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Radiocarbon dating of lacustrine and marine sediments from the Bunger Hills, East Antarctica

MARTIN MELLES[1], SERGEY R. VERKULICH[2] and WOLF-D. HERMICHEN[1]

[1] *Alfred Wegener Institute for Polar and Marine Research, Forschungsstelle Potsdam, Telegrafenberg A 43, D-14473 Potsdam, Germany*
[2] *Arctic and Antarctic Research Institute, Bering Street, 199 226 St. Petersburg, Russia*

Abstract: Radiocarbon dating was carried out on the total organic carbon of 19 lacustrine and marine sediment samples from the Bunger Hills. The results indicate that radiocarbon contamination is negligible throughout two sediment sequences from a fresh water lake. In contrast, two sequences from marine basins are irregularly influenced by the Antarctic Marine Reservoir Effect, which today amounts to more than 1000 years, depending on the degree of dilution with meltwater. All dated sediments were deposited during Holocene time.

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Introduction

Palaeoenvironmental investigations in the Bunger Hills (Fig. 1), the largest deglaciated coastal region (oasis) in East Antarctica, were hampered for long time by the absence of accurate age determinations of environmental changes (Rozycki 1960). Recently, however, major progress was made with the first radiocarbon dates from marine shells in raised beaches and till deposits (Verkulich 1991, Adamson & Colhoun 1992), of snow petrel guano (Bolshiyanov *et al.* 1990, Verkulich & Hiller 1994), and of total organic carbon in lacustrine sediments (Bolshiyanov *et al.* 1990). All dates are younger than 11 000 ^{14}C yr BP.

Because, in Antarctica, radiocarbon contamination processes may result in differences of several thousand years between the radiocarbon dates and the deposition dates of terrestrial, lacustrine, and marine sediments (Domack *et al.* 1989, Björck *et al.* 1991a, Gordon & Harkness 1992), one object of this study was to determine the usefulness and accuracy of radiocarbon dates in the Bunger Hills.

For this purpose a total of 19 samples from four lacustrine and marine sediment cores was dated. These cores were investigated sedimentologically by Verkulich & Melles (1992). Other objectives were to date the environmental changes reconstructed by those authors, to verify their correlations between the sequences, and to confirm their interpretation of an undisturbed, continuous deposition within the time interval documented in the sediment cores.

Methods

Radiocarbon dating was carried out on the total organic carbon using the Accelerator Mass Spectrometer facility in the Research Laboratory for Archaeology and History of Art, Oxford, England. The samples received HCl treatment only, except for sample OxA-3940 which had to be pre-concentrated with HF due to a much lower total organic carbon content (0.33 %) than those of the other samples (> 2 %). The radiocarbon dates (Table I) are expressed in conventional ^{14}C years BP and are corrected for isotopic fractionation effects by normalization relative to a $\delta\,^{13}C_{PDB}$ value of -25°/oo. The quoted errors in the dates are based on estimates of the reproducibility of measurement. A more detailed description of the equipment and method was given by Hedges (1981).

Results and discussion

The sediment cores 6069 and 6082 were recovered from the freshwater Figurnoe Lake in water depths of 56.5 m and 67.0 m, respectively (Fig. 1). Assuming that sedimentation rates above the uppermost samples are similar to those in the deeper parts of the cores (Fig. 2), the radiocarbon ages of the sediment

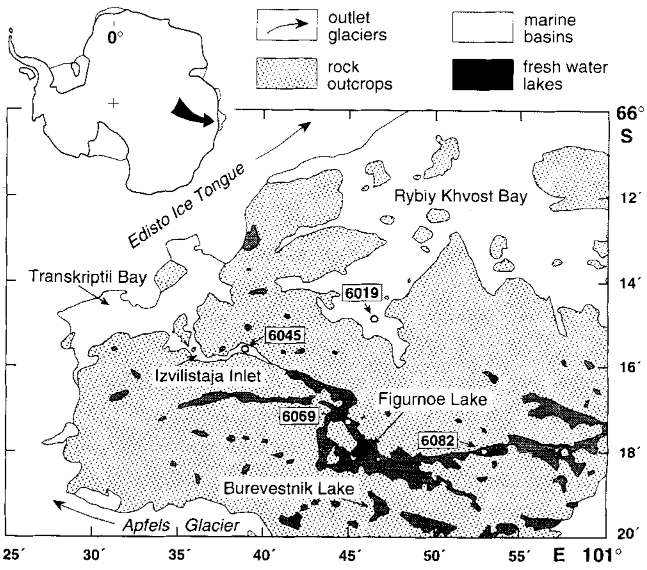

Fig. 1. Map showing the southern Bunger Hills and locations of sediment cores presented in Fig. 2.

