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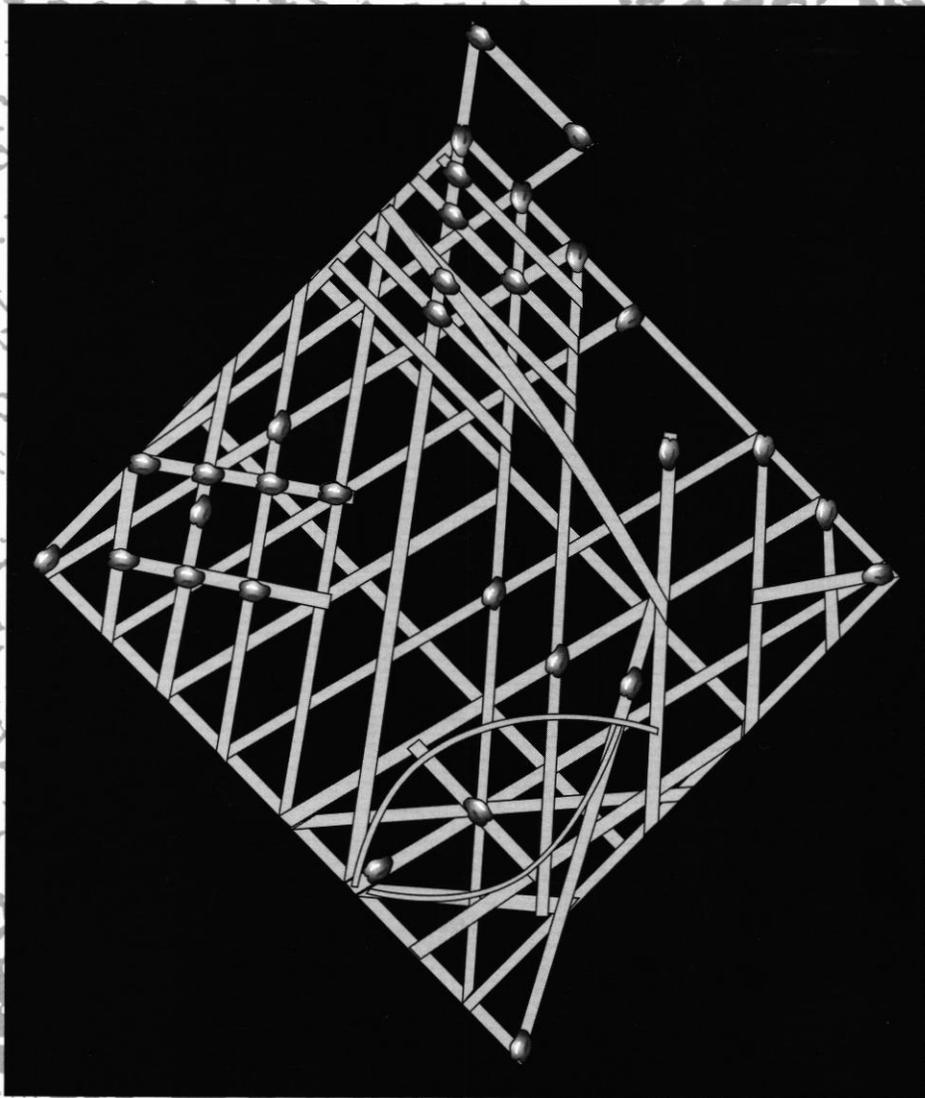
PREHISTORIC LONG-DISTANCE INTERACTION IN OCEANIA: AN INTERDISCIPLINARY APPROACH

Edited by Marshall I. Weisler

PACIFIC ISLAND ADZE GEOCHEMISTRY STUDIES AT THE UNIVERSITY OF AUCKLAND

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The characterisation of adzes and their source quarries has a long history at Auckland with most of the work being supervised or stimulated by Roger Green. Green's undergraduate background in geology lead him to strongly promote the characterisation and sourcing of a range of archaeological materials (Green 1974:141-144; 1997) including adze rock. This work has generally involved collaboration between staff and students in the departments of Geology and Anthropology and in 1980 the Anthropology department contributed funds to a project initiated by geologist Ian Smith to upgrade and automate the wavelength-dispersive x-ray fluorescence (WDXRF) facility in the Geology department.

A major part of this project involved the development of instrument control and data reduction software. Version 3.0 of the analytical system (Parker 1994a, b) represents the end product of a considerable period of software development and incorporates a variety of enhancements over earlier versions.

