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INSTRUMENTS AND METHODS

AN *IN SITU* GAS-EXTRACTION SYSTEM TO RADIOCARBON DATE GLACIER ICE

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Abstract. A new down bore-hole instrument to extract atmospheric gases entrapped in glacier ice was designed, developed and tested in a Greenland ice tunnel. Using this ice and a 7·5 kW. source, about 30 hr. are required to melt the approximately 1 metric ton sample, extract the gases, and to separate and collect with molecular sieves the minimum of 100 cm.^{3} of CO_2 necessary for the ^{14}C measurements made later using special low-level counters. Age results using the down bore-hole CO_2 samples agree with results obtained earlier from CO_2 samples collected at the same tunnel location using a vacuum-vessel melting technique. A mean value of $5{,}120 \pm 200$ yr. B.P. is obtained for the seven samples measured using both collection systems, making this the oldest natural polar glacier ice measured to date.

Résumé. *Système pour l'extraction des gaz in situ en vue de la datation par radiocarbone de la glace de glacier.* Un nouvel instrument a été mis au point: dans un trou de forage, il permet l'extraction des gaz atmosphériques occlus dans la glace. Il a été testé dans un tunnel de glace au Groenland. Dans cette glace, avec une source d'énergie de 7,5 kW, il faut en gros 30 heures pour fondre environ une tonne de glace, en extraire les gaz, et séparer et recueillir avec des tamis moléculaires le minimum de 100 cm^3 de CO_2 nécessaire pour les mesures au ^{14}C faites en laboratoire à l'aide de compteurs spéciaux à bas-niveau. L'âge des échantillons de CO_2 extrait dans les trous de forage est en accord avec celui d'échantillons de CO_2 collectés auparavant dans le même tunnel et aux mêmes emplacements à l'aide de fonte dans une enceinte sous vide. Une valeur moyenne de 5120 ± 200 années a été obtenue pour sept échantillons mesurés avec les deux techniques d'extraction, ce qui constitue actuellement la plus vieille glace polaire naturelle datée.

Zusammenfassung. *Ein System zur Gasentnahme in situ für die Radiocarbondatierung von Gletschereis.* Für die Entnahme atmosphärischer Gase aus Gletschereis wurde ein neues Bohrloch-Gerät entwickelt und in einem grönländischen Eistunnel erprobt. Bei diesem Eis und mit einer Energiequelle von 7,5 kW dauert es etwa 30 Stunden, bis die Eisprobe von ca. 1 ton Gewicht geschmolzen, die Gase entzogen und mit Molekular-Filtern die 100 cm^3 von CO_2 getrennt und gesammelt sind, die mindestens für die späteren ^{14}C-Untersuchungen mit besonderen, niederstufigen Zählern gebraucht werden. Die Altersbestimmungen aus den CO_2-Proben des Bohrloches stimmen mit den früheren Ergebnissen aus CO_2-Proben überein, die an derselben Tunnelstelle unter Anwendung einer Vakuum-Schmelztechnik gewonnen wurden. Es wurde ein mittleres Alter von 5120 ± 200 Jahren für die 7 untersuchten Proben aus bieden Entnahmesystemen gefunden; dies ist die bisher höchste Altersbestimmung für natürliches Gletschereis aus Polargebieten.

Introduction

Atmospheric gases become entrapped in polar glacier ice during a natural compaction process. In the first reported attempt to separate the CO_2 component of this atmospheric gas from iceberg samples for radiocarbon dating analysis (Scholander and others, 1962), a vacuum-melting system was used, and 10 to 20 metric tons of ice were required. In 1964, CRREL and the University of Bern conducted a joint project in the TUTO ice tunnel, Greenland (Langway and others, 1965; Oeschger and others, 1966), where refinements in sample collection, vacuum-melt processing and laboratory low-level measuring techniques (Oeschger, 1963) allowed smaller samples (1 metric ton) of "cold" glacier ice to be used for radiocarbon-dating purposes. Although the techniques used in this later study considerably reduced the amount of ice sample necessary for age-dating purposes, certain glaciological applications of the radiocarbon method were not possible using a vacuum-melt vessel technique. In the first place, the field logistics required with the vacuum-melt vessel technique are prohibitive at most marginal and inland glacier locations. Furthermore, a valuable application

of the radiocarbon-dating method would be to analyze the deep ice cores being recovered in Greenland and Antarctica by CRREL's deep ice-core drilling program, but this is also not feasible using the vessel technique. Even the reduced requirements of a 1 metric ton ice sample represents, for a 10 cm. diameter ice core, a 140 m. vertical profile, or depending on location, 500 to 2,000 years of accumulation. These considerations made it desirable to develop a system that would allow gas extractions to be made from within a shallow or deep bore hole at any glacier location.

Field Program

In March–April 1966 a team from CRREL and the University of Bern returned to the TUTO ice tunnel in Greenland to test the new down bore-hole device and to take samples from a complete profile along the 400 m. length of the tunnel. The tunnel ice is unfractured and its temperature is constant at −10°C. The earlier 200 m. location where in 1964 ^{14}C age dates had been obtained was used as a check point for the down bore-hole tests.

