# ARCHAEOLOGY IN NEW ZEALAND

# MEASURING SOIL TEMPERATURES FOR OBSIDIAN HYDRATION DATING IN NORTHERN NEW ZEALAND

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## INTRODUCTION

The use of radiocarbon dates within New Zealand archaeology is problematic. The high cost of the age determinations and the inaccurate dates provided do not allow for fine scale temporal resolution. While very accurate measurements of residual $^{14}C$ concentrations can be made from archaeological material, the corresponding "dates" suffer from a number of intrinsic problems, such as inbuilt age (Anderson 1991) and the nature of the calibration curve during much of New Zealand's prehistory (Stuiver and Pearson 1986). Problems can also occur in establishing the archaeological context of the material presented for dating purposes (Taylor 1987).

In response to these problems, and calls for alternative dating methods (Anderson 1987), the Centre for Archaeological Research, University of Auckland has implemented a research project to establish a working protocol for the use of Obsidian Hydration Dating (OHD) within New Zealand. This work is funded by the Foundation of Research, Science and Technology. OHD has been extensively used overseas, where it has been shown to be an accurate, quick and inexpensive process. Obsidian Hydration dates also have the advantage that they directly relate to cultural activities, as opposed to radiocarbon where this is not necessarily the case.

The sensible use of OHD requires that several fundamental variables are controlled for, and the Centre for Archaeological Research OHD project is addressing each of these. In particular this paper details the fieldwork directed towards establishing the necessary controls for regional soil temperature regimes within Northern New Zealand (Figure 1).

## OBSIDIAN HYDRATION DATING

The technique relies upon the observation that water diffuses into a freshly fractured face of obsidian at a rate that is directly controlled by the geochemistry of the obsidian and the temperature regime of the immediate environment. Once these variables have been determined the date can be calculated through the empirical relationship (Stevenson *et al* 1989)

$t=x^2/k$ equation 1:

where:
$t$=archaeological age
$x$=depth of the hydration band
$k$=annual hydration rate (dependant upon ambient temperature and material geochemistry)

Therefore in order to produce accurate OHD dates it is necessary to have precise control over soil temperature regimes and material geochemistry in order to generate artifact specific hydration rates (k), as well as the ability to measure the depth of the resultant hydration bands.

## THE SURVEY

In order to provide the necessary control over environmental temperature regimes it was decided to extend the work of Leach and Hamel (1984) and make an intensive regional temperature survey of the Northern half of the North Island (Figure 1). In their original study, Leach and Hamel placed 43 sets of zeolite cells in 42 sites throughout New Zealand, and concluded that it was necessary to intensify regional coverage, and to also study the variables that affect temperature regimes on a microregional scale. The current survey will address these issues, with 97 cells being placed in 60 locations (Figure 2) throughout the study region including 5 experimental sites which will test the effects of microregional variables.

The regional temperature regime is important to OHD as the term k in equation 1 is calculated by using the arhhenius equation;

$k=Ae\text{-}E/RT$ equation 2:

Where A is the pre-exponential term and E is the activation energy, R is the universal gas constant and T is the temperature. As T at any one time in a real situation is a function of time, the annual hydration rate is the integral

$k=Ae\text{-}E/Rf(t)\ dt$ equation 3:

An exponential average temperature, EHT (effective hydration temperature), can then be calculated by back substitution from equation 2. In practice, this

