



NEW ZEALAND
ARCHAEOLOGICAL
ASSOCIATION

NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION NEWSLETTER



This document is made available by The New Zealand Archaeological Association under the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.

To view a copy of this license, visit
<http://creativecommons.org/licenses/by-nc-sa/4.0/>.

PROGRESS TOWARDS THE ROUTINE SOURCING
OF NEW ZEALAND OBSIDIANS

B. Foss Leach*

At the NZAA Conference in Wellington last year, Professor Green initiated a discussion on the problem of routine sourcing of New Zealand lithic materials, and in particular of obsidian. He rightly drew attention to the gap between the initial, first stages of research, into source characterization, where a good deal of high quality results have been achieved, and the second stage of routine analysis of archaeological material. He deplored the time gap between these two stages, and urged those interested in this research area to put every effort into passing into what he dubbed the 'routinization' stage, where answers to meaningful culture-historical questions might be forthcoming. I fully sympathise with these sentiments and have been making some efforts towards this transition, but I feel it is also worthwhile to view this goal in a wider perspective and recognise the importance of continued background research into the properties of obsidian. This paper reviews some of the recent progress in this field, and suggests areas where further research may be fruitful. It is unfortunately necessary to use a few technical terms in this review - I have simplified the discussion as much as possible, but there is a limit to how much one can disguise the complexity of the problem of sourcing New Zealand obsidian.

New Zealand archaeologists are not alone with this problem of sourcing obsidian on a routine basis; however, there is one feature unique to New Zealand which compounds an already difficult problem. Prehistoric Polynesians were confronted with an exceptionally rich geological environment when they landed in New Zealand. In the case of obsidian there are no less than 18 primary sources which may be distinguished by existing analytical techniques. This can be compared with the Middle East where about eight sources are believed to exist, and several of these are known only from archaeological material. This difference in *number* of sources has two important consequences:

*Visiting Fellow, Department of Prehistory, Research School of Pacific Studies, Australian National University. September 1976.

1. The analytical difficulty of sourcing New Zealand obsidian is greater than in other parts of the world.
2. The sheer number of sources means that far larger archaeological samples must be analysed in order to yield meaningful patterns in the movement of the raw material by prehistoric groups.

Let me expand briefly on each of these points: as for the first, research work by New Zealand archaeologists and scientists has been of a very high standard and paves the way in a number of respects. The most recent work in a long string of studies is of trace elements by X-Ray Fluorescence (XRF) by Graeme Ward, and is a work of exceptional scholarship. This resulted in the more or less unambiguous separation of the 18 sources in question (Ward 1972, 1973, 1974a, 1974b). It should be remembered that Ward began with 42 geographical sources; that is to say 42 different locations where obsidian can be found in New Zealand and which may possess different physical or chemical properties.

After the trace element analysis, he regarded 18 petrographic sources as being distinguishable. In some cases, such as with Mayor Island, Waihi, Rotorua and Maraetai, individual sources contain material of very wide-ranging hand specimen character. In only a few cases could further clustering of these sources be achieved (which would incidentally simplify routine sourcing). This is because the pooling of dissimilar results into groups of sources has certain undesirable repercussions. Admittedly, the geographical separation of some of these sources is rather trivial, but their petrographic separation is most important. Unwarranted clustering of sources causes an arbitrary *increase* in the dispersion matrix; in turn this results in a serious *decrease* in the reliability with which archaeological obsidian could be related to the original geographic source. With judicious clustering of sources, the number might be reduced to perhaps 15; however, the resulting simplification of routine sourcing would not be significant, and there seems therefore little point in attempting this. If anything, the number may actually increase in future as further sources become known. There is already some evidence for an 'unknown source' in New Zealand from the results of XRF on archaeological material.