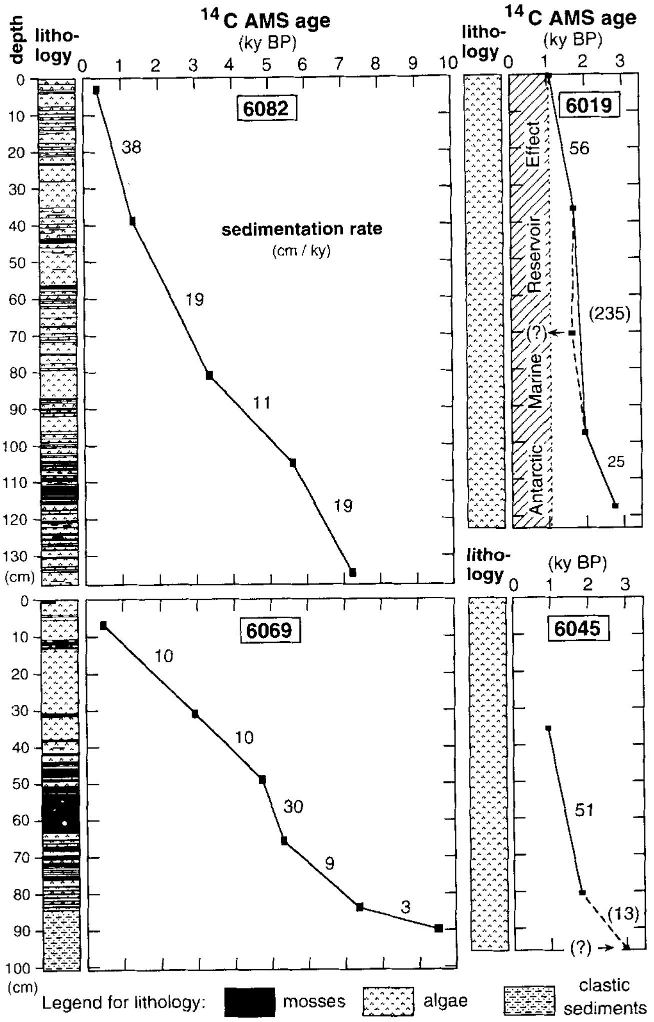

Fig. 2. Comparison of lithologies and radiocarbon ages in the sediment cores. Sizes of data points represent sample thicknesses and errors of measurements. Question marks and arrows indicate a probable reduction (core 6019) and presence (core 6045) of the Antarctic Marine Reservoir Effect on the respective samples.

Table I. Radiocarbon dating of total organic carbon in lacustrine and marine sediment cores from the Bunger Hills (for core locations see Fig. 1)

Core no.	Sediment depth [cm]	Laboratory no.	δ^{13}C [‰]	^{14}C Age [y BP]
6019	0–1	OxA-3922	-20.7	1065 ± 65
6019	36–37	OxA-3923	-20.6	1710 ± 65
6019	70–71	OxA-3924	-18.8	1645 ± 75
6019	97–98	OxA-3925	-19.9	1970 ± 60
6019	117–118	OxA-3926	-20.3	2765 ± 60
6045	35–36	OxA-3927	-10.1	935 ± 60
6045	80–81	OxA-3928	-13.7	1820 ± 65
6045	95–96	OxA-3929	-25.9	2985 ± 65
6082	2–4	OxA-3930	-21.6	365 ± 70
6082	38–39	OxA-3931	-12.5	1315 ± 65
6082	80–82	OxA-3932	-11.5	3480 ± 75
6082	104–106	OxA-3933	-24.6	5640 ± 70
6082	134–136	OxA-3934	-18.1	7245 ± 70
6069	6–8	OxA-3935	-20.9	460 ± 65
6069	30–32	OxA-3936	-15.9	2940 ± 70
6069	48–50	OxA-3937	-22.8	4740 ± 70
6069	65–67	OxA-3938	-22.4	5315 ± 70
6069	83–85	OxA-3939	-22.3	7375 ± 80
6069	89–91	OxA-3940	-25.6	9510 ± 90

surfaces are very close to present. This indicates an absence of radiocarbon contamination processes in Figurnoe Lake today. The sedimentation rates vary between 3 and 38 cm ky^{-1} (Fig. 2). These rates are similar to those determined on several fresh-water lake sediments from different areas of the Antarctic continent (e.g., Mäusbacher *et al.* 1989, Zale & Karlén 1989, Bolshiyanov *et al.* 1990, Björck *et al.* 1991b, Bird *et al.* 1991). From this similarity in sedimentation rates, as well as increasing radiocarbon ages with sediment depth, it is concluded that contamination processes are probably negligible throughout these cores.

Hence, the radiocarbon dates indicate that accumulation of the clastic sediments in the lower part of core 6069 had commenced before 9.5 ky BP (Fig. 2). Well-pronounced sorting and stratification of these sediments were correlated with deposition in flowing water rather than below grounded ice masses (Verkulich & Melles 1992). The date of 9.5 ky BP, therefore, represents a minimum age for deglaciation at the location of core 6069.