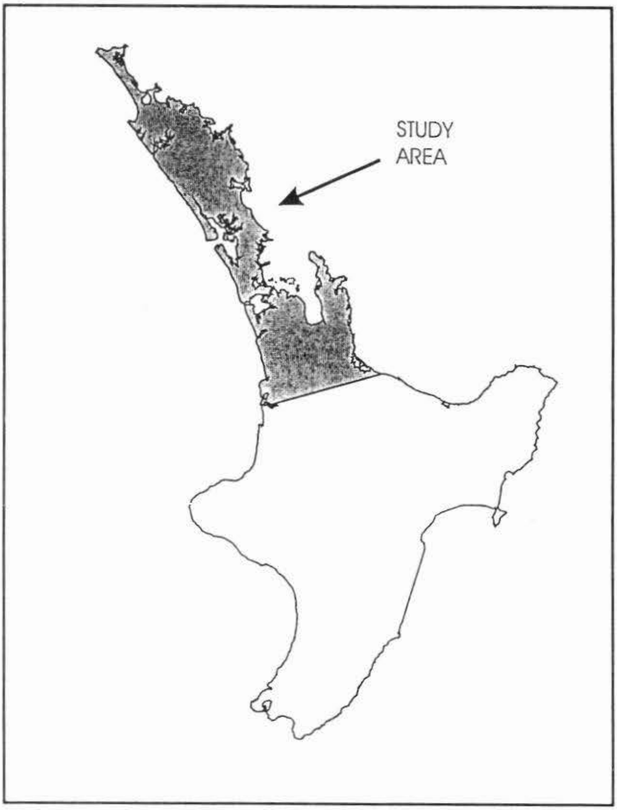

Figure 1. Location of study.

process requires extensive modelling and data analysis to provide an EHT. A simpler method is to use a device that directly measures the integrated temperature function (Ambrose 1980; Trembour *et al* 1988), such as exist in the form of zeolite cells. These cells consist of an absorbent material encapsulated in semi permeable plastic and when placed in a jacket of water absorb moisture at a rate exponentially related to the environmental temperature, in a process analogous to that of obsidian hydration. It is possible to leave the cells in location for a set period and from the weight gain during the recording period calculate the exponential mean temperature for the year at that precise point (Ambrose 1980; Leach and Hamel 1984; Michels *et al* 1983; Trembour *et al* 1988; Stevenson *et al* 1989).

As part of the thermal regime study we developed an experimental structure making use of these cells to try and establish the range exponential mean temperatures throughout the study region. This involved modelling both the range of EHT in similar situations throughout the study region (the macroregional variation) and the microregional variation.

As the results of the current survey will be compared to published meterological data the cells were placed in situations similar to the flat open conditions used in meteorological stations. We placed 60 cells throughout the study region at 30 cm depth in flat open locations (Figure 2). The 30 cm depth was chosen because meteorological stations record soil temperatures at this depth, and this depth has been shown to fairly well approximate the mean temperature for the top metre of soil (Aldridge and Cook 1983, Campbell 1977). In addition 30 cm represents the approximate first damping depth for most soils, so any variation due tominor fluctuations of soil properties within soil groups will be ameliorated (Hanks and Ashcroft 1980). In designing the macro-regional survey we wished to encompass the full range of conditions within the study region that would give rise to variation in EHT. Leach and Hamel (1984) point out that variables such as soil colour and aspect affect the soil temperature regime, so in order to isolate the variables that will be of importance at each stage of the experimental design we made use of the energy budget equation, that describes the balance of energy at the soil surface, and in turn determines the subsurface soil regimes (Campbell 1985, Monteith and Unsworth 1990). The energy budget equation is

$$Rn - G - H - LE = 0 \qquad \text{equation 4:}$$

Where

Rn is the Net radiation at the soil surface
G is the soil heat flux
H is sensible heat loss
LE is the latent heat loss

In the analysis of macro-regional variation, it is only the terms Rn and G that are of interest, as the other variables are assumed to be held constant on a macro-regional scale. Rn is given by the relationship

$$Rn = (1\text{-albedo})St + \epsilon_a \sigma t_a^4 - \epsilon_s \sigma t_s^4 \qquad \text{equation 5:}$$

Where;

St=global short wave
$t_a$=air temperature
$t_s$=soil surface temp
$\epsilon_a$=atmospheric emissivity
$\epsilon_s$=soil emissivity
$\sigma$=the stefan-boltzmann constant