The earliest published reference at Auckland involving characterisation using geological techniques appears to be that of Crosby (1963) describing thin-section analysis of materials from the Whiritoa, New Zealand site and their comparison to basalt from the Tahanga quarry (Opito Bay, Coromandel). Subsequently, a large adze/axe sourcing project was carried out at Auckland involving a collaboration between Susan Bulmer and John Chappell on the study of adzes/axes from Papua New Guinea (Bulmer 1966:42-43, 79-82; Chappell 1966). This work involved the characterisation of a large number of artefacts and quarries using thin-section petrography and macroscopic properties (Chappell 1966).

Following this, Green collaborated with Phillip Moore on the characterisation of materials recovered from Lapita sites in the Reefs/Santa Cruz with Moore studying 15 artefact thin sections (Green 1976:259; Moore 1978). Also during this time, Moore worked on the characterisation of major North Island, New Zealand adze quarries (Tahanga,

Motutapu) employing macroscopic properties (Moore 1975, 1976).

As part of a functional study on selected adze shapes, Simon Best provided a detailed description of North Island (Coromandel, Auckland and Northland) adze rock using thin-section petrography (Best 1975). Through this work Best was able to characterise the basalt from the Tahanga quarry and the distinctive Northland gabbro and documented their distributions throughout the North Island.

Geochemical analysis of adze materials at Auckland was initiated by Best as part of his Ph.D. research on Lakeba, Fiji. Best (1989: 398) reported petrographic information on 92 Fijian adzes, three Samoan adzes, 63 non-siliceous flakes and 12 samples of Fijian basalt, andesite and volcanic rock (Best 1989: A72). This was complemented by geochemical characterisation of 44 adzes and quarry samples from throughout the Pacific (Fiji, Samoa, New Zealand, Marquesas, Hawaii, Pitcairn, Ra'iatea and Henderson) using XRF spectrometry in the Department of Geology at Auckland (Best 1989:A74). The provenance of these samples and the methods of elemental analysis used are well documented in Best (1989:A70-A78).

Following Best, Richard Walter reported in his Ph.D. thesis (Walter 1990:228-237) on the archaeology of Ma'uke (southern Cooks) the results of XRF analysis 14 adzes and adze flakes and one geological sample (Ma'uke). The majority of these samples are from Ma'uke (8) although material from the other main islands of the southern Cook Islands was also analysed. In an appendix Walter (1990:Appendix B) also presented the results of an average linkage cluster analysis which included data from Best's earlier work and new samples analysed by Best and by Roger Green. This included a series of samples from the Samoan quarry of Tataga-matau. Both Best's early work and that of Walter indicated a significant early distribution of adzes from quarries in Samoa; however, it was not until the rediscovery of the large Tataga-matau quarry on the island of Tutuila, American Samoa and its subsequent

mapping and analysis (Leach and Witter 1987; Best *et al.* 1989) that a significant quarry was available for study.

As part of his work at Tataga-matau, Best carried out systematic sampling of rock variation at the quarry and vicinity. A total of 46 samples from the Tataga-matau quarry and 12 from other east Tutuila quarries and an additional set of adzes were analysed by XRF. These data (86 new analyses incorporating some published samples from the geological literature), along with reports on three thin sections were reported in Best *et al.* (1992) where the geochemical data were analysed and presented using both element plots and cluster analysis. This study documented the importance of the Samoan quarries and the potential of Pacific adze sourcing.

In 1993 Sheppard and Walter began a project to continue adze sourcing research in the southern Cooks. This involved the systematic sampling of adze rock on the islands of Rarotonga, Aitutaki, Atiu, Mitiaro, Mangaia and Ma'uke as well as a large number of adzes (see Chapter 6, this volume). This work has documented the movement of exotic adzes into the southern Cooks. Walter and Sheppard (1996) have also shown the correspondence between oral tradition and the results of sourcing for a cache of adzes from the early Ngati Tiare site on Rarotonga.

Research on the Cooks is continuing with samples from the northern Cooks being currently analysed and further work in the southern Cooks and Australs is in progress. In Samoa, as part of continuing research on the early quarry area at Leone, Tutuila, by Best, 24 new samples have been analysed for major elements, and seven of these for trace elements. In addition the Fagasā quarry, discovered by Dave Herdrich (Chapter 5), has also been sampled by Best, with 19 flakes analysed for major elements, and six of these for trace elements. Research on New Zealand adze sourcing has also continued with Matt Felgate presenting the results of his geochemical and petrographic analysis of the Tahanga quarry as an M.A. research dissertation (Felgate 1993; Felgate, Sheppard and Wilhmhurst ms). This work has demonstrated the potential for intra-site sourcing studies at the Tahanga quarry for examining the history of use of the source.

