constant related to the chosen probability level (= 1.96 for 95% confidence, following the distribution of t). The factor 1/2N is added as a correction for continuity which is important for small samples. A number of cases were found where P was either 1.0 or 0.0 and confidence limits cannot be assessed in these cases. For the sake of consistency an arbitrary one flake was added to the zero figure in these cases.

At this point then, each site can be plotted with a surrounding 95% equi-probability ellipse (Fig. 2) which indicates the uncertainty of its position on the two axes of time and proportion of Mayor Island obsidian (Jackson 1956). It will be readily observed that there are only a few sites whose position is reliably fixed in two dimensions.

RELATIONSHIP BETWEEN PROPORTION AND AGE

A. LEAST SQUARES REGRESSION

Given the large uncertainty in plotting each assemblage, the task of assessing the relationship between the two parameters, if any, is probably best undertaken using the simplest hypothesis – a linear relationship. This could be done using the familiar least squares method of linear regression analysis taking no account of the varying errors

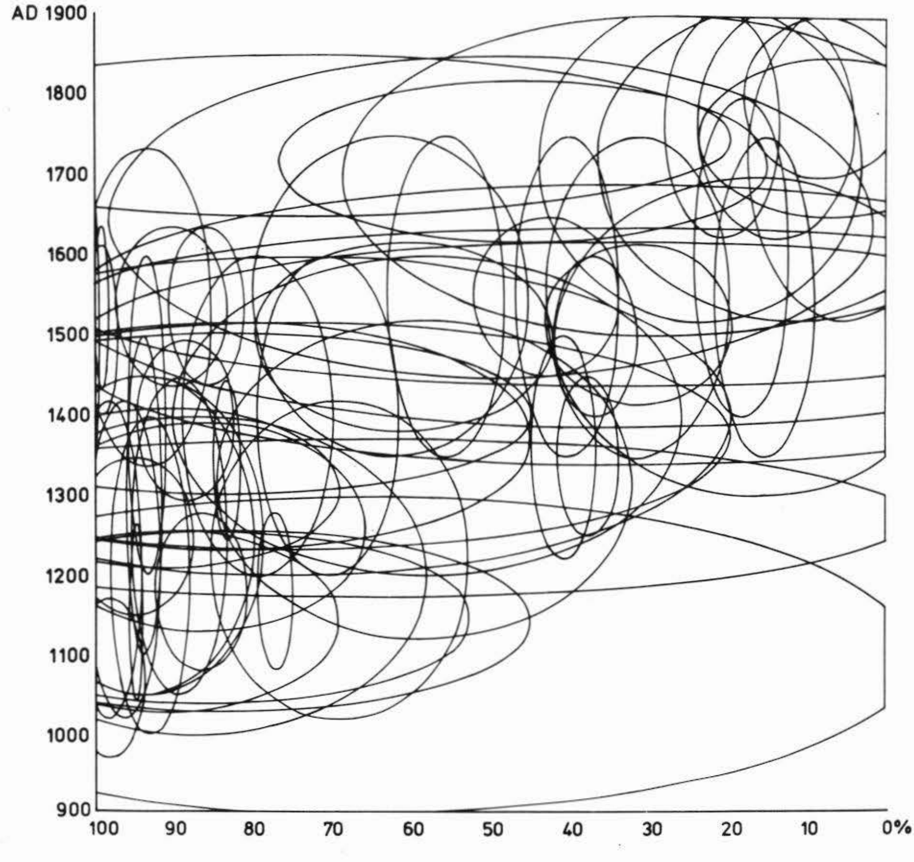

Figure 2 Percentages of Mayor Island obsidian showing the varying reliability of each point.

associated with each point in both dimensions. This technique yields the following formula:

Age (years A.D.) = –4.561 P (%) + 1721 . . . . (1)
Standard error of estimate = ± 140 years (68%)

When the residuals are calculated for each of the 65 points using this formula, they are found to range from 371 years too early to 317 years too late (Fig. 3). Clearly these residuals are very large. However, it must be stressed that when both co-ordinates are subject to error (as they are here) the residuals are only estimates of the true errors, and they may not be particularly good estimates. This makes interpretation of the residuals difficult and suggests that the least squares line, which minimises the sum of the squared residuals, is not the most appropriate in these circumstances. In any case it is known that the least squares estimate is biased when there are errors in both co-ordinates. Additionally, it is intuitively obvious that the fitted line should not give equal weight to each point, as some are quite precisely fixed in both dimensions while others are highly imprecise (Fig. 2). The ordinary least squares line takes no account of this highly variable precision and gives equal weight to good and bad points. Few attempts to cope with varying errors in both co-ordinates could be found in the literature; usually discussions were related to an error in one dimension only (for example, see Snedecor and Cochran 1967:164).

B. MAXIMUM LIKELIHOOD ESTIMATE

The maximum likelihood solution was determined by de Souza and Manley (n.d.) under the assumption that the errors of the two co-ordinates were independent. It can be shown that in these circumstances the maximum likelihood estimate of the straight line through n points (x_i, y_i) is that line which minimises Σk_i^2 where the factors k_i $(i = 1, 2, \ldots, n)$ are determined as follows. Given any line $y = mx + c$, an equi-probability ellipse is determined for each point such that the ellipse is centred on the observed point and is just large enough to meet the line at a tangent. Denoting the semi-axis lengths of any such ellipse as l_x and l_y, the factor k for that ellipse is given by $k = l_x/s_x = l_y/s_y$ where s_x and s_y are the standard errors of the co-ordinates. Thus the factor k can be thought of as a multiplier of the standardised ellipse (i.e., the ellipse having semi-axes equal to the standard errors); the standardised ellipse must be expanded (or contracted) by the factor k if it is to meet the line at a tangent.

The equation of the line may be found by differentiation and can be solved iteratively using a computer. An initial estimate of the slope is required to start the iteration and it is convenient to take this to be the least squares estimate.

Given any line $y = mx + c$, the sum, Σk_i^2, may be calculated and it can be shown that this sum has a chi-square distribution when the given line is correct. Thus, the term Σk_i^2 may be used as a X^2 test to assess how well any particular line fits the data; the smaller the value, the better the fit.

This maximum likelihood procedure worked very well. The final solution after 17 iterations was

Age (years A.D.) = –4.862 P (%) + 1750 . . . . (2)

and resulted in $\chi^2 = 883$ as compared with $\chi^2 = 1774$ for the least squares solution.