In short, we are stuck with a large number of sources, and this makes routine sourcing rather difficult. Of the techniques applied to date, which have examined such properties as density, refractive index, and element composition, there is no doubt that trace element analysis is by far the most effective. In this research area people in New Zealand have used high power wavelength-dispersive XRF, Emission Spectroscopy, low power energy-dispersive XRF, and a fairly

new method based on inelastic scattering of protons (qu Coote *et al.*, 1972). The results of these techniques share an important feature - they have yielded information on only the lighter elements. Some of the techniques used are only capable of light element analysis, but others cover the heavier elements also. The most successful source studies in other parts of the world have been of the heavier elements such as those in the 'Rare Earth' suite. In passing, it must be noted that *only* Ward's study has demonstrated the separation of the full set of New Zealand sources. Until alternative methods have been applied to the full reference collection of sources (and the results published) their success at separation must remain doubtful, and certainly should not be applied to routine sourcing.

The second point I raised relates to the size of archaeological samples. The large number of sources means that it is more difficult to derive statistically valid conclusions relating to fluctuations in the use of different sources in time and space. This problem is probably far more serious than any relating to source characterization. Again, having such a large number of sources makes it very difficult to prove that a particular source was *not* being exploited by a certain group of prehistoric people, short of analysing the entire assemblage. In other words, it is harder to draw inferences based on negative evidence. This situation can be alleviated to some extent by pooling a set of detailed results - for instance, adding together the numbers of pieces from Ongaroto, Maraetai and Taupo, and calling them 'Taupo Region'. Similarly, the Rotorua sources could be grouped in this way, and a number of others in the Coromandel region. I am not suggesting, however, that sources be grouped during analysis for the reasons mentioned earlier; although they could be during interpretation of results. Fluctuations in proportions of material from these different 'source regions' can be assessed for significance more easily. Unfortunately, however, the scale of the problem is greater than could be offset by this apparent advantage. This can be illustrated by reference to some results from the Washpool site in Palliser Bay (see Figure 1). This tabulation represents two versions of the proportions of Mayor Island obsidian to the pooled results for all other sources at three periods in the occupation sequence. Part A shows the proportions of green obsidian (putatively from Mayor Island) to other colours, while Part B shows the results of accurate sourcing by XRF trace element analysis and the use of multivariate discriminant functions. It should not be thought that the green colouration is necessarily a reliable guide to an origin from Mayor Island. On the contrary, Ward has demonstrated that colour can be most ambiguous and should not be used for source

allocation without hard supporting evidence. In the particular case of the Wairarapa obsidian, 144 pieces of green obsidian were analysed by XRF and all but six were found to be in fact from Mayor Island. This probably indicates that the two parts of Figure 1 reflect the same process of historical change. For Part A, the sample size is over 3,500 pieces and each fluctuation is highly significant. The sample size for Part B was 159 pieces, and, although the same pattern of increasing reliance on Mayor Island material is evident, significance cannot be proven at an acceptable statistical level.

FIGURE 1: SOME CHANGES IN WASHPOOL OBSIDIAN TYPES THROUGH TIME

Significances were calculated by Rosenbaum's exact probability method (qv Leach 1976: 466ff). Sources used were Mayor Island, Cooks Bay, Huruiki, Taupo, Rotorua, Purangi, Ongaroto.
Site = N168/22

A. Washpool Total Assemblage (N=3525) - Colour Analysis

Each change through time is significant (p less than .01)

<u>Period</u>	<u>Sample</u>	<u>Green Obsidian</u>	<u>Other Colours</u>
c.1538 AD	83	90.4%	9.6%
c.1345 AD	1975	83.5%	16.5%
c.1180 AD	1467	77.4%	22.6%

B. Washpool Random Sample (N = 159) - XRF Analysis

No change through time is significant (p less than .05)

<u>Period</u>	<u>Sample</u>	<u>Mayor Island</u>	<u>Other Sources</u>
c.1538 AD	22	81.8%	18.2%
c.1345 AD	98	71.4%	28.6%
c.1180 AD	39	69.2%	30.8%

The results in Figure 1 highlight, I think, the real nature of the problem with this kind of work. It is moreover a problem not unique to New Zealand, but is seldom recognised in its full perspective.