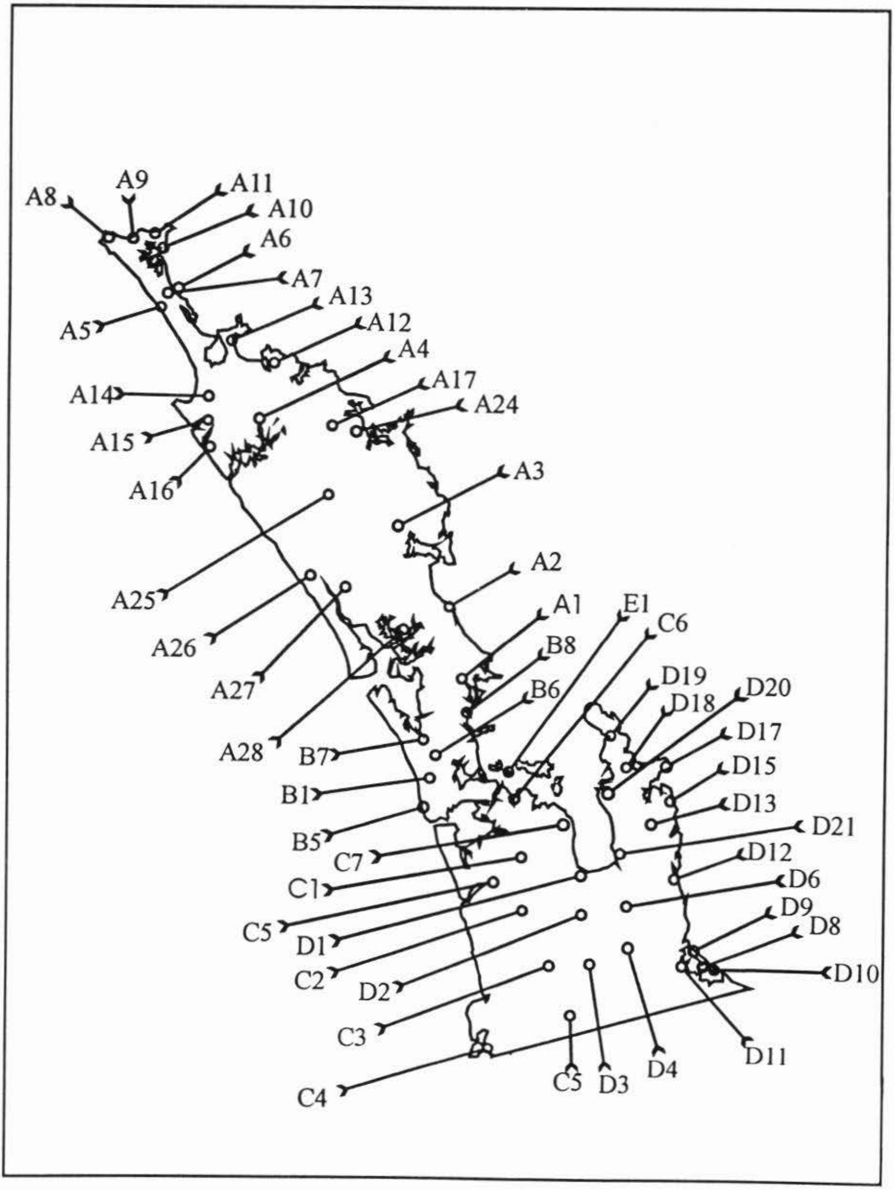

Figure 2. Location of cells in the study region.

From this relationship we can see that macroregional variables which affect the albedo, the global short wave per unit area, or the difference between soil and air temperatures will have an effect on the EHT. As the experimental structure specifies a horizontal surface, the only changes in St will be due to changes in latitude, whereas albedo is affected by soil type (colour). The differences between soil and air temperatures will only be affected where air temperature decreases due to an increase in altitude, or where air temperature is moderated by influences such as large bodies of water. The term G (soil heat flux) is largely a function of soil type (Campbell 1985; Hanks and Ashcroft 1980) and is a controlling factor in the variation of temperature with depth, so soil type again assumes importance in terms of the thermal regime. The important macroregional variables were isolated as:

1) soil type
2) geographical location
3) proximity to the sea or to ranges

The macroregional experimental structure was designed to incorporate the maximum relevant thermal variation within the study region. To this ends cells were placed in similar locations throughout the geographical range of the study region, incorporating the full range of soil types within each area. This will allow us to individually isolate the effects of each of the important variables, and consequentially extend the results to new areas within the study region.