When it is recognised that the points vary in precision, it is not possible to provide an expression comparable with the standard error of the estimate, and the question of "how good is an estimate of age" is difficult to answer. It is pointless to compute the residuals and compare them with those of the least squares line; the latter minimises the residual sum of squares and cannot be improved upon in this regard. What can be said, is that the

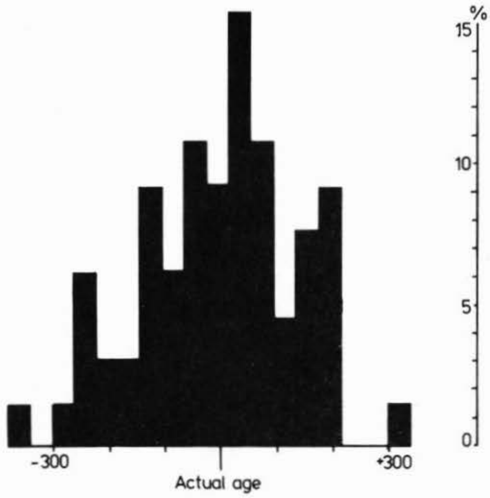

Figure 3 Residuals of predicted age from actual age.

maximum likelihood line should be more accurate than the least squares line and the true errors should be smaller. Additionally, the largest errors will be associated with the largest ellipses, and for more reliable points, the errors will be smaller.

It is now pertinent to consider whether or not the simple linear model discussed so far adequately describes the obsidian/age relationship found in the 65 archaeological assemblages.

C. MAXIMUM LIKELIHOOD ESTIMATE AFTER REJECTING OUTLIERS

The goodness-of-fit expression mentioned earlier was found to be:

(i) Least squares $\chi^2_{63} = 1774.11$ ($p<0.0001$)
(ii) Maximum likelihood $\chi^2_{63} = 883.26$ ($p<0.0001$)

Although the second figure represents a considerable improvement in the line fitted, both figures are clearly highly significant, and we are forced to conclude that a line of the general form of $y = mx + c$ did not truly reflect the behaviour of the full set of archaeological information. The hypothesis of a linear relationship must be rejected. The fitted lines suggested therefore have really no meaning. In point of fact, many of the data points are so far from either of the fitted lines that the probability of their conforming to such a relationship is negligible; these points may be regarded as outliers. The data was screened for outliers in the following way. All points for which the expansion factor (k) exceeded 2 – that is, were significantly far away from the maximum likelihood line at about the 5% level – were rejected. A new line was then fitted through the remaining points and the value of k recalculated for each point, again rejecting outliers. This process was repeated until no points remained which were outliers. Of the original 65 archaeological assemblages, only 37 remained. A new line was fitted to this reduced set giving:

$$\text{Age (years A.D.)} = -5.788\,P(\%) + 1806 \qquad (3)$$

The chi-square goodness-of-fit on this fitted line yielded $\chi^2_{35} = 34.82$ ($p \simeq 0.5$). Thus, there is no evidence to suggest that the linear relationship in this case is incorrect. The 95% confidence region for the fitted line is shown in Fig. 4, and for both the slope and intercept of the line in Fig. 5. It is possible to estimate confidence limits of any estimated age using an iterative procedure. This is a laborious process requiring a computer programme, but the values for two archaeological assemblages were determined to provide an indication of the kind of errors involved.

(i) Site 46: Washpool Midden Site (N168/22)

Sample size	= 1975 artefacts
Mayor Island obsidian	= 83.5% ± 1.7 (95%)
Predicted age using (3)	= AD 1323 + 46, –49 (95%)
Assumed true age	= AD 1345

(ii) Site 42: Motutapu Undefended (N38/30)

Sample size	= 56 artefacts
Mayor Island obsidian	= 14.3% ± 10.1 (95%)
Predicted age using (3)	= AD 1723 + 156, –137 (95%)
Assumed true age	= AD 1765

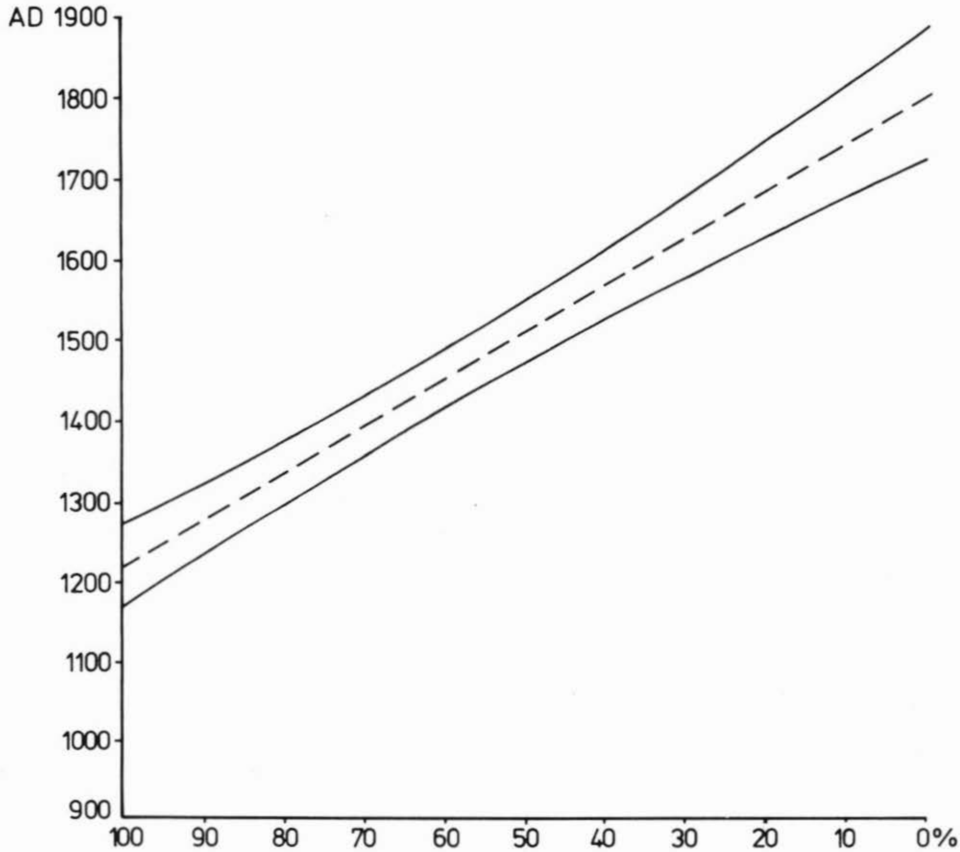

Figure 4 The 95% confidence region of the Maximum Likelihood Regression Line.

These examples show that where the obsidian assemblage is reasonably large, an estimate of age may be made with some confidence; but conversely where it is small, an age estimate has a confidence region which is intolerably large.

The key problem which now arises is how do we know when equation (3) may be applied legitimately, and when it may not. The two examples given above conform to the linear model, that is, they lie within the 95% confidence region of the line. We know this because we know the age as well as the amount of Mayor Island obsidian, and of course these two points were actually used to calculate equation (3). With newly discovered archaeological remains the "outlier" criterion cannot be used as this would simply reduce the whole model to a tautology – "the formula may be used when it gives an accurate looking answer"! Some independent reason must be found for the existence of these outliers.

