ARCHAEOLOGY IN NEW ZEALAND

LETTERS TO THE EDITOR

Dear Editor,

The Competing influences of the `Secular Effect' and the `Groube Effect': **A Curious Side-Effect of the Radiocarbon Calibration Curve**

How simple life was when one got a radiocarbon date which boldly stated that the age was 600 ± 50 years BP. It was awe-inspiring in its simplicity and confidence, especially when the error was apparently so small — usually inversely proportional to the size of the sample one was able to scrounge up from an archaeological layer. Then came the first clanger, that we could no longer rely on the Libby half life of 5568 years, so the people at the free dating service at Lower Hutt, the envy of archaeologists around the world, started to give two alternative dates for each sample, one based on the Libby half life and the other based on the "new half life" of 5730 years. Of course if it was a shell sample then this needed to be corrected for something curious called the "reservoir effect". Not really a problem. It's about 300 years out, so it's just some simple arithmetic. Thank goodness the Laboratory took care of all other corrections behind the scenes, such as that required for any departure from the expected ^{13}C value of -25 if it was a charcoal sample.

Then the Laboratory started to report three dates for each sample, one corrected for something called "secular variation". As if that wasn't enough then came the famous computer program called Calib (Stuiver and Reimer 1986), which enabled everyone to play their own games with radiocarbon dates. No longer could we present the age of an archaeological layer as 600 ± 50 years BP, it might have to be reported along the following lines:

Calibrated age(s) cal AD 1317, 1347, 1389 (Stuiver and Pearson 1986)
cal BP 633, 603, 561

cal AD/BC (cal BP) age ranges obtained from intercepts (Method A):

one Sigma	cal AD 1289-1404 (661-546)
two Sigma	cal AD 1280-1420 (670-530)

Summary of above

minimum of cal age ranges (cal ages) maximum of cal age ranges:

one sigma	cal AD 1289 (1317, 1347, 1389) 1404
	cal BP 661 (633, 603, 561) 546
two sigma	cal AD 1280 (1317,1347, 1389) 1420
	cal BP 670 (633, 603, 561) 530

cal AD/BC age ranges (cal ages as above) from probability distribution (Method B):

% area enclosed	cal AD (Cal BP) age ranges relative area under probability distribution
68.3 (one sigma)	cal AD 1302-1363 (648-587) .74
	cal AD 1376-1397 (574-553).26
95.4 (two sigma)	cal AD 1284-1412 (666-538)1.00

This is indeed how the Calib program reports the calcibrated age for the CRA of 600 ± 50 BP. Does this look ridiculous? Well, it's a fair statement of the real position, given the full extent of uncertainties and fluctuations in the amount of CO_2 in the atmosphere around 600 years BP. Is it any wonder that archaeologists might feel inclined to turn to thermoluminescence dating, or thermally stimulated current dating, or optical luminescence dating, or electron spin resonance dating, etc etc. What you get with these methods is a date full stop; no complicated distribution curves with multiple probability nodes. True, there are just as many hidden problems, but they do tend to stay more hidden.

The problem of secular correction is frankly terrifying in New Zealand, where we have such a short chronology. Am I going to say 1,000 years or 2,000 years, or only 600 years? No comment. Why is it terrifying? Because of these awful wiggles in the calibration curve, some of the worst ones occurring in the most interesting portions of the prehistoric period in New Zealand. I decided to investigate.

The first experiment was to artificially generate my own radiocarbon dates with the aid of a simple computer program. In the interests of keeping it simple, I decided to make them all charcoal samples (yep they are all twigs of short lived species), and they are all big samples so I get standard errors of ± 50 years every time. I imagined I had an archaeological site with exactly 1500 thin layers in it, each one deposited and then sealed annually and hermetically over the past 1500 years in perfect chronometric unison without fail, and without anyone digging post-holes and messing up the stratigraphy. So the CRA (conventional radiocarbon ages) for these samples ranged from 1 ± 50 BP to 1500 ± 50 BP.

The cost of doing the radiocarbon dating @$350 per sample would have been $525,000; just as well I used a computer simulation instead! (maybe the Waikato Laboratory would give me a discount for bulk samples?)

I then used the Calib version 3 program to calibrate each ^{14}C date, and once again, to keep things simple, I took note of the single year which had the highest probability in the distribution curve. I could have chosen a window of 5 years, or 10 years or even 50 years, but for the sake of this experiment it is the single highest year. I then plotted out my 1500 ^{14}C dates using the X axis for the CRA, and the Y axis for the calibrated age AD. This is illustrated in Figure 1A. You can see that it is a bit wobbly at the young end of the plot, but on the whole the relationship is reasonably linear, even if there are a few wiggles here and there. Whew!