The sample size of 159 is large by international standards for similar work, which is very time consuming and expensive. It might be compared with a recent and rather typical analysis of 99 pieces from the Middle East by neutron activation analysis (NAA), selected from such sites as Jarmo where nearly 40,000 pieces of obsidian have been recovered (Renfrew *et al.*, 1966: 58). In the Palliser Bay work, 211 pieces have been analysed, 19 of these by Graeme Ward, and the remainder by Atholl Anderson and myself. Even with this relatively large sample, few meaningful patterns of utilisation can be detected from the results. Over the past 10 years approximately 800 pieces of New Zealand obsidian have been used for trace element determination, and of these only about 300 have been archaeological in origin. The latter results have been tantalising, but not especially revealing in my opinion. Ideally, whole assemblages need to be analysed from each site in order to realise the full benefits of this work.

To summarise at this point: In order to advance into the second stage of routine sourcing of archaeological obsidian we need a technique or set of techniques capable of distinguishing between a large number of sources. It must be added that to be useful the technique must be relatively inexpensive (both in capital outlay and operating costs), very rapid in analysis, non-destructive of the sample, and able to be used by archaeologists with the bare minimum of technical training. Over and above this list of apparent impossibilities, the technique must be of a kind so that analyses of entire assemblages of artefacts are feasible - running into thousands of pieces in some cases. This may seem an insurmountable list of criteria, but I think it is a fairly realistic appraisal of the situation. In my opinion, phase 2 is just around the corner; however, it would be quite wrong to be lulled into complacency - even more than ever we should promote vigorous research for background information on New Zealand obsidian. A recent paper by Ericson *et al.* (1975) surveys an impressive range of properties of American obsidians from thermal expansion, density, hardness, chemical durability, electrical properties, and both Mössbauer and infra-red spectroscopy. With a little ingenuity these could be applied to a number of archaeological problems including source characterization.

One of the most important criteria is the expense of routine sourcing, both in terms of human energy and dollars. This is where most common methods of element characterization fall down. Conventional techniques such as high power XRF and emission spectroscopy are destructive of samples, the initial costs are beyond New Zealand archaeological institutions, and people in the laboratories which do

have such equipment quite naturally do not want hoards of archaeological samples being run on them - even were we to supply the large human energy required. A relatively new 'prompt nuclear analysis' technique might be mentioned at this point. This involves very rapid gamma ray analysis following irradiation in a nuclear reactor. The technique is being evaluated for its application to archaeological problems by Wal Ambrose at Australian National University (see Bird and Russell, n.d.). Unfortunately, the method requires a source of high energy particles such as supplied by a reactor or Van de Graaff accelerator, and much other backup equipment and technical management. The general demand for space in reactors is such that for routine work costs can be prohibitive (over \$3 per sample for irradiation and transport alone at the University of Bradford). Moreover, this new technique can only be used to analyse a few of the lighter elements at a time, and is therefore unsuited to such a complex problem as the New Zealand obsidian. It will be welcomed though for its application to many other archaeological problems, including the dating of obsidian. At the Oxford Research Laboratory for Archaeology an automated system of Atomic Absorption analysis is being developed for pottery trace element analysis to sort out trading patterns in Western Europe. Automated systems of sample transfer and energy spectrum interpretation can and have been applied to XRF, too, but these are still expensive to run, and require tedious sample preparation, and destruction of the artefact. The human time involved still precludes the analysis of thousands of samples.

The most exciting innovation by far in recent years has been the development of energy-dispersive low power XRF and the multi-channel analyser (MCA). In brief, this technique undertakes more or less instantaneous analysis over the entire spectrum of X-rays produced by the sample. In conventional high power wavelength-dispersive XRF, the wavelength spectrum was split up by means of a special crystal (LiF), and this was scanned mechanically with the scintillation counter mounted on a set of rotating gears. This was a time-consuming process, and there were always problems such as backlash in the driving mechanism. The new technique is quite revolutionary, and it is as if there were over a thousand scintillation counters operating simultaneously on the sample. In addition, the absence of the dispersive element means that the X-ray output of the tube can be reduced drastically. This is a major advantage, since the output of the conventional X-ray tube was perhaps 2,000 watts compared with 20 watts for the new system. The old XRF machines were a distinct health hazard, too, and required massive stabilised power supplies - the Milliprobe XRF machine at Oxford has a power supply 8ft high and weighs over a ton.