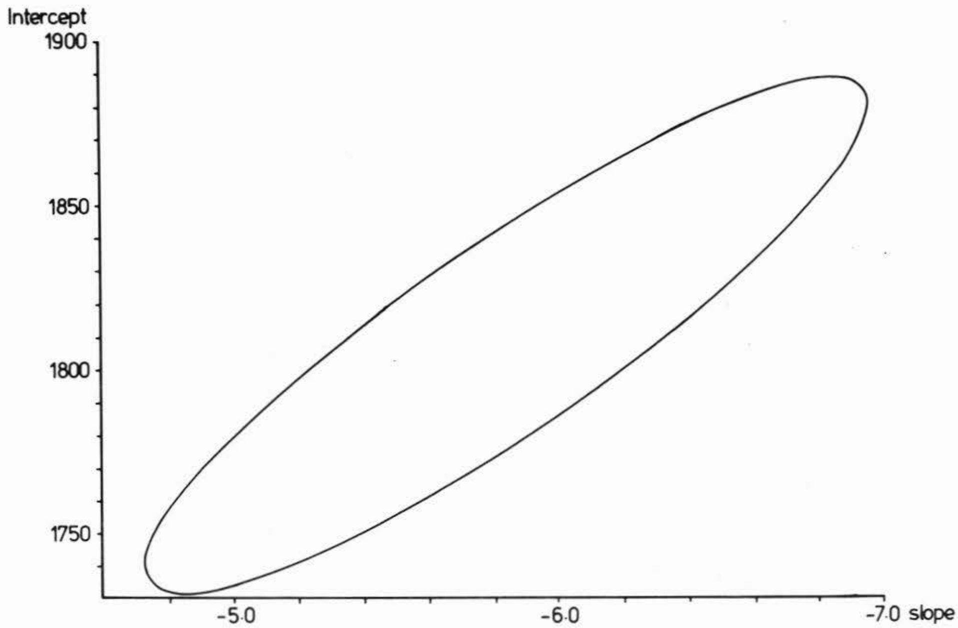

Figure 5 The 95% confidence region for the slope and intercept of the Maximum Likelihood Regression Line.

THE CULTURE-HISTORICAL SIGNIFICANCE OF THE OUTLIERS

The reason why some assemblages do and others do not conform to this pattern of decreasing reliance on Mayor Island obsidian through time is not so easy to detect. The information from the two sets of archaeological assemblages (the outliers and non-outliers) were examined from a range of viewpoints to find some independent factor – was one set associated with horticultural people and the other with hunter-gatherers? – and so on. No such obvious groupings could be found, but there are two possibilities which should be looked at closely: it might be thought that the overall pattern applies more to earlier archaeological sites than to very late ones, or that it only obtains for sites a large distance from the Mayor Island source. Green after all originally claimed that this model might only apply to sites not too close to Mayor Island (Green 1964: 139). These two possibilities were evaluated by comparing the relative numbers of outlier and non-outlier assemblages at different periods and at increasing distances from Mayor Island. The relative frequencies are shown in Figure 6. The significance of any differences between the number represented in each cell was assessed using a chi-square test (Reyment 1971) with the following results:

(i) Age related
$\chi^2_{15} = 16.92$ (not significant, $p = .25$)
(ii) Distance related
$\chi^2_{9} = 11.78$ (not significant, $p = .10$)

These results argue that neither age nor distance from the source has any direct bearing on the linear relationship observed. Just as many assemblages conform as do not, whether they are close to the source or far away. It must be concluded that as far as this overall trend is concerned, no simple culture-historical pattern can be detected as to which points conform and which do not. (The list of outliers is specified in Table 1 in case someone else can detect a pattern.) It follows that there is no way of knowing when equation (3) may be legitimately used and when it may not. Therefore, on a New Zealand-wide basis, the proportion of Mayor Island obsidian cannot be usefully applied to estimate age. It is, however, possible that examination of proportions within single regions, or amongst the debris left by individual communities over a period, will reveal significant trends which could be put to this purpose.

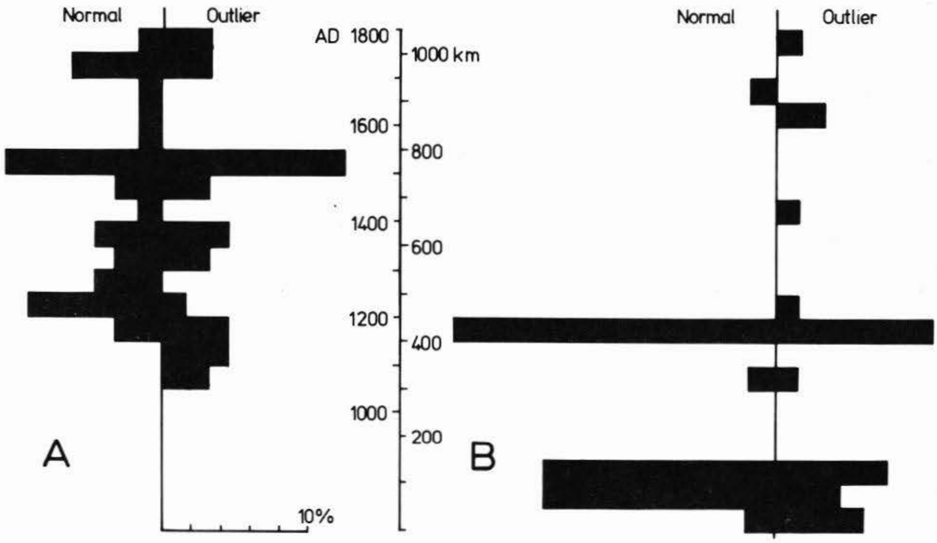

Figure 6 A comparison of outliers and non-outliers from the regression relationship. A = at different periods, B = at different distances from Mayor Island.

