The photomultiplier output signal was converted into both a linear and a five-decade, logarithmic, photon count rate. A commutated signal was used to monitor other parameters required for housekeeping purposes and for final data reduction. The primary data record was provided by an on-board digital tape recorder. In addition, all signals were relayed to the ground by an S-band telemetry link. Air was drawn into the apparatus through a 2.4 m length of black anodized, aluminium pipe (internal diameter 7.6 cm) and exhausted through a 2.4 m length of flexible tubing (internal diameter 10.2 cm) attached upwards to the payload support lines. The inlet and outlet openings both faced horizontally in opposite directions to prevent changes in air flow resulting from vertical motions of the balloon. The vertical separation of the openings was 2.4 m and the diagonal distance between them was 4.0 m. Laboratory studies in which 0.2 parts per 10^9 of NO were added at either end of the inlet tube to air flowing at 130 cm^3 atm s^{-1} and 27 torr showed that there was negligible adsorption of NO along the tube.

The flight was controlled from the ground to provide three cycles of ascent, float and descent to test for possible contamination from the balloon and flight packages or from the O_3 and NO/N_2 calibration gas used in the measurement. Some forty measurements of the ambient air, each of duration 2 min, were made during the flight. The instrument was turned on by ground control at 17.4 km, the lowest altitude for which the instrument had been calibrated. The maximum altitude reached by the balloon was 22.9 km.

The total error in the measurements is estimated at 60%. The largest error, ~20 to 30%, was due to the small count rates observed, and the balance due to the uncertainties in concentration of the calibrating gas mixture, the total volume flow rate and in the digital tape recording. Within this 60% accuracy, no differences were observed in the measurements taken during ascent, float and descent modes, indicating that there were no serious contamination problems associated with the sampling of the ambient air either from interference from the exhaust or from outgassing of the balloon or instrument package. Most of the measurements were made between 20.1 and 22.9 km. No differences in NO mixing ratio were observed over the altitude range 17.4 to 22.9 km within the experimental error. The average value of the NO mixing ratio was found to be 0.1 parts per 10^9 by volume $\pm 60\%$.

These results agree with those of a previous flight on December 12, 1972, at the same location, at 23.1 km although the data were limited owing to decomposition of the O_3 supply. Other flights at different altitudes and locations are planned. Full details of these measurements and the interpretation of their significance in terms of the SST pollution problem will be reported elsewhere.

B. A. RIDLEY
H. I. SCHIFF

York University,
Downsview,
Ontario

A. W. SHAW
L. BATES
C. HOWLETT
H. LEVAUX
L. R. MEGILL

Utah State University,
Logan, Utah

T. E. ASHENFELTER

National Oceanic and Atmospheric Administration,
Silver Spring, Maryland

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Pollen Evidence for Late Quaternary Climate Changes on Kerguelen Islands

INCREASING evidence indicates that late glacial and postglacial changes in climate and vegetation were essentially synchronous in the northern and southern hemispheres[1,2]. Pollen analysis of Quaternary deposits on subantarctic ocean islands should provide critical data, but has been inconclusive. The floras of most of the islands are depauperate and yield few identifiable sporomorphs. Species represented in the pollen rain are often of narrow geographical distribution and broad ecological tolerance, thus interpretation of changes in pollen and spore ratios and cross-correlations between islands are difficult[3]. These problems can be minimized by sampling in a location with a comparatively large flora, with many species widely distributed in the subantarctic, and with a variety of vegetation types. Kerguelen Islands fulfil these requirements.

This compact archipelago, 6,500 km^2, is located between 49° and 50° S and 68° 30′ and 70° 30′ E. The climate is cool and microthermal, with mean temperatures near sea level ranging from 1° C during the coldest months to 8° C during the warmest. Glaciers cover much of the western part of the main island (Fig. 1).

