Radiometric date for the Port Durnford peat and development of yellow-wood forest along the South African east coast

The age of the peat, or 'lignite', layer in the Port Durnford Formation on the Zululand coast has been established to be about 70 kyr by means of the $^{230}Th/^{234}U$ disequilibrium dating technique. This date places the peat temporally at the beginning of Isotope Stage 4, which is compatible with the palynological interpretation presented previously.[1]

The Port Durnford Formation is intermittently exposed on 20- to 30-m-high eroding seacliffs along some 80 km of the Zululand coast between the Mlalazi estuary and Cape St Lucia.[2] It is subdivided into a lower Argillaceous Member with a warm-marine faunal component[3] and an upper Arenaceous Member separated by an organic-rich layer — the Port Durnford 'lignite', which contains numerous wooden logs. The formation is overlain by a few metres of younger dune sand.

Early in this century, Anderson discovered mammalian bones in the lower part of the succession. On the basis of this collection the deposits were ascribed to the Pliocene.[4,5] Later, du Toit[6] correlated the extinct elephant and the buffalo with the Younger Vaal Gravels and indicated a Late Middle Pleistocene age for the fauna. Davies found an Acheulian cleaver associated with the Formation and also accepted a Middle Pleistocene age,[7] while Hobday and Orme[2] considered a Last Interglacial age as the most probable.[2] This would be in accordance with Cooper's[3] interpretation of the marine invertebrates in the lower Member as being a warm water fauna. McCarthy and Orr[8] reported a new find of mammalian bones as well as a rhinoceros tooth at the base of the Formation at an exposure just north of Richards Bay. They also observed that the basal Member rests unconformably on an older calcarenite which contains foraminifera of Pleistocene age.

Recently, Scott and Maud cored the sequence at a point some 100 m inland from the seacliff exposure at the Port Durnford lighthouse for pollen analysis.[1] The pollen spectrum of the peat layer indicates a succession from open marshland to terrestrial conditions associated with possible cooling, and suggests that the peat post-dates a marine transgression. This would place the peat-bed at the end of the Last Interglacial high sea level or at the onset of full glacial conditions.

For radiometric dating a sample of the peat was taken from the base of the layer, at 26.44-m depth in the borehole. A second peat sample and a piece of a wooden log were collected from the exposure on the adjacent beach.

The ^{230}Th/^{234}U method has proved to be a most useful technique for dating calcium carbonate precipitates.[9] It has also been shown to be applicable to peat deposits,[10–12] provided certain conditions are fulfilled. Peat is known to absorb uranium from aqueous solutions. The decay of the uranium-234 to thorium-230 provides the means for absolute dating. Problems that can arise include the possibility of isotope migration in thin peat layers and the inclusion of inherited thorium isotopes in impure peat deposits.

The analysis technique used for the peat samples is, first, to burn away the organic matter over a bunsen burner for 60 minutes and in a muffler oven at 800°C for 90 minutes. The uranium and thorium are then dissolved in strong boiling hydrochloric acid, co-precipitated with iron, and separated and purified on ion exchange columns. The uranium and thorium isotopes are then

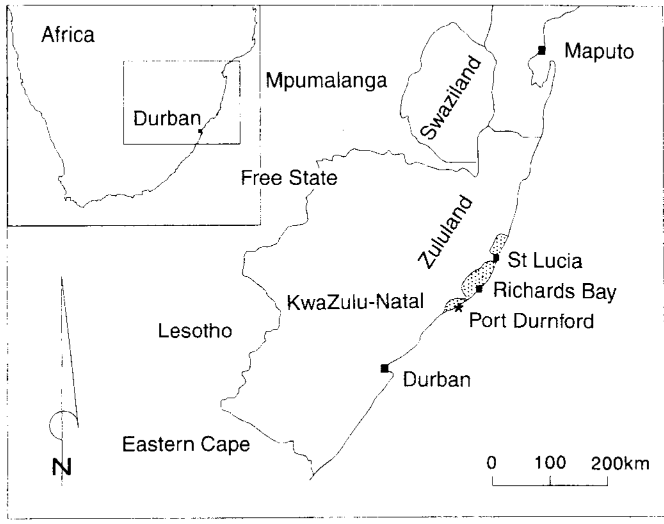

Fig. 1. Map showing the locality of Port Durnford. The shaded areas represent the extent of the Port Durnford Formation, after Hobday and Omre.[2]

electroplated onto steel discs to produce carrier-free sources and the alpha activities are recorded on an alpha spectrometer.[11,13] The wood sample was fired over a bunsen burner for 4 hours and the ash treated as for the peat samples.