A practical energy-dispersive low power X-ray analyser has been a reality for quite some years, but what was gained in miniaturization was accompanied initially by a loss of resolution amongst elements. Several generations of machines were not capable of resolving them to the kind of precision needed for the New Zealand obsidian problem. Under *ideal* conditions, with helium flush around the sample, the use of specially selected detector crystals (which incidentally are very expensive), and ultra-thin beryllium windows (these can be as thin as 7.5 microns and are expensive and very easily broken), these machines could resolve *some* of the New Zealand sources. Manufacturers quite naturally operate their machines under such ideal conditions to impress potential customers and claim replication to 1 part per million (ppm) for some elements. Some machines can produce results for chlorine and even sodium, and both these elements could be useful for the New Zealand problem. However, this is possible only under ideal conditions, and slightly sturdier machines cannot achieve the desired resolution.

Fairly recently, significant developments have come about which may prove to have overcome these early drawbacks. Scientists at the Nuclear Research Laboratories at Harwell in England have been working for six years perfecting a new X-ray tube with a power supply so small it is packed inside the cooling fin of the tube itself. The whole arrangement is only about 40cm long and 10cm in diameter. It operates on an indirect or scatter principle so that X-rays from the tube itself strike a secondary target (usually of lead) which causes X-ray fluorescence from this target. In turn these secondary X-rays, which are in a narrow energy band, are directed at the obsidian. This in turn fluoresces X-rays and these strike the detector crystal. From this point on, the electronic analysis is the same as previous analysers. Resolution of element peaks is enhanced greatly by this scatter technique, although the tube must be operated at slightly higher power, at about 40 watts. Coupled to this innovation, the efficiency of lithium drifted silicon detector crystals has been improved significantly in the last few years, further assisting element resolution. Again, this method has been known about for many years, but a thoroughly developed version will not appear on the market until later this year.

I have had the opportunity of trying New Zealand obsidian on this new tube and it is able to produce absolute concentrations for about 20 elements to the precision required in about ten minutes. Another welcome feature of these machines is that the price is coming down.

Five years ago a similar system would have cost about \$70,000; vastly superior machines are now approximately half that price.

In summary, machines do now exist, which although expensive in terms of initial outlay, have practically no running costs, and are capable of the kind of resolution needed. They will cope with thousands of samples, they are non-destructive, and with very little training anyone can operate one. With only slight modifications to computer programmes already developed in New Zealand (qv Leach 1969; Ward 1972), a machine like this can be totally automated so that a person can simply put a piece of obsidian in a plasticine holder in front of the tube, press one button, wait five to 10 minutes and the teletype will print out a message like:

'The sample came from Mayor Island,
with a probability of 95%'.

There are many additional advantages that this new generation of machines will offer. One research possibility was quickly developed by the Oxford Research Laboratory for Archaeology (see Hall *et al.*, 1973). The use of these highly sensitive detectors (operating at the temperature of liquid nitrogen) also enables element analysis in the higher energy X-ray spectrum using a low output radioactive source as an alternative to an X-ray tube. Hence the commonly used jargon of 'isoprobe' - a probe using isotopes, and the 'SEFA', meaning a Source Excited Fluorescence Analyser. I have conducted some preliminary tests with the Oxford Isoprobe on our obsidian with some surprising results. Those who have followed the problems of New Zealand obsidian sourcing will appreciate that a great bulk of the work could be circumvented if a simple test could be devised to screen off Mayor Island material. Its green colouration is neither characteristic of Mayor Island, nor indeed confined to Mayor Island. No doubt, sorting by colour would be thoroughly reliable in some assemblages; equally it would be thoroughly unreliable in others. The problem is that one does not know when hand sorting can be applied and when it cannot, without additional scientific evidence. It would appear from the Isoprobe results that the screening of Mayor Island obsidian could be achieved quite satisfactorily using a small quantity of a radioactive isotope - I have been using an isotope of Americium (^{241}Am). This has shown up a number of elements which cannot be resolved with a low power XRF tube such as silver, lanthanum, barium and cerium. I have since found with neutron activation analysis that these elements are very useful in separating sources. More to the point, however, the peaks of barium