Two cores about 5 cm in diameter were collected for pollen and radiocarbon analyses along stream cuts in gently sloping terrain on the south shore of Golfe du Morbihan (Fig. 1) in early 1971. Both cores included mainly organic-rich silts. There was no clear correlation between soil type and pollen content. The ^{14}C dates obtained from the cores are shown in Figs 2 and 3. In core 1, the two lowest dates present an anomaly, either due to contamination of the lowest sample or the presence of reworked older sediments in the sample above. The anomaly does not seriously affect the interpretation of data from core 1. The bottom of core 1 rested on sediments with rounded boulders, perhaps of glacial origin. If the lowermost organic layers in core 1 result from colonisation of a recently deglaciated area, extrapolation of the ^{14}C dates (Fig. 2) indicates that deglaciation occurred about 10,000 to 12,000 BP. Buried soils found below the bottom of core 2 were not sampled because of seepage problems. If this site was ever glaciated during the late Quaternary, the ice retreated considerably before 11,000 BP (Fig. 3).

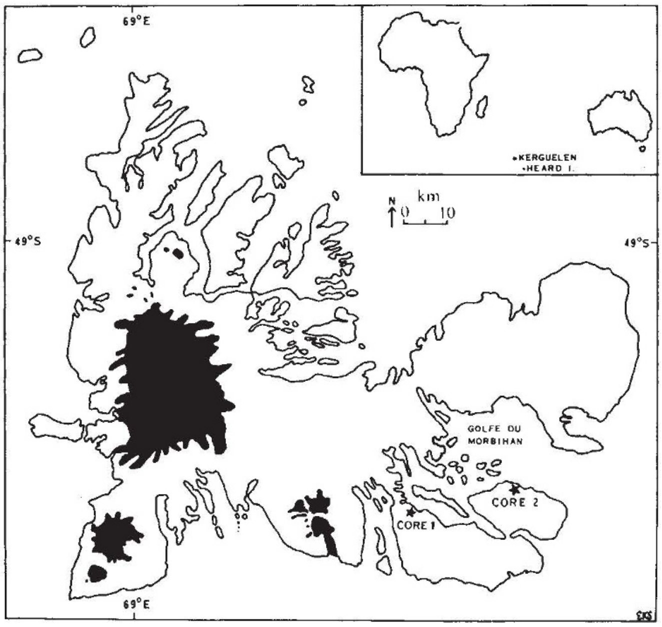

Fig. 1 Map of Kerguelen Islands indicating extent of present glaciers (black) and core sites. Inset shows position of islands in relation to Africa and Australia.

Kerguelen supports about thirty native species of vascular plants. Many are confined to a narrow range of habitats. The most extensive vegetation formation is the upland wind desert, dominated by the cushion plant, *Azorella selago* Hook f., which also occurs near sea level in drier exposed areas. Closed vegetation, dominated by *Acaena adscendens* Vahl, is abundant at lower elevations on the eastern portion of the island, but is rare or absent in the more rugged western regions[4].

The ratio of *Azorella* to *Acaena* pollen has been used in a vegetation history of Marion and Prince Edward Islands[5] as an indication of 'upland' versus 'lowland' conditions. Although the distribution of these plants on Kerguelen is not always correlated with elevation, this distinction is generally valid. We therefore regard the preponderance of *Azorella* pollen and lack of *Acaena* pollen in the lowest levels of both cores (Figs 2, 3) as evidence of cold 'upland' conditions. The rapid rise of *Acaena* pollen, at about 10,000 BP in core 2 and at a similar, but less accurately dated time in core 1, suggests a general warming trend. If there was a difference in the time of the onset of this trend at the two stations, it could be explained by the position of the retreating glaciers, which would have been nearer to the site of core 1. The subsequent wide fluctuations in the ratio of *Azorella* and *Acaena* pollen probably reflect local changes at the core sites. Pollen grains of Kerguelen grasses, although abundant, cannot be distinguished from one another and are of little value in determining climate. But pollen and spores of several rarer taxa help clarify the interpretation of the past 9,000 yr.

Lycopodium saururus Lam., *Blechnum penna-marina* (Poir.) Mitt., *Uncinia compacta* R. Br., and *Galium antarcticum* Hook f. are confined to protected habitats at elevations of less than 220 m (ref. 4). *Lycopodium saururus* and *Uncinia* are rare, and found only in the warmest situations. All of these species are apparently near their limit of cold tolerance on Kerguelen. Although widely distributed in the southern hemisphere, none occurs on Heard Island[6], which lies 450 km south of Kerguelen and has a more polar climate. A significant rise of pollen or spores from more than one of these species would suggest a proliferation of 'lowland' conditions.