REGIONAL AND COMMUNITY-SPECIFIC PATTERNS

Twelve of the assemblages looked at were from the Palliser Bay region, and these were considered as a group to see if any overall time trend could be seen. When the points are plotted (Fig. 7), a wide variation in proportions is apparent at all periods. This is especially true for the six most reliable points (those with the smallest errors on both axes), which are circled in Figure 7. It appears that even in one region in New Zealand, the pattern of supply of obsidian to different communities was a complex matter. Precise identification of the actual sources of the obsidian which found its way into Palliser Bay clarifies this issue. Identifications were based on XRF analysis of samples from 13 of the Palliser Bay assemblages (B. F. Leach 1976:353-360). Seven sources were apparently used, and four of these were in evidence in the 12th century A.D. (Table 2). The 18 known sources of New Zealand obsidian may be grouped into four different regions, and of these only that from Great Barrier Island has not been found at Palliser Bay. The supply of obsidian from the three remaining regions (Fig. 8) shows a remarkable constancy over a period of eight centuries. It is interesting though that inland sources may have dried up before A.D. 1400, and also that by the 17th century Northland material may have begun

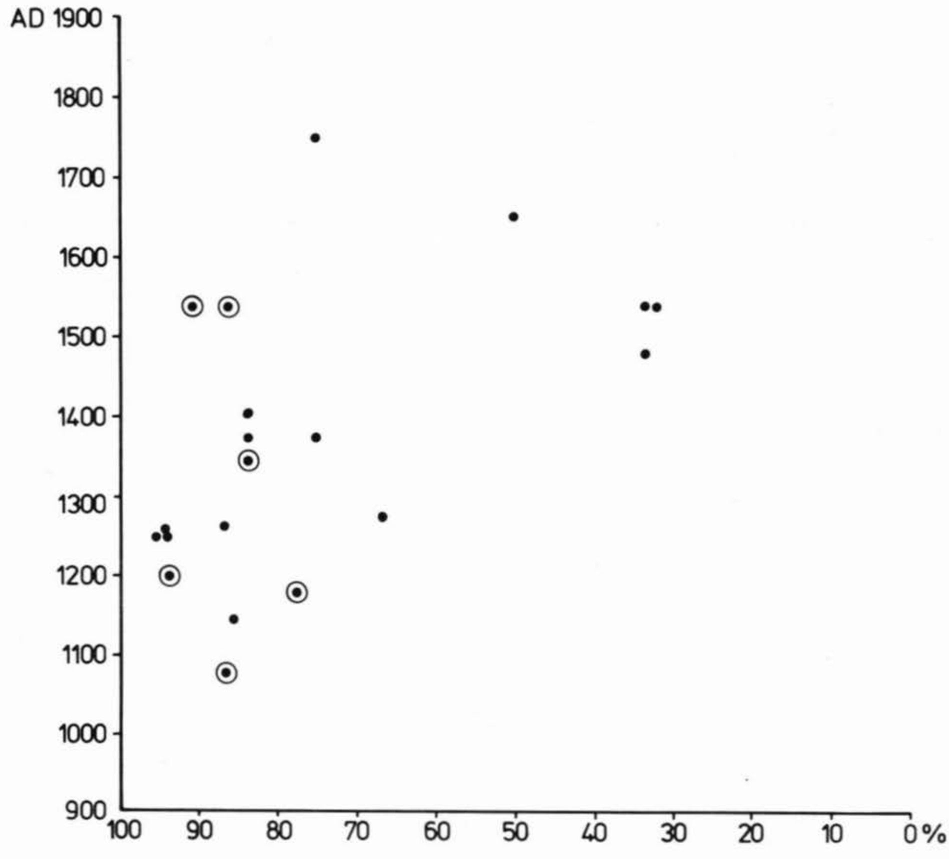

Figure 7 Percentages of Mayor Island obsidian from 20 sites in one region of New Zealand (Palliser Bay). The six most reliable points are circled.

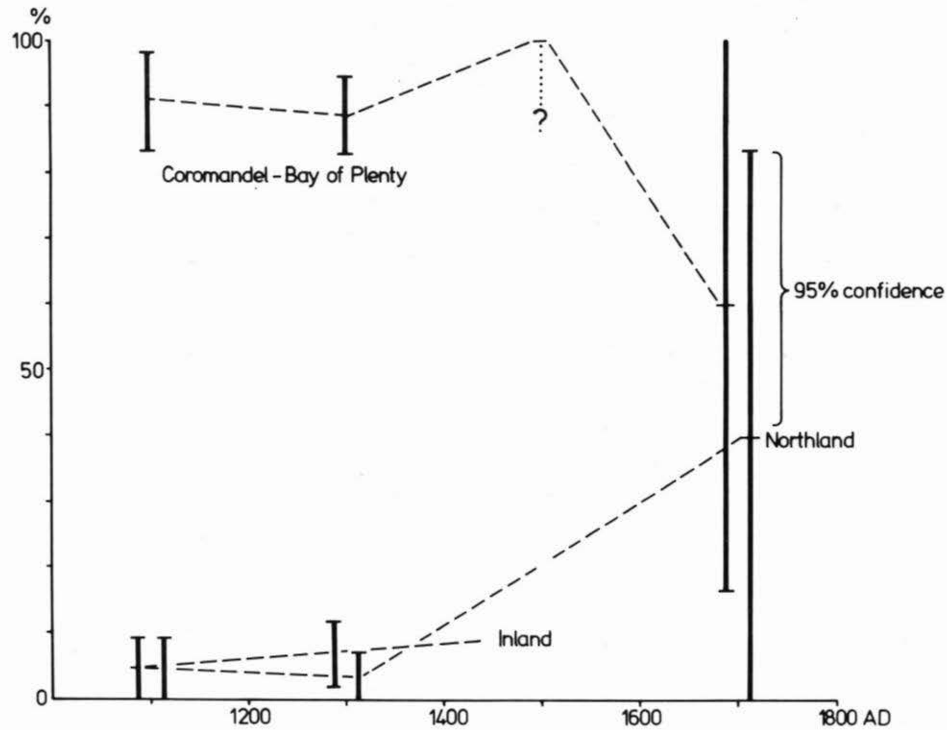

Figure 8 The changing consignment of obsidian to Palliser Bay from the main regions of supply, based on Table 2 (N.B: Great Barrier obsidian has not been found at Palliser Bay.) The confidence limits of the proportion of Coromandel-Bay of Plenty obsidian at A.D. 1450 could not be assessed.

to undermine the dominating role which Coromandel-Bay of Plenty seems to have had prior to this. These suggestions must be very tentative though, because none are significant at the 95% level. On the whole, therefore, neither the proportion of Mayor Island obsidian nor that from particular regions of New Zealand may be used to suggest the age of archaeological sites in the Palliser Bay region.

One particular archaeological site warrants close attention since a large assemblage of obsidian is present, and is divided into three temporal units which range over most of New Zealand's prehistoric period. This is the Washpool Midden site, a village complex in Palliser Bay. The cultural layers in this site are believed to have been deposited by a single community resident in the Washpool Valley from the 12th to 17th century A.D. (Leach n.d.). Therefore, a reasonable case may be made that the proportions of different rock types in this site truly reflect changes in the supply lines of a single cultural exchange network. Such a case is impossible to argue when one is dealing with sites widely distributed in time and space, and when the identity of the individual communities responsible for those sites and their relationships are not known. The hope that these relationships will be clarified by studying the changing proportions of different rocks involved in exchange systems on a New Zealand-wide or a regional basis has not received much support from this present study. What then is the situation with the Washpool site, where it does appear that a single community is involved over a long period? There are two aspects to this which can be considered: what the actual trend is in obsidian usage, and what cultural meaning can be attributed to it.