GEOCHEMICAL ANALYTICAL METHODS

The XRF methods used in the above work were developed for major and trace element analysis of mafic to felsic silicate rocks. The analytical work was done on a wavelength dispersive Philips 1410 XRF spectrometer which had been automated with the addition of a micro-computer for instrument control and data processing. Spectrometer calibration was based on international rock standards such as BR, MRG, JB-1, W-1, AGV-1, JG-1, GH, GA, G-2, SY-2, NIM-S, NIM-L and BCS-375. Standard element concentrations were taken from Abbey (1983) and Govindaraju (1989). In addition the Auckland University Geology Department has developed three internal standards MEB (basalt), MTA (andesite) and TO (obsidian) which are now well analysed by XRF methods. These secondary standards have been useful in evaluating spectrometer performance and calibration techniques for a variety of instrumental conditions and sample weights.

Sample processing

Two main sample types have been analysed: (1) source samples and (2) adze core samples. Source samples were treated as ordinary rock samples with a substantial weight of material (100-200 g or more) taken for crushing and grinding. After fine grinding in a ring mill, a 50 g split was bottled. In the analytical work separate aloquats of powder were taken for major element fusions and trace element briquettes (Parker *et al.* 1993).

Sampling of adzes and adze flakes originally involved the cutting of relatively large slices from archaeological specimens. However, beginning in 1973 (Best pers. comm.), adzes were generally sampled using a diamond coring drill. A coring bit of 10 mm diameter, producing an 8 mm core, was used to take samples from broken surfaces of adzes. An electric drill and a simple drill press with attached wooden clamp allowed a core of greater than 3 g to be typically extracted in 10 minutes. The hole can then be filled with two-part emmerkit epoxy putty that can be tinted and textured to match the adze. The small adze-core samples were first cut for thin sections and the remaining material (2-3 g) used for analysis. An automatic agate mortar and pestle grinder were used for grinding the small amounts of material available from the cores.

In order to standardise the trace analytical procedures a fixed weight of 2 g was taken for preparation of pressed powder briquettes. To check the accuracy of the data for these relatively low weight briquettes, comparative analyses were made with normal weight briquettes (8 g) using the three departmental standards (MEB, MTA and TO). The results of this comparative work indicated no systematic differences outside of the errors expected from counting statistics and sample preparation (Table 12.1).

Once the adze trace-element analyses were completed the rock powder was recovered from the briquettes (by removal of the boric acid backing) and fusion discs were prepared for major element analysis as described below.

	MEB		MTA		TO		dl
	2g	8g	2g	8g	2g	8g	
Ba	208	206	813	827	645	652	11
Rb	19	17	55	55	119	121	2
Sr	481	477	617	620	80	83	2
Pb	8	7	20	18	19	18	4
Th	6	4	7	6	14	15	4
Zr	165	163	115	115	148	157	2
Nb	33	33	5	6	8	8	1
Y	21	21	21	22	22	23	2
La	24	24	17	16	24	24	5
V	206	211	218	217	<dl	<dl	8
Cr	284	294	60	58	<dl	<dl	6
Ni	217	219	11	12	<dl	<dl	6
Zn	121	118	72	71	<dl	<dl	4

MEB: alkali basalt; MTA: andesite; TO: rhyolite. dl: detection limit for basaltic matrix. Spectrometer settings: Rh tube (60 RV, 40 mA), LiF220, fine collimator. Counting times varied from 40 s (heavy traces) to 120 s (light traces). Detectors: Scint (Nb-Pb), Scint+Flow (Ni+Zn), Flow (Cr-La).

TABLE 12.1. Comparison of briquette analyses.

Major element analysis of fusion discs

A chromium x-ray tube was used to measure x-ray intensities on fusion disks for all elements in a single analytical pass. The data reduction programs use procedures similar to those in Parker and Willis (1977). Net peak counts are corrected for dead time and machine drift and relatively narrow detector pulse height windows were set for Mg, Na and P radiation. Matrix correction procedures follow the methods given in Norrish and Hutton (1969). Multi-standard calibration lines are constructed using methods described in Parker (1978). An example of a SiO_2 calibration is given in Table 12.2. Further details on the instrumental and data processing techniques are given in Parker (1994a). Sample preparation is described in Parker et al. (1993).