Although the bottom of the sediment sequence was reached neither by core 6069 nor by any other of the cores investigated, there is some evidence that the clastic sediments represent the initial lake stage. For example, a fining upward in the sediments and an increase of organic carbon contents indicate gradually decreasing proximity to a glacial sediment source. The low organic carbon contents and the occurence of only a few freshwater diatom skeletons (Z. Pushina, personal communication, 1993) point to a limited biogenic production, which could be due to coverage by floating ice. However, because the sample from 89–91 cm in core 6069 was taken from the top of the clastic sediments (Fig. 2), and nothing is known about the sedimentation rate below the sample, the date of deglaciation at the core location cannot be estimated. For the Bunger Hills, a start of deglaciation close to Pleistocene/Holocene boundary time was assumed by Bolshiyanov *et al.* (1990), Adamson & Colhoun (1992), and Verkulich & Hiller (1994).

In core 6069, a sharp boundary at about 8 ky BP separates the clastic sediments from predominantly biogenic accumulation of layered algae and water mosses (Fig. 2). The only two radiocarbon dates available so far from lacustrine sediments of the Bunger Hills were obtained from two sediment cores a few centimetres above a similar boundary (Bolshiyanov *et al.* 1990). The sample from western Figurnoe Lake was dated to 9850 ± 600 ^{14}C yr BP (LY-1984), about 2 kyr older than the boundary in core 6069. The sample from Burevestnik Lake (Fig. 1), however, was dated to 8310 ± 80 ^{14}C yr BP (LY-2289), similar to the 8 ky BP

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estimated for the boundary in core 6069. The moss-rich sediments in core 6069 are replaced by a dominance of algae at a level corresponding to about 5 ky BP. A similar transition occurs in core 6082 at approximately the same time level.

The sedimentation rates measured in core 6082 are mostly higher than those in core 6069 (Fig. 2). This is probably due to the closer proximity of core 6082 to the ice sheet (Fig. 1), resulting in both enhanced terrigeneous sediment supply by icebergs and glacial meltwater and enhanced algae production due to the related higher nutrient inflow (Verkulich & Melles 1992).

Core 6019 was obtained in a water depth of 88 m from southern Rybiy Khvost Bay (Fig. 1), a marine basin (epishelf lake) connected to the open ocean below the Shackleton Ice Shelf in the north of Bunger Hills. The radiocarbon age of the uppermost centimetre of sediment (1065 ± 65 ^{14}C yr BP, Table I) points to radiocarbon contamination processes. One possible source, a reduced gas exchange between the water and the atmosphere, is unlikely as the ice cover of Rybiy Khvost Bay is only semi-permanent. A supply of old carbon from soils, weathered carbon-bearing rocks, or glacier ice can also be excluded due to absence of such sources in the surroundings of the core location. The most probable explanation, therefore, is the Antarctic Marine Reservoir Effect, which was determined to be 1300 years for Vestfold Hills, about 1000 km west of Bunger Hills (Adamson & Pickard 1986). The lower date in Rybiy Khvost Bay probably reflects the dilution of seawater by meltwater in this ice-bound bay (Kaup et al. 1990).

The sedimentation rates measured in core 6019 are much higher than in the cores from the fresh-water Figurnoe Lake (Fig. 2). This is due to a higher algae accumulation caused by a much higher nutrient concentration in Rybiy Khvost Bay waters (Verkulich & Melles 1992, Kaup *et al.* 1990). Similar differences in sedimentation rates between marine and lacustrine conditions were found by Bird *et a*l. (1991) in the Vestfold Hills.

Due to the high sedimentation rates in core 6019 the three central samples (36–37 cm, 70–71 cm, and 97–98 cm) are scarcely significantly different in age (Table I, Fig. 2). The older radiocarbon age of the sample from 36-37 cm than the deeper sample from 70–71 cm cannot be resolved even at the 1 standard deviation confidence level for analytical precision. However, this older age could also be due to a contamination process leading towards younger dates of the lower sample because, in the sediments at 70–71 cm, a distinct increase of fresh water diatoms (Z. Pushina, personal communication, 1993) indicate an increased meltwater inflow, which presumably results in a reduced reservoir effect. An opposite process is documented in core 6045 from Izvilistaja Inlet, eastern Transkriptii Bay (Figs 1 & 2). At this core location today, the entire water column (37.5 m) is composed of chemically transformed meltwater (Kaup *et al.* 1990). In the deeper parts of the bay (> 88 m), however, this melt water body is underlain by seawater. During the time of deposition of the lowermost sediment in core 6045 a dominance of marine over fresh water diatoms (Z. Pushina, personal communication, 1993) probably reflects a rise of the seawater layer and, as a consequence, an influence of a marine reservoir effect.

Conclusion

From this study we conclude that radiocarbon contamination processes are probably negligible in sediment sequences from the fresh water Figurnoe Lake. The radiocarbon dating in this lake gives a time resolution of less than 100 years. In contrast, sediments from the marine basins of the Bunger Hills show irregular influences of the Antarctic Marine Reservoir Effect, which today is more than 1000 years. In these sediments a resolution of a few hundred years can only be reached in combination with microfaunal investigations, allowing an estimation of dilution processes between seawater and meltwater.

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