TABLE 2
THE SOURCES OF PALLISER BAY OBSIDIAN

			North-land	Great Barrier	Coromandel-Bay of Plenty			Inland			Totals
Site No.	Name	Age	Huruiki		Mayor Island	Cooks Bay	Purangi	Rotorua	Ongaroto	Taupo	
AD1800											
58	BR2	1750	—	—	2	—	—	—	—	—	2
53	Titoki Pit	1650	2	—	—	1	—	—	—	—	3
		Totals:	2(40%)	0		3(60%)			0		5(100%)
AD1600											
52	M4 House	1539	—	—	—	1	—	—	—	—	1
45/48	Washpool III	1538	—	—	18	4	—	—	—	—	22
51	M3 Cleft	1480	—	—	—	—	1	—	—	—	1
		Totals:	0	0		24(100%)			0		24(100%)
AD1400											
50	Circular Pit	1375	—	—	4	—	—	—	—	—	4
49	Terrace Gdn	1375	—	—	1	—	—	—	—	—	1
46	Washpool II	1345	4	—	70	14	1	2	1	6	98
60	BR4	1273	—	—	1	—	—	—	—	—	1
62	Pararaki	1249	—	—	10	1	—	—	—	—	11
		Totals:	4(3.5%)	0		102(88.7%)			9(7.8%)		115(100%)
AD1200											
56	Moikau	1180	3	—	17	2	—	1	—	—	23
47	Washpool I	1180	—	—	27	10	—	2	—	—	39
59	BR3	1147	—	—	4	—	—	—	—	—	4
		Totals:	3(4.5%)	0		60(90.9%)			3(4.5%)		66(99.9%)
AD1000											

A. MAYOR ISLAND OBSIDIAN AT THE WASHPOOL

The obsidian assemblage was examined using XRF analysis to identify the actual sources of obsidian (B. F. Leach 1976:353-360; Leach and Anderson 1978), and the results are summarized in Table 3. Colour in transmitted light was also recorded, and the proportions are given in Table 4. Thus, it is possible in this case to test the reliability of the colour method, and the two sets of information are presented in Figure 9. There is no doubt from this, that the utilization of Mayor Island obsidian increased in the course of time in comparison with other sources. As might be expected, the actual proportions revealed by the two methods vary somewhat, and the significance of the change through time is not easy to evaluate statistically. A positive case is presented by Leach and Anderson (1978). This of course was a most unexpected result, since the observed trend through time is completely opposite to the overall pattern exhibited by the pooled results for New Zealand sites as a whole. This example illustrates admirably one of the dangers

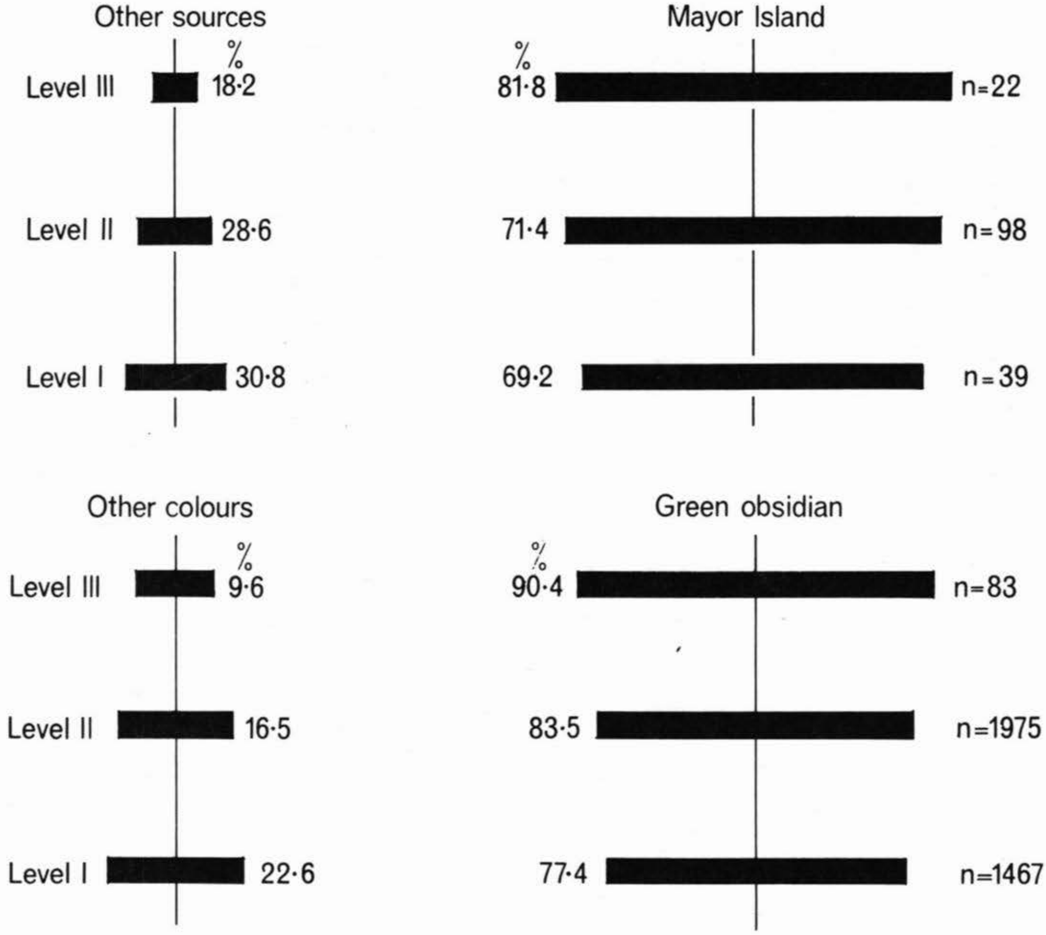

Figure 9 A comparison of Mayor Island obsidian in the Washpool site based on both XRF sourcing and colour analysis. Level I = about A.D. 1180, Level II = about A.D. 1350, Level III = about A.D. 1540.