In appraising calibration line quality particular attention is given to evaluating the back calculated standard errors, i.e., the goodness of fit of the standards with respect to the calibration line. Calibration errors outside counting statistics may be due to a variety of possible sources such as sample preparation, matrix effects, standard inhomogeneity and peak overlaps. However, with care, the standard calibration errors can be reduced to low levels as indicated in Table 12.2.

Trace element analysis on briquettes

X-ray intensities were measured on pressed powder briquettes using a Rh (rhodium) x-ray tube and a single pass for all elements. The measured peak counts were corrected for machine drift, backgrounds, peak overlaps, tube-line interferences and for mass absorption effects. Background counts were corrected for curvature and sample

and standard matrix effects were corrected using major element compositions to calculate bulk mass absorption coefficients. Further details on trace element methods are given in Parker (1994b).

An example of a Y (yttrium) calibration is given in Table 12.3. The calibration data provides a comprehensive listing of the various stages in the calibration process in order to monitor the various corrections applied to the raw data such as background curvature, peak overlaps and matrix effects. A similar approach is applied to evaluating the quality of the trace calibrations as discussed above for major element calibrations. In setting up for trace element analysis particular care has been paid to the following.

Background curvature. The spectral lines for Nb (niobium), Zr (zirconium), Y, Sr (strontium), Rb (rubidium), Th (thorium) and Pb (lead) are affected by relatively high and curving backgrounds associated with the Rh Ka Compton peak and this requires careful calculation of background correction factors (BCF's). In addition due to anomalous reflections in the LIF_{220} crystal fitted to the spectrometer, the background curvature for Rb is dependent on the sample matrix and a linear regression technique was used to correct for this effect (Parker 1994b). The size of this background curvature correction for Rb was minimised by increasing the degree of secondary collimation of the spectrometer (Parker 1993a). This increased collimation obviated the need to apply similar corrections to the BCF's for Th and Pb.

Standard	StdC	CalC	AbsER	RelER	CCPS	NorMAC
9030 BR	39.52	39.52	0	0	11280	1.02
9030 BR	39.52	39.48	0.04	0.1	11267	1.02
9020 MRG	39.79	39.86	-0.1	-0.2	11377	1.021
9020 MRG	39.79	39.66	0.13	0.3	11320	1.021
9510 JB-1	52.89	53.32	-0.4	-0.8	15217	1.011
9510 JB-1	52.89	52.86	0.04	0.1	15085	1.011
9160 NIM-S	63.82	63.73	0.08	0.1	18189	0.989
9160 NIM-S	63.82	63.93	-0.1	-0.2	18246	0.989
9500 JG-1	72.67	72.35	0.33	0.4	20648	0.989
9500 JG-1	72.67	72.89	-0.2	-0.3	20804	0.989
9050 GH	76.31	76.1	0.21	0.3	21718	0.983
9050 GH	76.31	76.29	0.02	0	21774	0.983
SLOPE	ITBK:WPC	CPS	DLIM	AAE	ARE	FOM
3.50E-03	0.14	40	0.02	0.14	0.24	0.2

Counting time: 20; DM CT: 186100.
Abbreviations for Table 12.2: StdC = standard concentration (adjusted for loss on ignition); CalC = standard concentration back calculated from calibration line; AbsER = absolute error (wt %), RelER = relative error (%); CCPS = corrected counts per sec, NorMAC = Norrish mass abs; SLOPE = calibration slope factor (SLOPE * CCPS = concentration); ITBK = iterated background, WPC = wt %, CPS = counts per second; DLIM = detection limit (wt %), AAE = average absolute error (wt %); ARE = average relative error (%), FOM = figure of merit; DM CT = drift monitor count.

TABLE 12.2. Major element analysis: SiO_2 calibration.