In Figure 1B I plotted the difference between the CRA and the calibrated age BP for all 1500 ^{14}C dates. This doesn't look quite so good. Recent dates up to about 400 BP are all over the place, with differences ranging from about -200 to +150 years. The generally zig-zag nature of the plot is anything but confidence inspiring.

In the second experiment I took all of the 1500 probability distributions of the individual calibrated ^{14}C dates and added them together. Each probability distribution adds up to 1.000, or very nearly so. We used to think that these probability distributions were normal in character, that is Gaussian shaped. If we add 1500 Gaussian curves together, each one with its mean separated by only one year, we would end up with a flat topped curve with a sloping side on both the left and right hand sides.

Unfortunately, the reality is far from flat topped. In Figure 2A I plot the probability curves for three typical calibrated ^{14}C dates, 400, 800 and 1200 BP ± 50 in each case. As can be readily seen, none of these curves are remotely Gaussian in shape. When all 1500 calibrated ^{14}C dates are added together we get the curve plotted out in Figure 2B. This graph is quite interesting. What it clearly shows is that there is a far higher probability of obtaining ages in the region of 1250 to 1450 years AD than on either side of this. The two highest peaks are centred on 1273 and 1430 AD, and the chances of obtaining an age in the vicinity of these two dates is twice as high as any time after 1500 AD, or between 11–1200 AD.

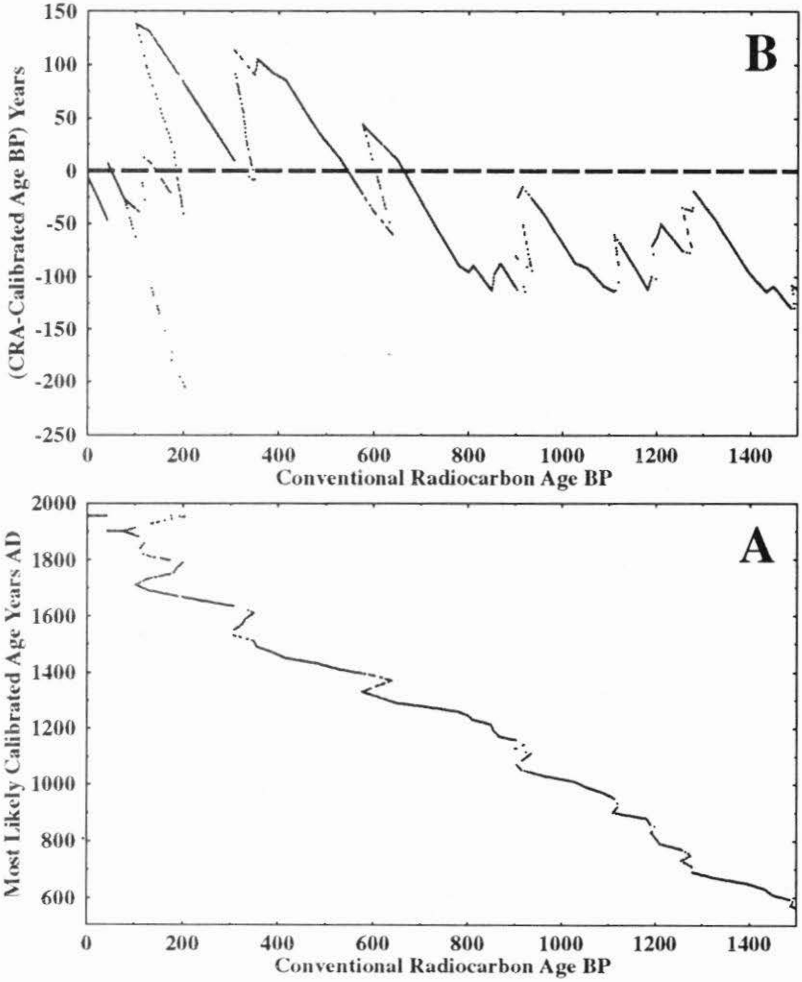

Figure 1. The relationship between conventional radiocarbon ages and dates corrected for secular effects. A: The CRA plotted against the most probable age in each case over the last 1500 years. B: The difference in years between the two ages in each case