The results are listed in the table. The two peat samples had only a low concentration of organic matter (60% and 42% incombustible, insoluble sediment, respectively). As a result the leachates of these samples contained a relatively enhanced amount of thorium-232, which indicated that the sand particles already contained leachable thorium when they were deposited, and no age could be calculated directly from the ^{230}Th/^{234}U activity ratios. The wood sample, on the other hand, showed much less thorium contamination and the derived apparent age of 74 200 yr will be only slightly higher than the age of deposition.

A correction for the contaminating thorium can be effected in two ways which are essentially the same. The first is to calculate what activity ratio, ^{230}Th/^{232}Th, of the initially present thorium is

Table 1. Isotopic activity ratios and ages for peat and wood.

Sample no.	C-4710	C-4964	C-4964
Anal. no.	U475/8	U476/7	U488
Material	Peat	Peat	Wood
Site	Bh, 26.44 m	Beach	Beach
Weight (g)	10.0	10.0	61.7
% insol.	60%	42%	2%
U content (ppm)	2.744	0.996	0.236
Th content (ppm)	9.781	2.780	0.033
^{230}Th/^{234}U	1.039	0.926	0.501
^{234}U/^{238}U	1.040	1.064	1.132
^{230}Th/^{232}Th	0.921	1.073	12.436
Apparent age (yr)	>350 000	261 000	74 200 ± 5 300
Model age (yr) (f = 0.5)	69 000	73 000	70 000 ± 5 000
Combined age (yr) (extrapolated)		70 000 ± 6000	