STD		CONC	MAC	N-PK	M-PK	TOT-BK	CORBK	T-IF	P-IF
9160	NIM-S	3	9.9	870	39920	39050	12889	0	26161
9160	NIM-S	3	9.9	430	39475	39045	12662	0	26383
9140	NIM-N	7	12	1168	11902	10734	10561	0	173
9140	NIM-N	7	12	1074	12033	10959	10715	0	244
9350	G-2	11	8.7	2834	26182	23348	14037	0	9311
9350	G-2	11	8.7	2376	25913	23537	14304	0	9233
9020	MRG	16	17	1314	10010	8696	8435	0	261
9020	MRG	16	17	1789	10082	8293	8093	0	200
9330	AGV-1	21	11	3880	18980	15100	12159	0	2941
9330	AGV-1	21	11	4061	18748	14687	11693	0	2994
9040	GA	21	8.7	4806	28575	23769	14216	0	9553
9040	GA	21	8.7	4468	28263	23795	14368	0	9427
9300	W-1	26	13	3741	14144	10403	9679	0	724
9300	W-1	26	13	3788	14184	10396	9691	0	706
9380	BHVO-	27	14	4062	13861	9800	9439	0	361
9380	BHVO-	27	14	3770	13642	9872	9475	0	397
9700	DR-N	30	12	4748	18448	13700	10795	0	2905
9700	DR-N	30	12	4944	18606	13662	10716	0	2946
9030	BR	30	15	4010	14954	10944	9368	0	1576
9030	BR	30	15	3956	14657	10702	9200	0	1502
9050	GH	70	7.7	21704	60462	38758	14930	9	23828
9050	GH	70	7.7	20998	60005	39007	15207	0	23800
9000	SY-2	130	11	25028	46198	21170	11509	0	9661
9000	SY-2	130	11	23949	45441	21492	11776	0	9716

STD	CONC	CCONC	AbsER	RelER	S INT	CORPK	CEC	CEP	DL	nMAC
NIM-S	3	4.2	-1.2	-38.5	21527	716	231	1.3	2.8	0.823
NIM-S	3	2.1	0.9	31.6	21710	354	231	1.3	2.8	0.823
NIM-N	7	6.8	0.2	2.5	174	1177	152	0.9	1.8	1.008
NIM-N	7	6.3	0.7	10.3	246	1082	153	0.9	1.8	1.008
G-2	11	12	-0.5	-4.3	6735	2050	161	0.9	1.9	0.723
G-2	11	10	1.4	12.5	6678	1718	161	0.9	1.9	0.723
MRG	16	11	5.2	32.6	369	1860	194	1.1	2.3	1.416
MRG	16	15	1.3	8.2	283	2533	192	1.1	2.2	1.416
AGV-1	21	20	1.1	5.1	2603	3433	163	0.9	1.9	0.885
AGV-1	21	21	0.1	0.7	2649	3594	162	0.9	1.9	0.885
GA	21	20	0.9	4.2	6889	3466	165	1	1.9	0.721
GA	21	19	2.3	11	6798	3466	165	1	1.9	0.721
W-1	26	24	2.2	8.4	794	4102	172	1	1.9	1.097
W-1	26	24	1.9	7.3	774	4153	172	1	1.9	1.097
BHVO-	27	28	-0.5	-2	422	4747	180	1	2	1.169
BHVO-	27	26	1.4	5.3	464	4406	179	1	2	1.169
DR-N	30	28	2.5	8.3	2899	4739	179	1	2	0.998
DR-N	30	29	1.4	4.6	2940	4934	179	1	2	0.998
BR	30	29	1.3	4.4	1944	4945	198	1.2	2.2	1.233
BR	30	28	1.7	5.6	1852	3878	196	1.1	2.2	1.233
GH	70	81	-11.2	-15.9	15355	13986	203	1.2	2.2	0.644
GH	70	79	-8.5	-12.2	15337	13531	203	1.2	2.2	0.644
SY-2	130	135	-5.3	-4.1	9001	25318	242	1.4	2.4	0.932
SY-S	130	130	0.5	0.4	9052	22313	241	1.4	2.4	0.932

Notes: Element Y Slope Fac: 172.34; AAE: 2.3; ARE: 10.0; FOM: 6.9; Counting Time: 40; AV RCE: 3.3; AV CEP: 1.1; AV DL: 2.1; BCCF: .990; PIF1: .202 (Rb Kb on Y Kα).
Abbreviations for Table 12.3: STD = standard; CONC = concentration (ppm); MAC = mass absorption coefficient; N-PK = net peak count; M-PK = measured peak count; TOT-BK = total background count; CORBK = corrected background; T-IF = tube interference; P-IF = peak interference; CCONC = standard concentration back calculated from calibration line; AbsER = absolute error (ppm); RelER = relative error (%); S INT = sum interference counts; CORPK = corrected peak count; CEC = counting error (counts); CEP = counting error (ppm). DL = detection limit (ppm); nMAC = normalised MAC; Slope Fac = calibration slope factor (corrected net peak counts per ppm); AAE = average absolute error (ppm); ARE = average relative error (%); FOM = figure of merit; AV RCE = average relative count. AV CEP = average counting error (ppm); AV DL = average detection limit (ppm); BCCF = background curvature correction factor; PIF1 = peak interference correction factor.

