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Palaeoecology

A 3,000-year record of penguin populations

There are no historical records of changing penguin populations in the maritime Antarctic[1,2]. Here we analyse[3,4] the concentration of 'bio-elements' in a lake-sediment core dating back approximately 3,000 radiocarbon years. We found that the deposition of penguin droppings had a significant effect on the geochemical composition of the sediment core. Changes in sediment geochemistry reflect fluctuations in penguin numbers and suggest that variations in climate had an impact on penguin populations, which peaked somewhere between 1,400 and 1,800 years ago.

We collected sediment cores from a lake on the Ardley Peninsula (maritime Antarctica) during the fifteenth China Antarctic Research Expedition (December 1998–March 1999) using a 12-cm-diameter PVC pipe. One 67.5-cm core (Y2) spanned almost 3,000 radiocarbon years. This core was sectioned at 1.0-cm intervals for the upper 64 cm, with the bottom section being a consolidation of 64–67.5 cm. We collected, stored and processed samples using clean techniques, and then analysed the concentration of geochemical elements and isotope ^{13}C.

We found that the concentration of elements such as sulphur, phosphorus (represented by P_2O_5), calcium (represented by CaO), copper, zinc, selenium, strontium, barium and fluorine in Y2 was much higher than in other lake sediments in the maritime Antarctic. The relative concentration of these elements was similar at different depths in the core (Fig. 1a). The average concentration of fluoride reaches about 7,700 p.p.m., almost 30 times the level in the soil of this region.

These unusually high levels of bio-elements result from penguin droppings, which are rich in these elements[5,6]. The organic-carbon stable isotope ($\delta^{13}C$) values of between −9.038‰ and −26.327‰ (mean, −20.420‰) in Y2 lake sediment also indicate a contribution from penguin excreta[7,8] (Fig. 1b). There is a penguin rookery around the lake, and their droppings are probably deposited in it both by catchment snow-melt and directly into the water.

We used Q-mode factor analysis[3,4], a method for decomposing multiple factors, to determine the concentration of bio-elements in the sediments. This revealed that 99.8% of the variance in the data could be explained by two factors (54.7% for factor 1 and 45.1% for factor 2). The first factor was defined to reflect changes in the input of penguin droppings to the sediment; the second factor is opposite to the first factor.

Deposition of seal hairs has been used as an index of changes in Antarctic mammal populations[9]. We have used changes in the deposition of bio-elements from penguin droppings as an indirect measure of population change. Thus, the first factor in Fig. 1c represents penguin population changes during the past 3,000 years. Our results show that the penguin population began to decline at 3,000 yr before present (BP) and was lowest at 1,800–2,300 yr BP, a period of low temperature[10]. After this, the population increased, peaking between 1,400 and 1,800 yr BP. The peak corresponds almost exactly to a period of high precipitation[11] (Fig. 1c). Incremental sediment erosion cannot account for the high concentration of penguin droppings in the sediment. Historically, the size of penguin populations seems to be related to climate, and climate change might still affect the survival and abundance of modern penguin populations.

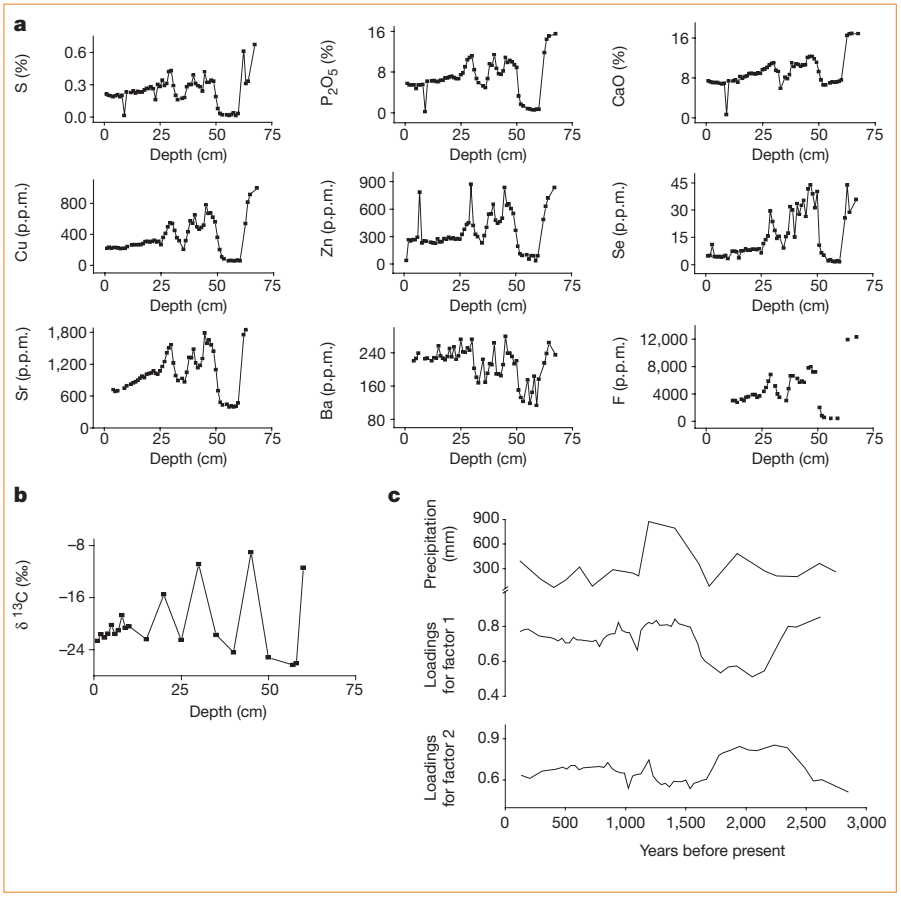

Figure 1 An isotope record of droppings from penguin populations. **a,** Concentration of elements S, P (as P_2O_5), Ca (as CaO), Cu, Zn, Se, Sr, Ba and F in Y2 lake sediment versus depth. **b,** Values of stable isotope $\delta^{13}C$ of organic carbon in Y2 lake sediment. **c,** Comparison of the results from Q-mode analysis with precipitation; variation in loadings of factor 1 (middle curve) shows the variation in penguin populations during the past 3,000 years.

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