TABLE 3
CHANGING PROPORTIONS OF DIFFERENT OBSIDIANS IN THE WASHPOOL MIDDEN SITE BASED ON TRACE ELEMENT ANALYSIS

N.B. These figures have been compiled using the data given by B. F. Leach (1976: Appendix 5)

Source		Level I	Level II	Level III*
Mayor Island	N	27	70	18
	%	69.23	71.43	81.82
Cooks Bay	N	10	14	4
	%	25.64	14.29	18.18
Huruiki	N	–	4	–
	%	–	4.08	–
Taupo	N	–	6	–
	%	–	6.12	–
Rotorua	N	2	2	–
	%	5.13	2.04	–
Purangi	N	–	1	–
	%	–	1.02	–
Ongaroto	N	–	1	–
	%	–	1.02	–
Totals:	N	39	98	22
	%	100	100	100

* No samples from Level III were subjected to XRF analysis; the figures given here are those from the site N168/20, the Stone Wall Garden site nearby. It is argued by B. F. Leach (1976) that this site belongs to the Level III period at the Washpool. The suggested pattern of increasing dominance of the Mayor Island source above is strengthened by the results given in Table 4.

TABLE 4
CHANGING PROPORTIONS OF GREEN OBSIDIAN AT THE WASHPOOL MIDDEN SITE

N.B. These figures derive from K. Prickett's colour analysis of Palliser Bay obsidian (Prickett n.d.).

Colour		Level I	Level II	Level III	Garden Site*
Green	N	1135	1650	75	202
	%	77.37	83.54	90.36	85.23
Other colours	N	332	325	8	35
	%	22.63	16.46	9.64	14.77
Totals	N	1467	1975	83	237
	%	100	100	100	100

* N168/20 (see Footnote to Table 2).

of pooling such results in archaeology: that the phenomena observed on an average may never have actually applied to any real community in the past. Patterns should be looked for first in localised communities and then compared with others to see if generalisations can be made.

B. CULTURAL MEANING IN THE TREND OF OBSIDIAN USAGE

The network of communications in which this Washpool community was involved has been described in detail by Leach (1978), and it has been shown that the people in the early period had very strong ties with communities to the north, particularly in the Bay of Plenty and Coromandel area, but that in the course of time these relationships became less important as more effective links were developed with groups of people elsewhere in the Cook Strait region in both islands. Taken as an isolated set of information, the obsidian data (Fig. 8) appear to show the contrary – that links with the Bay of Plenty area strengthened through time, since Mayor Island obsidian came to the Washpool in increasing amounts. This interpretation cannot be maintained when the full suite of information is examined. These people made stone tools from at least 23 different kinds of stone, and of these no less than 11 were imported from outside Palliser Bay. One of these, obsidian, was obtained from at least seven sources in the North Island. It is hazardous to employ a simple analysis of one rock type in isolation, and then derive interpretations relating to communication patterns of prehistoric groups. They may turn out to be well shy of the mark as is the case here.

CONCLUSIONS

There appears to be a slight New Zealand-wide correlation between age and proportion of Mayor Island obsidian, but no useful application of this correlation is apparent. It has been shown that only about half the assemblages studied actually conform to this model, and there is no obvious pattern in why some do and others do not. It was found that this wide variation occurred whether one considered all New Zealand assemblages, or only those relating to a particular region. Moreover, in the case of a specific prehistoric community, it was seen that their supply of Mayor Island obsidian actually increased in the course of time, and was therefore contrary to the overall pattern. As a guide to age then, the proportion of this type of obsidian can be thoroughly misleading, and this idea should be abandoned.

Attempts to disclose prehistoric trade and communication patterns have been carried out with high expectations of results. After about a decade of active research in developing sourcing techniques in New Zealand it is a moot point just how much has been revealed about prehistoric social and economic relationships. No doubt we should press ahead with this work, but present indications are that it will be some time before generalisations can be made with any confidence. It is essential that the whole suite of rock types being used by prehistoric people should be examined. As a guide to the overall pattern of external relationships, the results from single resources may be highly misleading. This present study shows that pooling results can lead to quite erroneous interpretations, and that an "average trend" may never have applied to any individual prehistoric group. This suggests that changing patterns in the delivery and utilization of trade items should be first understood in their regional economic setting and only later examined on a national basis.

Mayor Island was clearly the most important single source of obsidian for most groups of people through the course of New Zealand prehistory. It is both abundant and of a high quality well suited to the manufacture of stone tools requiring a keen cutting edge. Much could be learned of changing technology in New Zealand by carrying out archaeological research on Mayor Island itself. Obsidian from this source is certainly present in the earliest known archaeological sites in New Zealand, but so too is "other" obsidian (an average of 13.5% of all the 10 assemblages earlier than A.D. 1200). Consequently, there is no reliable evidence at present that the Mayor Island source or any other was the earliest discovered.

The Palliser Bay studies show that seven sources were being utilized by about A.D. 1350 and four as early as A.D. 1180 (Table 2). The earliest group consists of Huruiki in the far north, Cooks Bay on Coromandel Peninsula, Mayor Island in the Bay of Plenty, and inland Rotorua. This illustrates that by this period prehistoric people in New Zealand had already undertaken extensive exploration and had acquired a considerable knowledge of this country's geological resources. The obsidian sources are confined to the North Island, but other lithic materials were also being imported from the South Island into Palliser Bay (Leach 1978), showing the wide extent of this knowledge. In addition, groups resident in different parts of the country were involved in an economic relationship in which several raw materials were exchanged. This supposes a reasonably large population in the 12th century A.D. Given the low net birth rate which Houghton is documenting for the prehistoric inhabitants of New Zealand (Houghton n.d.), a lengthy period of occupation must be proposed before the earliest known sites to allow for the development and spread of this population.

APPENDIX 1

DOCUMENTATION OF THE PROPORTION OF MAYOR ISLAND OBSIDIAN IN NEW ZEALAND ARCHAEOLOGICAL SITES AND THEIR AGES

In what follows, an attempt is made to document the information for each site used in the analysis and summarized in Table 1. All figures are based on the assumption that green obsidian derives from Mayor Island. Non-green obsidian is classified as from a different source. Nearly half the figures derive from Green's synthetic study (1964); however, each point raised in his table is given fuller documentation below. Unless otherwise stated, any proportions of Mayor Island obsidian derive from Green's paper (1964:141).

A number of the figures presented in Table 1 are bound to be revised as new information comes to hand on dating and also by further finds of obsidian. Such revisions are unlikely to affect the overall conclusions of this paper.

Site 1: *Kauri Point Swamp* (N53-54/5) The date of A.D.1536 ± 16* is a pooled estimate of the two given by Law (1974:4).

Site 2: *Kauri Point Settlement* (N53-54/6) The date of A.D.1805 ± 60 (Law 1974:4) is not considered reliable. The site is thought to be contemporary with Site 1 (Green 1963a:152). Increasing the standard error to 100 years seems reasonable.

Site 3: *Kauri Point Beach Midden* (N57/1) There are no radiocarbon dates for this site, but Green (1963a:146) argues that it is an early site since it contained a hog-back adze. An estimate of A.D.1200 ± 100 is probably reasonable.