TABLE 12.3. Trace element analysis: Y calibration.

2-theta scanning. Peak overlap interferences are significant for a number of elements and interference corrections are required. The accuracy of the peak interference factors (PIF's) is critically dependent on the reproducible and accurate positioning of the goniometer on the analytical peak. Since the goniometer 2-theta peak position can drift over time, peak scanning subroutines were built into the spectrometer control software and these procedures ensured reproducible on-peak goniometer settings for the overlapped trace elements. These procedures also improve the quality of the net peak data for all elements.

Pulse height scanning. Data quality was further improved by using pulse height scanning under automation control to ensure the correct setting of the pulse height windows for the flow and scintillation counters. Both pulse height and 2-theta scanning was done on a regular basis during the analytical runs to ensure that the settings were continuously updated.

Trace element analysis on fusion discs

In a number of adze samples the recovered sample cores produced only small amounts of material (0.5-1.5 g) which was insufficient to make 2 g trace element briquettes. However, fusion discs could be prepared (minimum weight = 0.5 g) for major element analysis.

Because of the importance of trace element data in the statistical evaluation and grouping of samples it was decided to investigate trace element analysis on the fusion discs using multi-standard calibration procedures similar to those described for the pressed powder briquettes. This was successfully achieved for Nb, Zr, Y, Sr, Rb, Th, Zn (zinc), Ni (nickel), Cr (cromium) and V (vanadium) although detection limits were higher using this method. The presence of La (lanthanum) in the Norrish flux prevented the analysis of this element. The analysis of Ba (barium) was also precluded because of low count rates and the influence of nearby La lines.

Analysis of international rock standards

The mineral complexity of rocks and the large variation in their chemical compositions means that analytical methods should include development, testing and calibration using natural rock standards rather than using pure element synthetic standards. The availability of reliable standards is therefore of considerable importance and over the years a range of natural rock standards have been prepared and released by various international organizations.

As an example the International Working Group (IWG) on rock standards prepared in 1986 the new granite standard

AC-E for distribution and analysis. The resulting data from Auckland University and from other laboratories around the world (128 laboratories participated) was collated in 1987 by the IWG and the preferred 'working values' published for AC-E in October 1987. Table 12.4 lists a comparison between the IWG 'working values' and the values determined in the Geology Department at Auckland. It is clear that there is excellent correspondence between the two sets of data and this may be used as an independent measure of the quality of the XRF analytical methods developed at Auckland.

Future analytical developments

Further work is currently being done on flux fusion methods for the analysis of both majors and traces on small (i.e., 1-2 g) samples with the aim of reducing detection limits and extending the range of trace elements to include all those that are normally done on pressed powder briquettes. This requires increasing the sample to flux ratio (e.g., 1:4 vs 1:5.36), increasing counting times and the use of a La free flux such as the Norrish 12/22 flux. Initial tests on such fusions are producing encouraging results.

This work links with the recent acquisition by the Geology Department of a new Siemens SRS 3000 spectrometer which provides increased analytical sensitivity

	A Auckland XRF Analysis	C Compilation working values	Compilation 1 σ	A - C (absolute difference)
SiO_2	70.49	70.35	0.42	0.14
TiO_2	0.11	0.11	0.03	0
Al_2O_3	14.71	14.70	0.29	0.01
Fe_2O_3	2.63	2.53	0.13	0.1
MnO	0.06	0.06	0.01	0
MgO	0.07	0.03	0.04	0.04
CaO	0.34	0.34	0.09	0
Na_2O	6.58	6.54	0.23	0.04
K_2O	4.42	4.49	0.13	0.07
P_2O_5	0.02	0.014	0.02	0.007
H_2O	0.10	0.15	0.07	0.05
LOI	0.34	0.37	0.12	0.03
Total	99.87	99.63	1.58	0.487
Nb	115	110	16	5
Zr	791	780	80	11
Y	187	184	21	3
Sr	<2	3	3	-
Rb	146	152	10	6
Th	19	19	3	0
Ni	<3	2	4	-
Cr	<4	3	4	-
Ba	64	55	20	9
V	<3	3	2	-
La	62	59	8	3

TABLE 12.4. XRF analysis of standard AC-E.

and an automatic sample changer. In addition the flux fusion facilities have been upgraded with the acquisition of an automated fusion and casting machine (Automated Fusion Technologies Phoenix 4000) which greatly facilitates the production of high quality fusion discs.