and cerium are quite different for Mayor Island and other sources. Obsidian from Pungaere and Waiare have very large peaks for both elements, while Mayor Island has no barium peak but a large cerium one. The remaining 15 sources have the exact reverse - large barium peak and no cerium. A screening process therefore would be qualitative and could be undertaken in about two minutes per sample from chips straight out of the ground after washing. The equipment itself can be used in the field since it is not bulky and uses very little electrical power. Dr McKerrell of the National Museum of Scotland has one of these machines installed in his vehicle, running off an ordinary car battery. The important difference between this technique and the Tube Excited Fluorescence Analyser (TEFA) is that in the case of the SEFA or Isoprobe the very tiny element peaks clearly stand out against a practically flat background.

At the beginning of this paper I suggested that background research into the physical and chemical properties of obsidian should continue abreast of any scheme to implement routine sourcing - one never knows what will turn up, like this accidental finding of the barium and cerium peaks with the Isoprobe. Recently I have been carrying out a programme of element research into about 200 source specimens of New Zealand obsidian by neutron activation analysis in the School of Archaeological Sciences at the University of Bradford. This technique has detected significant quantities of at least 26 elements down to concentrations of about 100 parts per billion (ppb), and although results are only partly processed as yet, there are some interesting surprises.

One of these is that the concentrations of uranium and thorium are very high in certain sources. For the most part, uranium occurs at about 3 ppm and thorium at about 12 ppm in New Zealand obsidian; and this is consistent with obsidians from other parts of the world. However, in the case of Pungaere, Weta and Waiare (all sources north of the Bay of Islands) the concentrations are much higher at about 30 ppm uranium and 100 ppm thorium. These results will enable calibration of New Zealand obsidian fission track dating, and with 30 ppm of uranium in Waiare obsidian there should be a fair number of tracks present. It may be enough to date cultural events in cases of annealed obsidian which frequently occurs in sites where structures have been burnt. There is a good deal of interest in fission track analysis by nuclear physicists because of the application to personal radiation monitoring. Sophisticated but inexpensive devices have been made which are thoroughly portable and automatically scan and count fission tracks on solid state dosimeters

worn by people where there is a radiation hazard (see for instance Becker, 1973: 197ff). It is possible therefore that sourcing obsidian by fission track dating could develop into a rapid, inexpensive and accurate technique. It seems unlikely that this could be achieved without at least partial sample destruction.

Since finding these differences in uranium and thorium contents, I have initiated a series of experiments to count the α and β particles which naturally emanate directly from the obsidian - after all these two elements are radioactive. I have found that although a very few α particles can be detected, as many as 90 counts per minute per gram can be detected from Waiare obsidian with a β counter. It is thus a relatively simple matter to screen out of an archaeological assemblage obsidian from these three sources from the far north using a geiger counter.

There are several other innovations I have been following up and which may assist obsidian sourcing in future. It is well known that the complex shape of thermoluminescent (TL) glow curves is more related to the minor and trace element content than to the major elements in a sample. The former group of elements have the effect of distorting the lattice structure which give rise to unique combinations of electron traps. It might therefore be anticipated that the complex changes in trace element content in different obsidians could be revealed by measurement of the TL. This is indeed the case. I have carried out tests in the Chemistry Department at the University of Hawaii on obsidians from all the New Zealand sources, and found pronounced differences between each. The analysis takes about five minutes per sample, and requires only a tiny sample of about 7mg.