$f = (^{230}Th/^{232}Th)_{t=0}$

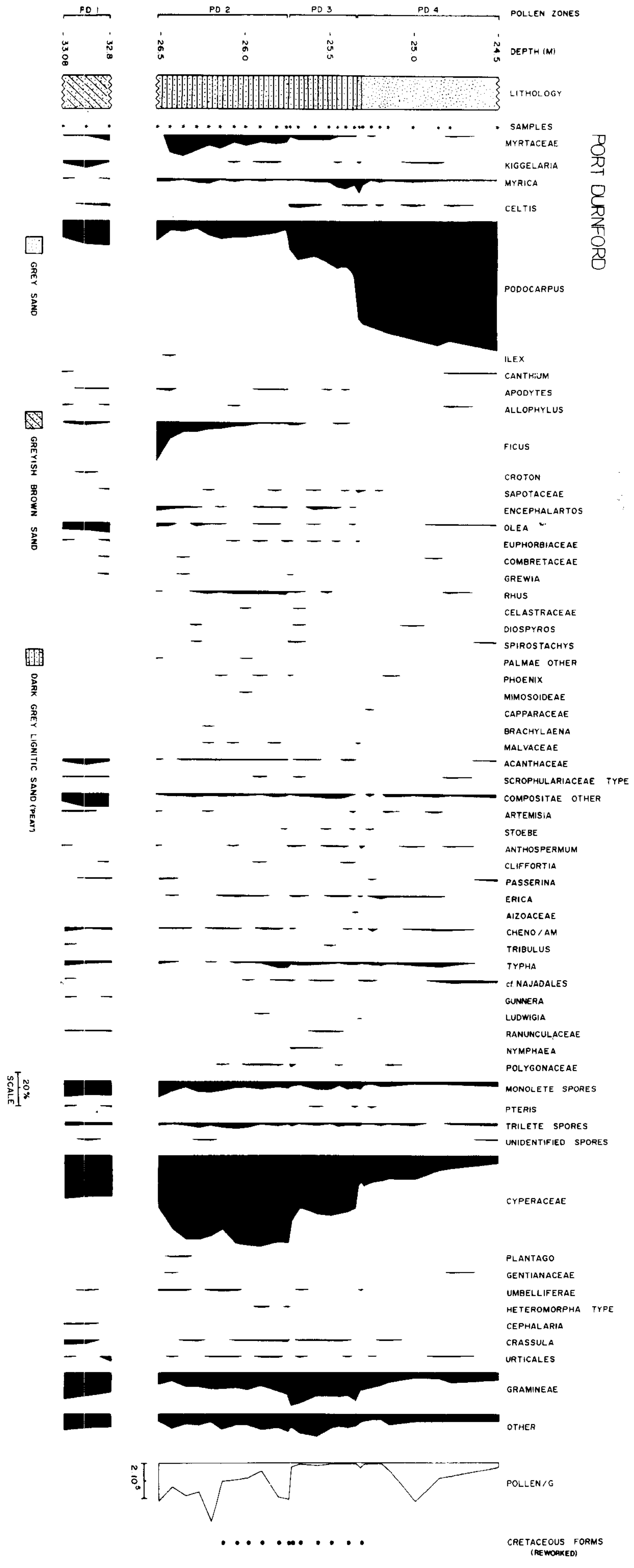

Fig. 2. Pollen diagram of productive sections of the Port Durnford borehole. Details of lithology are described by Scott *et al.*[1]

required to produce the same age for all three samples. A value,[14] $f = (^{230}Th/^{232}Th)_{t=0} = 0.5$, fits the data best. The age obtained in this manner, called the 'model age' in the table, is 70 000 ± 5000 yr. The second procedure is to plot the appropriate activity ratios against the ^{232}Th (normalized) and to extrapolate to $^{232}Th = 0$, as originally described by Kaufman.[15] This gave an age of 70 000 ± 6000 yr for the peat layer.

The pollen in the peat sample and in the immediate overlying organic sands of the borehole sequence, 100 m inland, shows a succession from open marshland to terrestrial forest dominated by *Podocarpus*.[1] Details about the pollen analysis that have not previously been published, are presented in Fig. 2. Interestingly, *Podocarpus* is not an important constituent of coastal forests in the Port Durnford area today. In order to establish the position of the beach peat exposure in relation to the palaeoenvironmental sequence observed in the borehole, a palynological correlation was attempted. For this purpose pollen in a sample of the dated level has been analysed and compared with the pollen profile.

Palynomorphs in the dated peat were, however, found to consist of more than 70% ferns (mainly monolete spores), differing from all components of the borehole profile (Fig. 2). Although this may imply that the borehole sequence is incomplete, the low numbers of *Podocarpus* pollen and swampy indications in the exposed peat from the beach suggest a broad correlation with the lower peaty levels in the borehole at *c.* 25.75 m. It is reasonable to assume that the palynological anomaly in the dated facies is the result of a local successional gradient along the 100 m of ancient swamp. Since the peat layer becomes thinner in an inland direction,[1] it is possible that the borehole penetrated a shallower marginal area with more Cyperaceae than the deeper, fern-dominated peat exposed along the seashore.

It can be concluded that yellow-wood forest developed after the formation of the peat level, coinciding with the deposition of sandy levels with lower organic content (Fig. 2). The previous interpretation[2] of rising sea levels following peat formation is not supported by the pollen spectra and the measured age of the deposit. It is further disputed by the presence of rare freshwater diatoms above the peat at 22.4–25.5 m, coinciding with *Podocarpus*-dominated levels (P. Alhonen, pers. comm.).

The age of *c.* 70 000 ± 5000 yr supports the interpretation of the pollen data as pointing to a cooling period, post-dating the maximum of a marine transgression. The data place the formation of the peat at the beginning of the Last Glacial (Isotope Stage 4), so that the immediately underlying marine deposits can safely be ascribed to the Last Interglacial period. The presence of pollen right at the base of the Lower Argillaceous Member of the Formation and the lagoonal conditions indicated by these furthermore suggest that the accumulation started before the last high sea level reached its maximum. Since the mammal bones apparently derive from this level, they can be ascribed approximately to the transition from the Middle to the Upper Pleistocene.