In both cores *Lycopodium saururus, Blechnum* and *Uncinia* first appear in noticeable quantities about 8,000 to 9,000 BP. The proportions rise rapidly, as do other, less important 'lowland' indicators such as *Lycopodium magellanicum* (Beauv.) Sw. (Figs 2 and 3). High proportions are maintained until about 6,000 BP, at which time *Galium* pollen rises. The spores and *Uncinia* quickly taper off after this point, but *Galium* remains common and reaches a secondary peak in core 2.

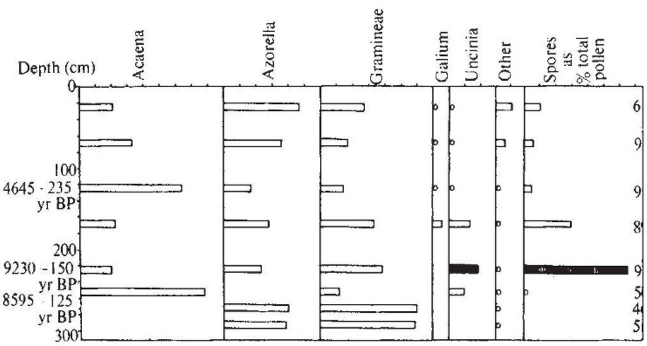

Fig. 2 Simplified pollen diagram of core 1 with ^{14}C dates. Each division on left equals 20 cm, each division on top equals 10%. Each histogram represents an average of several counts (of 150 grains each), the number of which is shown on right. An open circle indicates 2% or less. Solid black histograms identify maximum % of indicator species. Symbols on spore histogram: m, *Lycopodium magellanicum*; s, *L. saururus*; b, *Blechnum penna-marina*.

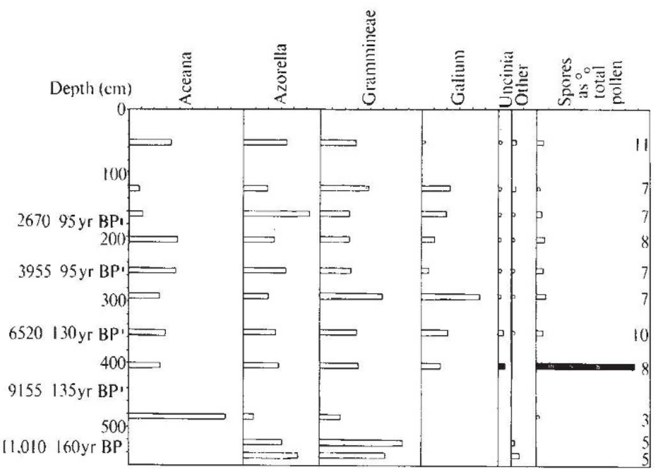

Fig. 3 Simplified pollen diagram of core 2. Symbols same as in Fig. 2.

The upper levels of both cores are marked by a continued low representation of the 'lowland' indicator species.

The following outline of climatic changes of Kerguelen can be constructed on the basis of our pollen analysis. A first warming trend began about 12,000 BP, culminating in a major glacial retreat by 10,000 BP. Thereafter, low temperatures prevailed for about 1,000 yr; most of the deglaciated areas supported a cold-tolerant vegetation consisting mainly of *Azorella* and grasses. *Acaena* became important as a major warming trend began. By 8,000 BP several cold-tolerant species had colonised the core sites. This apparent expansion of a vegetation containing a mixture of 'lowland' species suggests that the climate of Kerguelen at that time was considerably warmer than at present. *Blechnum* and *Uncinia* presently grow most luxuriantly in moist habitats, while *Galium* is usually found in dry habitats. As *Galium* pollen reached a peak later than the other 'lowland' species, possibly the latter part of the climatic optimum was drier. By 5,000 BP, the cold-tolerant species (partially excepting *Galium*) had declined to low levels, indicating that the warm period on Kerguelen was over. A similar history has been found in southern Chile, where the climatic optimum was followed by a glacial readvance about 4,500 BP (refs 1 and 7). In the northern hemisphere the climatic optimum tapered off more slowly and elevated temperatures often persisted until about 3,000 BP (refs 1 and 2).

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STEVEN B. YOUNG
EILEEN K. SCHOFIELD*

*Institute of Polar Studies,
The Ohio State University,
Columbus, Ohio* 43210

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* Present address: New York Botanical Garden, Bronx, New York 10458.

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