In studying the microregional variation it is important to consider the full energy budget equation (equation 4). Variation of all the variables on a microregional basis must be incorporated into the structure. As such it is important to look at the effects of aspect (Eastern and Western as well as North versus South), type of vegetative cover, microregional soil variations and depth. To test this component of the soil temperature regime we chose 5 test sites (Table 1) and placed multiple cells in each in order to test these variables. At each site cells were placed at multiple depths (10,30,60 cm) in an horizontal exposed situation. Cells were then placed in different aspects, in situations with different vegetative covers, and when the test site was in an archaeological region, cells where placed in different features under the assumption that soil composition will vary between different features.

In all we placed 97 cells in 60 locations throughout the Northern half of the North Island, with 5 test sites spread through the region (Table 1, Figure 2). The results will allow us to model the range of exponential mean temperatures on both a macro and microregional basis. As the data will only provide this range for a single year, and provide no controls for variations through time, 10 cells were placed at meterological station soil temperature monitoring stations, or in very close proximity. This will allow us to develop numerically based predictive models from data normalised over a period of 50 years or more, using the models developed in the cell survey as a reference.

To model the full 12 month temperature cycle we will be placing 2 sets of cells each for a 6 month period. This is for two reasons, the most important being that this reduces the risk of the cells becoming saturated and any consequent changes in the absorbtion function of the cells. The second benefit of having two 6 month cycles is that it allows us to explore the range of EHT between the seasons.

The first set of cells was put in place between November the 8th and November the 18th 1993. These cells will record the summer temperature regimes and will be removed in mid May and then replaced by the second set which will record the winter temperature regimes.

This research represents a fundamental part of the effort to provide precise mean exponential temperatures, and to subsequently generate accurate obsidian hydration dates for New Zealand. It will probably be the case that the results of this survey in themselves are not enough to provide the accuracy necessary to fully control for all of the variables of importance in soil temperature regimes, though they will be vital to the development of the final models.

## ACKNOWLEDGMENTS

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## REFERENCES

Aldridge, R. and Cook, F., 1983. *Estimation of soil temperatures at 0.1 and 0.3 m depths*. N.Z. Soil Bureau Scientific Report 62. New Zealand.

Ambrose, W., 1980. *Monitoring long-term temperature and humidity*, Institute for the Conservation of Cultural Material Bull., 1, 36-42.

Anderson, A., 1987. *Supertramp Science: some thoughts on archaeometry and archaeology in Oceania*. In W.R.Ambrose and J.M.Mummery (eds), Archaeometry: Further Australasian studies. Australian National University, Canberra.

Anderson, A., 1991. *The chronology of colonization in New Zealand*. Antiquity, 65(249),767-795.

Campbell, G., 1977. *An introduction into environmental biophysics*. Springer-Verlag. New York.

Campbell, G., 1985. *Soil physics with Basic*. Elsevier, Amsterdam.

Hanks, R. and Ashcroft, G., 1980. *Applied Soil physics*. Springer-Verlag, Berlin.

Leach, B. and Hamel, G., 1984. *The influence of archaeological soil temperatures on obsidian dating in New Zealand.* New Zealand J. Science, 27, 399-408.

Michels, J.W., Tsong, I.S.T., and Smith, G.A. 1983. *Experimentally derived hydration rates in obsidian dating*. Archaeometry, 25, 107-117

Monteith, J. and Unsworth, M., 1990. *Principles of environmental physics (2nd edition)*. Edward Arnold. London.

Stevenson, C., Carpenter, J. and Scheetz, B., 1989. *Osidian Dating: recent advances in the experimental determination and application of hydration rates*. Archaeometry 31, 2 193-206.

Stuiver, M., and Pearson, G. 1986. *High-precision calibration of the radiocarbon Time scale*. Radiocarbon, 28(2B), 805-838.

Taylor, R., 1987. *Radiocarbon dating: An archaeological perspective*. New York: Academic Press.

Trembour, F., Smith, F., and Friedman, I. 1988. *Diffusion cells for integrating temperature and humidity over long periods of time*. Materials Reseach Society Symposium Proceedings, 123:245-251.

Table 1: **Microregional Test Sites**

| LOCATION | NUMBER OF CELLS |
|---|---|
| A17 | 8 |
| B1 | 7 |
| D6 | 6 |
| D8 | 7 |
| D17 | 8 |