Site 4: *Whiritoa Beach Midden* (N53-54/4) The dating of this site is difficult. Green (1964:141) places the site in his "Experimental Phase" as does Crosby (1963:48); an estimate of A.D.1400 ± 100 is used here.

Sites 5, 6, 7: *Skippers Ridge* (N40/7) The figures given in Green (1964:141) relate to Layers 2-4. The following equivalences are extracted from Green (1963b:60) and Davidson (1975:6): Level I = Layer 4 and beneath, Level III = Layer 3, and Level IV = Layer 2. Green placed the obsidian assemblages in three of his successive phases from A.D.1100 to 1650 (Green 1964:138). However, Davidson (1975:38) in her recent re-evaluation of this site, argues that Levels I-III were occupied continuously through only a short period of time. She gives A.D.1143 ± 57 as a mean date for the three levels. The "Proto Maori" status of Level IV is probably acceptable. An estimate of A.D.1550 ± 100 is therefore used.

* This and other similar figures are rounded up to ± 100 (p95%).

Site 8: *Curry and Moore Gate Beach Midden* (N40/1) There is some confusion in the literature relating to this site. Green (1964:141) gives figures of 21 Mayor Island and 113 "other sources" for obsidian from N40/1, while in Green (1963b:62) the figures for the same site (?) are four Mayor Island and nine from other sources. Trower (1963:45), however, states that only two flakes of non-Mayor Island source were found. Reference has been made to a collection of flakes from another midden at N40/1 called the "Lower Midden" which was completely removed by the sea (Jolly and Green 1963:42). Perhaps this collection is the source of the figures given by Green (1964:141). Green places the site as "Proto Maori" from about A.D.1450 to 1650 (Green 1964:141), but the argument advanced for this dating apparently relates to the "Upper Midden" (Green 1963b:62). In the meantime, a date of A.D.1550 ± 100 is accepted.

Site 9: *Pohutukawa Beach Midden* (N40/2) In the absence of radiocarbon dates, Green's assessment of "Experimental Phase" is used (Green 1964:138).

Site 10: *Fisher's Beach Midden* (N40/4) The Archaic status of this site is based on artefacts (Green 1963b:58), and a date of A.D.1220 ± 100 is used.

Sites 11, 12: *Opito Beach Midden* (N40/3) There are two Archaic levels in this site consisting of an earlier Layer 4c, and a later Layer 4a (with the nearly sterile Layer 4b included). A radiocarbon date from Layer 4c is A.D.1310 ± 50 (Green 1972:28). Green (1964:138) places the later level between A.D.1350 and 1450, and a date of A.D.1400 ± 100 is used here.

Site 13: *Tairua Beach Midden* (N44/2) The obsidian derives from Bed 2 (Layer 2), the earlier occupation on the site. One of the radiocarbon dates is considered reliable at A.D.1071 ± 49 (Jones 1973:146). A recent result from shell of A.D.1380 ± 60 (Rowland 1975:6) suggests that the age of the Tairua site is still debatable.

Sites 14, 15, 16: *Ponui Island Beach Midden* (N43/1) There are three levels on this site, the third being the earliest. Nicholls places these in Green's "Developmental, Experimental, and Proto-Maori" phases (Nicholls 1964:36), and the following estimates are used here: A.D.1220 ± 100, A.D.1400 ± 100, A.D.1550 ± 100.

Site 17: *Tokoroa Moa Hunter Camp* (N75/1) Slightly different obsidian figures are reported by Green (1964:141) and Law (1973:158); however Green's figures are adhered to. The date of the site was considered by Green (1964:138) to be very early (A.D.900 to 1100); however, Law (1973:159-60) argues for a date of about A.D.1100 to 1400. This latter range is used here.

Site 18: *Harataonga Bay Ridge Pa* (N30/3) Slightly different obsidian figures are given by Green (1964:141) and Law (1972:115); however, Green's numbers are used here. The site has been radiocarbon dated to A.D.1509 ± 55 (Morwood 1974:96, Law 1975) using a burnt post at the base of the fill of a pit structure. Practically all the obsidian derives from the upper layer of this pit (Law 1972:114), and is therefore somewhat later than the dated feature. An estimate of A.D.1600 ± 100 is used.

Site 19: *Harataonga Bay Eastern Beach Midden* (N30/4) This site is dated by two radiocarbon samples (Law 1975:48) which are pooled here as A.D.1719 ± 16.

Site 20: *Harataonga Bay Western Beach Midden* (N30/5) Law argues that this site is reasonably fixed in the 13th century A.D. (Law 1975:48, 1972:100). A date of A.D.1250 ± 100 is used.

Site 21: *Awana Midden* (N30/19) Although there are no radiocarbon determinations, Green (1964:138) estimates the age of this site as falling within the "Experimental" Phase. A date of A.D.1400 ± 100 is followed here.

Sites 22, 23, 24: *Sunde Site* (N38/24) Only one piece of obsidian was found under the Rangitoto ash at this site. Green (1964:141) states that this was non-Mayor Island type, but lists it as Mayor Island elsewhere (ibid.: 138). Davidson clearly identifies this as the piece with the rather thick hydration rim identified as from Mayor Island by Reeves (Davidson 1972:6). There are five radiocarbon dates from reliable samples taken below this ash (Law 1974:6). These give a pooled estimate of A.D.1322 ± 70. It was previously thought that this level was somewhat earlier (Scott 1970:13), and the problem has been discussed at length by Davidson (1972:6). It now seems that nearby Rangitoto was active until a considerably later time. Thus the pre-ash occupation level at the Sunde Site may need to be updated from the suggested pre-A.D.1188 ± 50 (Scott 1970:16), even though the dates provide only a *terminus ante quem* for the occupation. The pooled date of A.D.1322 compares favourably with A.D.1340 suggested by the recently published radiocarbon date NZ1898 (Davidson 1974a:9). Clearly, the chronology expressed by Green (1964:138) must be viewed with caution. It is suggested here that the sequence should be moved up at least a century, and the following estimates are therefore used for the three Sunde Site samples described by Green (1964:138): A.D.1100 ± 100, A.D.1320 ± 100, A.D.1500 ± 59. Precise details are now known of the sources of Sunde Site obsidian (Davidson 1972:14).

Sites 25, 26: *Mt Roskill Pa* (N42/11) Green's dating is accepted here as approximately A.D.1550 ± 100, and A.D.1720 ± 100.

Site 27: *One Tree Hill* (N42/6) Green's estimate of dating is used: A.D.1720 ± 100.

Site 28: *Taylors Hill Pa* (N42/84) As with Site 27, the date is put at: A.D.1720 ± 100.

Site 29: *Manukau Head Midden* (N46-47/16) This site clearly belongs in the Archaic (Green 1970:22), and Green's suggestion of "Developmental" age seems appropriate. A date of A.D.1220 ± 100 is used here.