A second interesting possibility was suggested to me by a physicist at the University of Newcastle-on-Tyne. He pointed to the fact that different obsidians may have different amounts of remnant magnetism if they were formed at different periods under varying external magnetic conditions. Preliminary tests with samples from Mayor Island and Cooks Bay have shown significant differences in both magnetic stability and intensity, and suggest that this technique may be useful for sourcing also.

Finally, another possibility can be put forward which also is based on magnetic properties. The NAA research revealed that Mayor Island obsidian possesses about 4% of iron compared with about 1% for all other sources in New Zealand. Since the presence of iron has

the effect of increasing the inductance of a coil and, given a suitable electronic arrangement for measuring this effect, the magnetic susceptibility of irregular samples of obsidian could be determined with a high degree of accuracy. Initial tests with Mayor Island and other obsidians on a simple balanced bridge circuit have given promising results. They suggest that the Mayor Island material could be screened from assemblages simply by placing a flake in such a coil and observing the large meter deflection which results. An electronics expert at the University of Bradford believes it is possible to improve the sensitivity of existing equipment designs (for example, Schollar 1968) by a factor of ten, which even may distinguish among other New Zealand obsidian source deposits.

In conclusion, even on the basis of present knowledge, a feasible system of routine obsidian sourcing could be set up. This would involve two steps:

1. A rapid process of screening off Mayor Island material using either a test for barium concentration with a radioactive isotope, or measurement of magnetic susceptibility.
2. XRF spectrum analysis using a low power secondary target system

Such a procedure could operate at a moderate pace of perhaps 1500 to 3000 samples per month, allowing plenty of time for maintenance and more general research applications of the equipment. A sourcing scheme like this could be largely automated so that we can forget about elements and X-rays and simply learn to press the appropriate button.

ACKNOWLEDGMENT

This paper is a revised version of one delivered to the NZAA Conference in Whakatane, 1976. I am indebted to Graeme Ward for helpful suggestions during the revision.

REFERENCES

- Barnard, N. (ed.) n.d. *Scientific Methods of Research in the Study of Ancient Chinese and Southeast Asian Metal Artefacts: A Symposium*. In press
- Becker, K. 1973 *Solid State Dosimetry* CRC Press, Ohio
- Bird, J.R. and L.H. Russell n.d. Application of Prompt Nuclear Analysis Techniques to the study of Artifacts including Southwest Pacific Obsidian. In Barnard, n.d. (qv)
- Coote, G.E., N.E. Whitehead and G.J. McCallum 1972 A Rapid Method of Obsidian Characterisation by inelastic scattering of protons. *Journal of Radioanalytical Chemistry* 12:491-6
- Hall, E.T., F. Schweizer and P.A. Toller 1973 X-Ray Fluorescence Analysis of Museum Objects: A New Instrument. 1: A non-dispersive X-Ray 'Isoprobe' *Archaeometry* 15(1):53-57
- Leach, B.F. 1969 The Concept of Similarity in Prehistoric Studies. *Studies in Prehistoric Anthropology* Vol.1
- _____ 1976 *Prehistoric Communities in Palliser Bay, New Zealand*. Unpublished PhD Thesis in Anthropology, University of Otago
- Renfrew, C., J.E. Dixon and J.R. Cann 1966 Obsidian and Early Cultural Contact in the Near East. *Proceedings of the Prehistoric Society* 32:30-72
- Schollar, I. 1968 A simple Direct Reading Susceptibility Bridge. *Journal of Scientific Instruments* (Journal of Physics E) Series 2, Vol.1:781-2
- Ward, G.K. 1972 *Obsidian and New Zealand Archaeology*. Unpublished MA Thesis in Anthropology, University of Otago
- _____ 1973 Obsidian Source Localities in the North Island of New Zealand. *NZAA Newsletter* 16(3):85:103
- _____ 1974a A Paradigm for Sourcing New Zealand Archaeological Obsidians. *Journal of the Royal Society of New Zealand* 4(1):47-62
- _____ 1974b A Systematic Approach to the Definition of Sources of Raw Material. *Archaeometry* 16(1):41-53