Statistical analysis

The results of the XRF analysis have been published in tabular form and are available as EXCEL, SPSS and ASCII text databases. The analysis of these data has varied considerably over the years. In theory, if all sources are known, it might be possible to find one or a small set of elements which would discriminate sources with a minimum of statistical manipulation. Unfortunately, it does not seem probable that all adzes are derived from large quarries with many possibly coming from very small quarries or river cobble or beach deposits (Chapter 6). It also seems probable, as in New Zealand, that over time reliance on large quarries may have declined introducing a chronological effect of great interest. Under these conditions it is important to employ both techniques which have been shown to discriminate among known sources and techniques which search for structure or clustering using all available data. Among the latter are cluster analysis and principal components analysis. Both types of approaches have been employed at Auckland.

Best (1989) found that a simple ternary plot of the percentages of iron, titanium and phosphorous allowed discrimination among his set of quarry samples. Similar plots using the ratio of iron to titanium against phosphorous have been used in Best *et al.* (1992). Such simple plots are methodologically attractive; however, as more data has been added, discrimination, especially within island groups, has decreased and it seems likely the situation will become steadily worse (Best *et al.* 1992:64). In addition the use of a small number of elements requires a high degree of confidence in the accuracy or precision of a few elements and close evaluation of effects such as weathering which might significantly alter elements such as iron. The use of a large set of elements in some form of multivariate pattern seeking procedure may have the effect of smoothing out noise created by aberrant values for particular elements.

Cluster analysis on Log10 transformed and standardized (mean 0, standard deviation of 1) data has been the technique used most often at Auckland. The data have been transformed to normalize it and equalise the weighting of the different elements (Baxter 1994:45; Bishop and Neff 1989:63). As a general rule both Average Linkage and Ward's Method cluster analysis on euclidean distances have been employed to assess the stability of clusters across methods. No rule has or can be made for determining cluster cut points.

It can be expected that in large datasets encompassing different islands or island groups major sources will be represented by relatively tight groupings while non-quarry focused adze manufacture may be represented by loose clustering with samples joining at comparatively low levels of similarity. The results of cluster analysis have been presented as data tables ordered according to the cluster dendrogram. This allows the reader to evaluate the significance of any distinctions made within the analysis. Recently principal components analysis has been used with considerable success as a means of searching for data structure and representing the results in simple plots of component scores (Walter and Sheppard 1996).

CONCLUSIONS

The development of routine accurate geochemical analysis of silicate samples has found fertile application in the field of archaeometry. This is well illustrated in provenance studies on basaltic adzes in the South Pacific. Workers in the Anthropology Department at Auckland University have amassed a large amount of geochemical (> 265 analyses) and other information over the last ten years resulting in a considerable advance in our knowledge of prehistoric spatial interaction in the Pacific.

Underpinning this archaeometric work has been the ongoing development of XRF instrumentation and analytical methods in the Geology Department with particular attention being given to spectrometer calibration procedures. Calibrations are based on a range of natural rock standards of varying concentrations and matrix characteristics and the calibration quality is evaluated in terms of minimising the standard errors with respect to the calibration lines.

In addition, the quality and accuracy of analytical procedures has been evaluated by the analysis of new international rock standards with the results compared with the final compilation values for each element. This provides a crucial check of the procedures since the new standards are analysed as unknown samples without any knowledge as to what the final compilation results will be.

Analysis of small sample weights is facilitated by methods that allow both majors and traces to be determined on the same fusion disk. Development of such methods has proved to be useful for a number of samples and it is anticipated that further work will be done in extending the sensitivity of the methods for trace element analyses on fused disks.

Using high quality geochemcial data, our experience suggests that examination of clustering or principal components analysis when combined with simple graphical presentations, petrographic analysis and petrogenic knowledge, is the best method for assessing the probability of an adze sample belonging to a source or source region within the Pacific. Ideally, future work will attempt to provide some probabilistic assessment of confidence in source attribution.

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