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Air pollution over Pietermaritzburg during the passage of cold fronts

The air pollution dispersion climatology of Pietermaritzburg displays cycles at three interrelated scales. There is a seasonal increase of pollution during winter, largely as a result of the anticyclone macroclimatology of southern Africa. It is then, too, that conditions are exacerbated in the Pietermaritzburg basin by local topographically controlled climatology; in the clear-sky conditions associated with the anticyclone a regular increase in pollution at night is followed by a daytime clearing.[1,2] Finally, conditions are alleviated every five to 10 days during winter by the passage of the well-known sequence across southern KwaZulu-Natal of northwesterly Berg winds, a lee depression (coastal low), westerly wave and cold front driven by wind having a strong southerly component. This periodic dissipation of pollution during the passing synoptic episodes is illustrated below in the records of 24-hour smoke concentrations during July and August 1994.

The method used in the determination of smoke and soot in the atmosphere is based on the standard methods recommended by Kemeny and Halliday[3] as derived from the Department of Scientific and Industrial Research in Great Britain. A measured volume of air is drawn through a white filter paper of which the light transmission has been measured. Smoke and other particulate matter suspended in the air collect to form a stain of varying darkness. At the end of the sampling period the light transmission of the now-soiled paper is again measured. From the two light transmissions a soiling index may be calculated and expressed in units of micrograms per cubic metre.

Twenty-four-hour samples were taken for each day between 4 July and 17 August 1994, with monitoring equipment located in the central business district of Pietermaritzburg. The results are presented in Fig. 1, which shows the accumulation and clearance of particulates over the city on several occasions during that period.

Details of one particular event are given for illustrative purposes. Climatic data for the period 20–26 July (Figs 2–5) indicate temperatures, relative humidities and wind frequencies from different directions on the given dates as recorded at the same site.

On the night of 20 July 1994, atmospheric conditions were calm and stable with well-developed katabatic flow into the hollow from the north-west (Fig. 3). Under such conditions, pollution accumulated in the inversion layer. With the rise of the sun on the morning of 21 July under clear conditions, there was a rapid increase in temperature (Fig. 2), resulting in severe pollution fumigation. A smoke level of 140 µg/m³ was measured for the 24-hour period from noon of the previous day, reaching 56% of the South African guideline concentration (93% of the World Health Organisation's recommended guideline). Visibility was consequently down to three kilometres and less. Climatic conditions remained largely unchanged until 23 July, when Berg winds

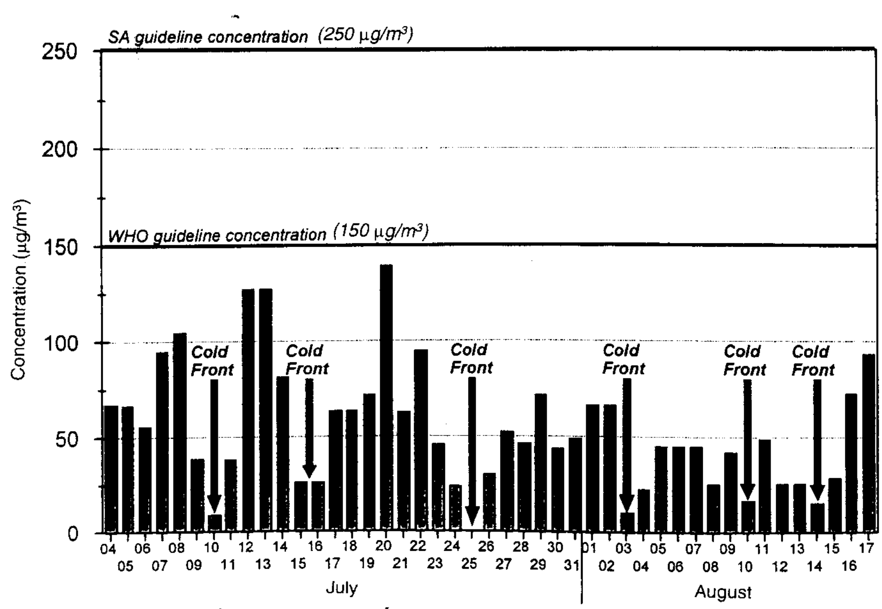

Fig. 1. Twenty-four-hour average smoke concentrations measured using the standard filter method in central Pietermaritzburg, from 4 July to 17 August 1994. Filters were changed manually at noon. South African and World Health Organisation guideline concentrations are shown for reference.