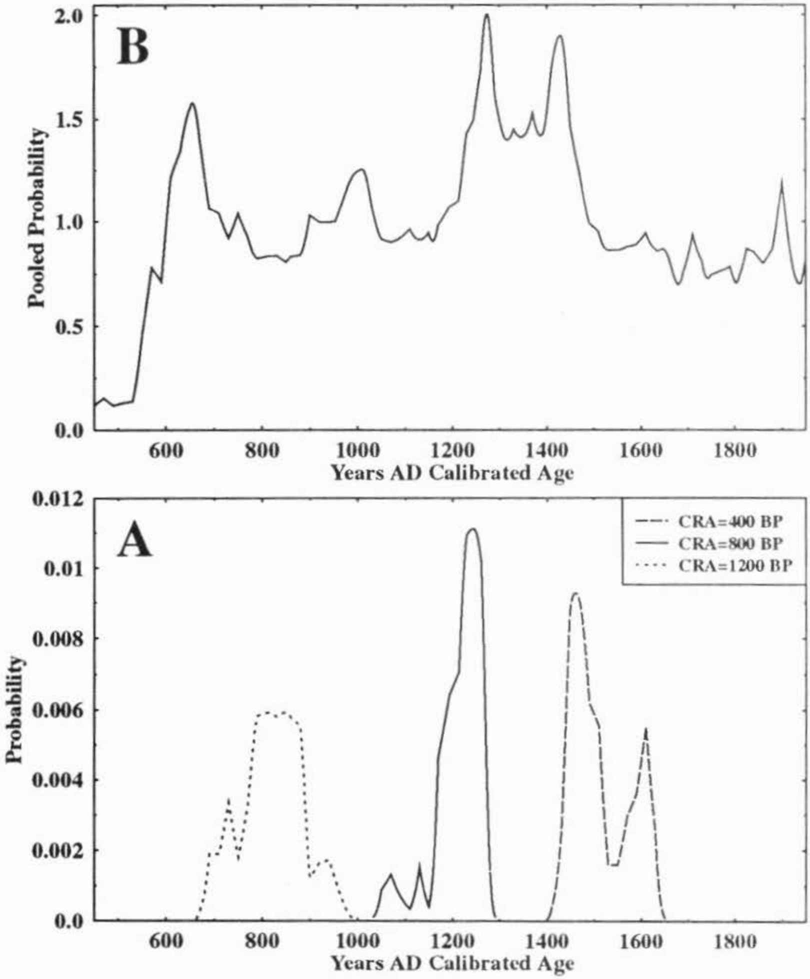

Figure 2. The probability distribution of CRA following correction for secular effects. A: The distribution curve for three typical ^{14}C dates. B: A series of 1500 ^{14}C dates from the present to 1500 BP, after pooling their probability distributions.

What this little experiment shows is that if we took charcoal samples from a large number of archaeological sites randomly and dated them, we would not get a uniform distribution of calibrated ages from them. Is that what one might expect? Far from it. In point of fact, a large random sample of archaeological sites would not have a uniform distribution of dates like the experiment just described with 1500 dated layers. As Groube so elegantly proposed (Groube 1967, 1970), the ravages of time combined with natural population growth means that there are far greater numbers of archaeological sites per capita from the recent past than from the distant past. It does not matter whether these two competing processes are exponential or linear, the result is similar — almost all of the archaeological sites in New Zealand will be recent ones. Therefore, dated samples from a large number of randomly drawn archaeological sites will be heavily biassed towards recent dates.

But... some heavenly influence has verily come to our aid in the form of the secular calibration curve. This surely will serve to balance things out and made sure that the 'Groube Effect' fully compensates for the 'Secular Effect' by biassing radiocarbon dates towards older ones.

Cornelius Zeiker
Institut fur Nuklear Archeologie
Franz Josef Glacier

References

Groube, L.M. 1967. Models in Prehistory. *Archaeology and Physical Anthropology in Oceania* 2(1): 1-27.

Groube, L.M. 1970. The origin and development of earthwork fortifications in the Pacific. pp 133-164. In: Green, R.C. and Kelly, M. (eds). Studies in Oceanic Culture History, Volume I. *Pacific Anthropological Records* 11. Department of Anthropology, Bernice P. Bishop Museum.

Stuiver, M. and Pearson, G.W., 1986. High-precision calibration of the radiocarbon time scale, AD 1950-500 BC. *Radiocarbon*, 28, 805-838.

Stuiver, M. and Reimer, P.J. 1986. A computer program for radiocarbon age calibration. *Radiocarbon* 28 (2B): 1022–1030.