Field Experiments

Figure 1 shows a diagram of the apparatus which consists of two main parts: (1) the seal and (2) the heater. A 4 m. deep bore hole is hand augered and the down bore-hole device inserted. Critical to the success of the down bore-hole concept was the necessity of a vacuum-tight seal of the hole above the heater. The seal used consists of a double-walled latex tube

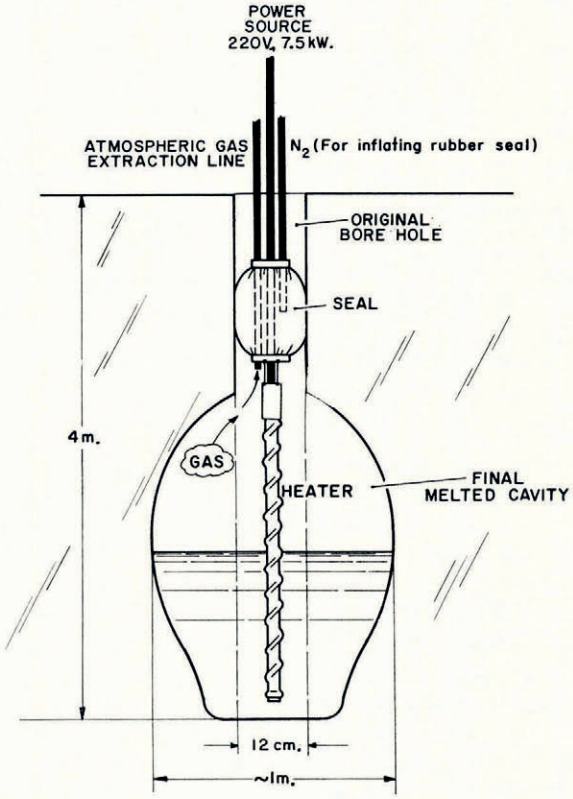

Fig. 1. Schematic diagram of a portable down bore-hole gas-extraction system

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which surrounds a cylindrical brass core. The latex tube is joined to the core at both ends and when in place it is inflated with nitrogen to an over pressure of about 2 atmospheres which presses the rubber seal against the wall of the ice bore hole. The gas extraction line and the power line for the heater pass through the brass core. An energy source of 7·5 kW. is used for the heater. The heating element is wound around a stainless steel cylindrical pipe for mechanical stability and heat reflection, and it was designed not to overheat in air. The bore hole is pumped down to about 2 mm. Hg (the vapor pressure of ice at −10°C.) and held for several hours before the heaters are turned on. Constant pumping is made during heating to extract the gases as the bubbles burst. Continuous checks were made on gas-extraction flow rates, no irregularities indicating leaks were observed. About 30 hr. were required to melt slightly over 1 metric ton of ice to collect the necessary minimum of 100 cm.^{3} of CO_2. During this time the gases passed through a molecular-sieve gas-extraction line. From experience gained in 1964, it was found that the NaOH and molecular sieve CO_2 collectors provided compatible results, but since molecular sieves are simpler to handle and process they were adopted for the 1966 investigations.

Laboratory Results

The CO_2 contained in the molecular sieves was processed in the Radiocarbon Laboratory at the University of Bern and measured for ^{14}C, using special low-level counters.

The results of the 1964 vacuum-vessel samples and the new 1966 vacuum vessel and the down bore-hole samples are given in Table I.

Table I. ^{14}C Measurements of Ice Samples from the 200 m. Station, TUTO Ice Tunnel, Greenland

Year collected	*Sample number*	*Technique*	*Gas collector*	*Age* yr. B.P.
1964	L3	Large vessel	NaOH	5,040±400
1964	O3	Small vessel	Molecular sieve	6,030±700
1964	O4	Small vessel	Molecular sieve	5,410±400
1966	L11	Large vessel	Molecular sieve	5,380±300
1966	O11	Small vessel	Molecular sieve	5,250±450
1966	DH1	Down hole	Molecular sieve	5,160±400
1966	DH2	Down hole	Molecular sieve	4,490±300
			Average age for 200 m. station	5,120

Discussion and Conclusions

From Table I we see a close agreement in the ages within the limits of statistical error, determined for both the 1964 and 1966 small and large vacuum-melt vessel samples. Most important, the down bore-hole samples (DH1 and DH2) give essentially the same data. This good agreement is an indication of the validity of all methods used. A mean value of 5,120 yr. B.P. is obtained for the age of the ice at the 200 m. location. To date, this is the oldest natural polar glacier ice ever measured.

The simplicity of the down bore-hole gas-extraction system enables one to apply the carbon-dating method to any natural, undisturbed polar or temperate glacier ice mass which can be sampled by boring. By using helicopters, portable laboratories and shallow, hand core-augering equipment, it is possible to age date the termini of many temperate glaciers or the marginal zones of polar ice sheets for chronological and ice-movement studies. The fascinating problem of ^{14}C dating the entire vertical profile of a contemporary polar ice sheet is now possible (a feasibility study is currently in progress) by attaching a down bore-hole system to the hoist-cable mechanism of the CRREL drilling rig now being used to penetrate through polar ice sheets (Hansen and Langway, 1966).

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