Sites 30, 31, 32: *Hot Water Beach* (N44/69) The obsidian numbers are totals for Layers 3b, 4 and 5 published by Leahy (1974:53). The seven radiocarbon dates for the site present some problems. All are from Layer 4 (Leahy 1974:72). Two of these (a grease fraction and a fish bone fraction) gave very modern results and appear to be quite unreliable. The remaining five are of the same order of magnitude and give a pooled estimate of A.D.1500 ± 34. Leahy argues persuasively that Layer 5 has an age of about A.D.1350 ± 50 on the basis of waterworn Loisels pumice (Leahy 1974:73). An estimate for Layer 3b is A.D.1550 ± 100.

Site 33: *Heaphy River* (S7/1) The obsidian figures and radiocarbon date are published by Wilkes and Scarlett (1967:207, 210).

Site 34: *Otakanini* (N37/37) The obsidian figures are given by Bellwood (1972:286). This sample cannot be directly related to dated features (Bellwood 1972:287); however, an estimated age is A.D.1500 ± 100.

Site 35: *Huriawa Pa, Karitane* (S155/1) The obsidian figures relate to Gathercole's excavation of Area A and were calculated by H. Leach (1975:pers. comm.). A date of A.D.1800 ± 50 is an estimate.

Site 36: *Mangakaware I* (N65/28) The obsidian figures are given by Peters (1971:136). On artefactual grounds the age is definitely late, and an estimate of A.D.1700 ± 100 is used here.

Site 37: *Rakaia River* (S93/20) Unfortunately Trotter's test excavation yielded very little obsidian. Two samples of obsidian were obtained from surface collections, and these are pooled here (Trotter 1972:145, 149). Trotter argues that the radiocarbon dates he obtained are fairly reliable for the site as a whole (Trotter 1972:144). There are five radiocarbon dates (Trotter 1972:135), but three of these are clearly unreliable. The two collagen dates give a pooled estimate of A.D.1395 ± 34.

Site 38: *Shag Point* (S146/5) The obsidian figures and date derive from Trotter (1970:473, 479).

Site 39: *Tiwai Point* (S181/16) The obsidian figures were calculated by H. Leach (1975:pers. comm.; see also Armitage *et al.* 1972); the radiocarbon date was published by Park (1971:176).

Site 40: *Mapoutahi Pa* (S164/13) The obsidian figures are published by Anderson and Sutton (1973:114-5) and a date is estimated (Anderson and Sutton:107-8) as A.D.1750 ± 50.

Site 41: *Tahunanui* (S20/2) The obsidian figures and date are given by Millar (1971:163, 170).

Site 42: *Motutapu Undefended Site* (N38/30) Obsidian figures are given by Leahy (1970:78), and the age is discussed by Davidson (1972:9, 10). It is probably comparable to N38/37 (see site 43 here), and the same radiocarbon date is used as an assessment for this site. The actual sources of the obsidian are now known and are discussed by Davidson (1972:13, 1974b; also Ward 1974b).

Site 43: *Motutapu Undefended Site* (N38/37) Obsidian figures are given by Davidson (1970:47, 53), and the radiocarbon age appears in Davidson (1972:5). Actual sources of the obsidian are discussed by Davidson (1972:13, 1974b; also Ward 1974b).

Site 44: *Houhora Midden* (N6/4) The obsidian figures are derived from Best's study (1975:22), and the radiocarbon date is taken from Law (1974:3).

Sites 45, 46, 47: *Washpool Midden Site* (N168-9/22) The dates for the three levels of this site are discussed by B. F. Leach (n.d.). The obsidian figures are derived from those presented in Table 4. In Table 3 the actual sources of the obsidian at the Washpool Midden site are given. It will be noticed that these vary somewhat from the Mayor Island/other assessment given in Table 4. This problem is discussed fully elsewhere (Leach and Anderson 1978). To be consistent the values based on colour are used in the present analysis.

Site 48: *Washpool Garden Walls* (N168-9/20) The obsidian figures and radiocarbon date for this site are given by H. M. Leach (1976: Chapter 3).

Site 49: *Washpool Terrace Garden* (N168-9/24) The obsidian figures and radiocarbon dates are discussed by B. F. Leach (1976:Chapter 4).

Site 50: *Washpool Circular Raised Rim Pit* (N168-9/24) See Site 49.

Site 51: *Washpool Cleft Burial* (N168-9/27) See Site 49.

Site 52: *Washpool House Terrace* (N168-9/29) See Site 49.

Site 53: *Washpool Titoki Pit* (N168-9/31) The obsidian figures are given by B. F. Leach (1976:Chapter 4). Two phases of the pit's history are dated, and an estimate of the age of this small sample of obsidian would be A.D.1650 ± 100.

Site 54: *Washpool Camp Site* (N168-9/21) See Site 49.

Site 55: *Great Wall of Whatarangi* (N168-9/16) The date is discussed by H. M. Leach (1976:Chapter 3), and the obsidian figures are derived from K. Prickett (n.d.).

Site 56: *Moikau House* (N165/9) The obsidian figures are the combined totals for the house and cooking area excavations by N. Prickett (1974) and a small surface collection by K. Prickett (n.d.). The two radiocarbon dates are published by Anderson and Prickett (1972) and are pooled here.

Site 57: *Whangaimoana Midden* (N165/10) The obsidian figures derive from K. Prickett (n.d.); the date is estimated on the basis of artefact finds comparable to other 13th century sites in Palliser Bay. An estimate of A.D.1250 ± 100 is used here.

Site 58: *Black Rocks Midden BR2* (N168-9/77) Obsidian figures are from K. Prickett (n.d.) and the date from Anderson and Prickett (1972).

Site 59: *Black Rocks Midden BR3* (N168-9/77) See Site 58.

Site 60: *Black Rocks Midden BR4* (N168-9/77) See Site 58 (two radiocarbon dates pooled).

Site 61: *Pararaki Houses* (N168-9/41) The obsidian figures and the age are discussed by Prickett *et al.* (n.d.).

Site 62: *Pararaki Midden Wall* (N168-9/41) See Site 48.

Site 63: *Kawakawa River Mouth* (N168-9/51, 53) The obsidian figures are combined totals for a small excavation by H. M. Leach (n.d.) and a surface collection by K. Prickett (n.d.). The date is from a stone wall considered to be part of this site complex (see H. M. Leach 1976:Chapter 3).

Site 64: *Pararaki Oven Area* (N168-9/42) The obsidian figures are given by K. Prickett (n.d.) and are from a surface collection. Many Archaic artefacts have been found in this area, and an estimated age of A.D.1250 ± 100 is used.

Site 65: *Foxton Midden Site* (N148/1) The obsidian figures and the date were provided by B. G. McFadgen (1975:pers. comm.).

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