A temperature index in a Late Quaternary sequence at Wonderkrater, South Africa

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Wonderkrater is a Late Quaternary archaeological site in the Limpopo Province of South Africa[1], and has a high-resolution Late Quaternary pollen sequence[2-4]. An initial multivariate analysis of pollen spectra facilitated the quantification of a temperature index (SSF1) for two borehole sequences.[5] An attempt to calibrate the SSF1 temperature indices was made by Thackeray[6]. Scott et al.[7] and Thackeray and Scott[8] identified the 'Younger Dryas' cooling event in Borehole 3. This palaeoclimatic phenomenon is generally known in the northern hemisphere, dated between 10 600 and 12 900 BP (calibrated years). In this study, palaeotemperature estimates from the initial multivariate study[5] are re-examined in the context of calibrated radiocarbon dates[7] in order to make comparisons with dates for the Younger Dryas in the northern hemisphere.

Age-depth relationships

On the basis of the SSF1 palaeotemperature index, Thackeray and Scott[8] recognised certain Wonderkrater samples as being associated with the Younger Dryas. Critical in this regard are dates for the relevant deposits. Scott et al.[3] and Scott[4] have used various techniques to resolve chronological issues. Whereas there is a linear relationship between age and depth for the last 16 000 years BP, the rate of deposition is not constant for earlier deposits for which the rate is slower and variable; hence the need for complex chronological modelling which presented a major challenge.[3,4] However, for purposes of this study, attention is focused on age-depth relationships for the Terminal Pleistocene and Holocene, within the last 16 000 years, for periods in which least squares linear regression is suitable. This offers a relatively simple but robust approach for dating postglacial deposits at Wonderkrater.

Three age-depth relationships were obtained by using calibrated radiocarbon dates (and associated standard deviations) for 12 Late Pleistocene and Holocene samples[7] from Borehole 3, using linear regression analyses. All 12 of these samples were selected by Scott et al.[7] because they were considered to be reliable. Others were deliberately excluded because they were outliers and were assumed to be associated with contamination by roots.

Equation 1 is obtained by relating mean values for calibrated radiocarbon dates (CAL-1, *y*-axis) and depth (D, *x*-axis), for the 12 samples selected by Scott et al.[7] in their Table 1:

$$\text{CAL-1} = 40.423\ \text{D} - 1431.30\ (r = 0.99) \qquad \text{Equation 1}$$

Equation 2 is obtained by relating depth to chronological values which are two standard deviations *below* the mean CAL-1 date for each sample:

$$\text{CAL-2} = 39.696\ \text{D} - 1487.98\ (r = 0.99) \qquad \text{Equation 2}$$

Equation 3 is obtained by relating depth to chronological values which are two standard deviations *above* the mean CAL-1 date for each sample:

$$\text{CAL-3} = 41.182\ \text{D} - 1413.32\ (r=0.99) \qquad \text{Equation 3}$$

On the basis of depth, all three equations were applied in order to estimate dates for 50 samples from Borehole 3. Estimates for CAL-1 relative to the SSF1 palaeotemperature index are shown in Figure 1.

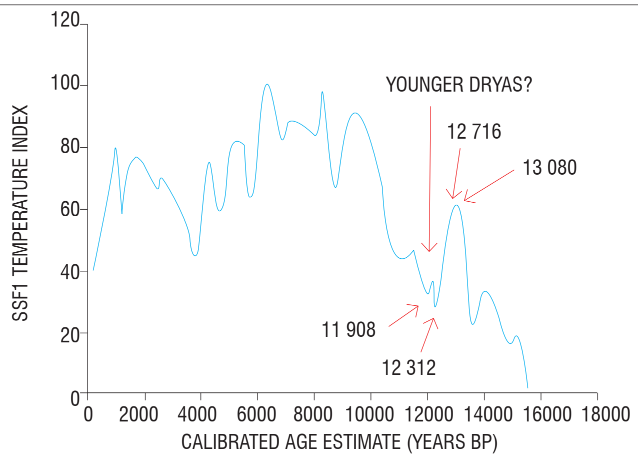

Figure 1: A temperature index (SSF1) based on multivariate analysis of pollen spectra from Wonderkrater in relation to estimated CAL-1 dates (cal years BP) based on Equation 1. A cooling event appears to occur after 12 716 cal years BP – here associated with the onset of the Younger Dryas which is well documented in the northern hemisphere where it is dated between 12 900 and 11 600 cal years BP.

Dates in relation to temperature index

Notable in Figure 1 and Table 1 is that relatively low temperatures are identified at 12 312 cal years BP (sample 5609), continuing to 12 100 cal years BP (sample 5606) and further to 11 908 cal years BP (sample 5605). This cool event appears to be initiated at 12 716 cal years BP (sample 5611) after a slightly warmer period at 13 080 cal years BP (sample 5613).

Table 1: Wonderkrater samples listed by number; depth (cm); calibrated dates (CAL-1, CAL-2 and CAL-3 estimates based on Equations 1–3); and SSF1 temperature indices based on multivariate analyses of pollen spectra from Borehole 3, Wonderkrater sequence[5]. CAL-2 and CAL-3 are the lower and upper limits (two standard deviations), respectively, for estimates of the mean calibrated dates (CAL-1).

Sample #	Depth	CAL-2 (lower limit)	CAL-1 (mean)	CAL-3 (upper limit)	SSF1
5599	300	10 420	10 695	10 941	46
5601	310	10 817	11 099	11 353	43
5603	320	11 214	11 504	11 765	46
5605	330	11 611	11 908	12 177	32
5606	335	11 810	12 110	12 382	37
5609	340	12 008	12 312	12 588	29
5611	350	12 405	12 716	13 000	57
5613	359	12 762	13 080	13 371	61
5615	365	13 001	13 323	13 618	37

In the context of lower (CAL-2) and upper (CAL-3) limits for estimated CAL-1 dates (Table 1), the results from this study are consistent with calibrated radiocarbon dates for the Younger Dryas in the northern hemisphere. At Wonderkrater, sample 5611 at 12 716 cal years BP is close to the date of 12 900 cal years BP for the onset of the Younger Dryas in the northern hemisphere.[9]

The Younger Dryas in Borehole 4

The Younger Dryas is also represented in Borehole 4. On the basis of palaeotemperature indices for this sequence, a cooling episode can be identified from at least one sample.[3,4] The calibrated date of circa 12 200 BP for this sample from Borehole 4 is almost identical to the mean date (12 433 cal BP) for the three Younger Dryas samples from Borehole 3.

The Younger Dryas and a cosmic impact?

Among others, Kennett et al.[10] have claimed that the Younger Dryas cooling event may be associated with a cosmic impact of some kind. Evidence given in support of this possible cosmic impact, at least for the northern hemisphere, are spikes in nanodiamonds[10,11], platinum[12], magnetic and glassy impact-related spherules, high-temperature minerals and melt glass, carbon spherules and/or osmium at the onset of the Younger Dryas[9].

A spike in nanodiamonds has been reported for Younger Dryas deposits in Mexico.[13] As yet, no corresponding site has been reported for the southern hemisphere. In the context of dates given here for palaeotemperature indices for the Wonderkrater sequence, it is recommended that exploratory analyses be undertaken on specific samples (notably 5605, 5606 and 5609 from Borehole 3) from this important South African site, to test whether or not there is evidence for nanodiamonds or other indicators of a cosmic impact that may have affected climates globally sometime after 12 900 cal years BP.

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