

GLASGOW UNIVERSITY RADIOCARBON MEASUREMENTS I

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INTRODUCTION

Two radiocarbon counting systems have been established in the Chemistry Department, University of Glasgow, since late 1967.

The counting gas is methane, at pressures up to 10 atm, and 2 alternative procedures are followed for methane production, (a) high pressure synthesis in a stainless steel 4.5 l reactor and (b) low pressure synthesis in an all glass flow-reactor. Both systems employ 0.5% ruthenium on alumina pellets as catalyst (Engelhard Industries Ltd.). Early samples synthesized with Air Products' hydrogen showed evidence of tritium contamination. This gas supply was later replaced with tritium-free hydrogen supplied by Messrs. Griesheim, Düsseldorf, Germany. Both detectors used for routine measurements are 0.5 l internal gas counters supplied by Beckman Instruments Inc., California. The detectors are surrounded by a concentric-wall multiple anode anticoincidence counter. The entire counter assembly is encased within a 4-in.-thick lead shield manufactured from aged lead by J. Girdler and Co., London. Counter electronics, anticoincidence system and power supply are of Beckman design (Sharp and Ellis, 1965).

Both detectors have plateaus of length 1000 to 2000 volts with a slope less than 0.5% per 100 volts. Background count rates at sea level for the 2 detectors are 3.45 ± 0.10 and 3.13 ± 0.10 ($\pm 2\sigma$) counts/min. at 1 atm barometric pressure and 5 atm filling pressure. The variation of background count rate with atmospheric pressure amounts to -0.11 counts/cm.Hg for both detectors. The activity of N.B.S. Oxalic Acid modern standard is 18.76 ± 0.12 counts/min. ($\pm 2\sigma$) in both detectors at 5 atm pressure at 18°C, after correction for fractionation and decay.

The basic pretreatment of wood, peat, and charcoal samples consists of visual examination for intrusive rootlets followed by boiling successively in distilled water, 5% HCl, distilled water, 5% NaOH, distilled water, 5% HCl, and distilled water. Shells and marble samples are leached in 5% HCl to remove 20% by weight. Tree seeds, received from the U. K. Forestry Commission, are suitable for analysis without pretreatment.

Methane samples are normally stored for 2 weeks prior to counting to allow for radon decay. This is not essential, however, for most tree seed and spirit samples. A 5 atm gas fill is routinely employed. Samples are counted at least twice, several days apart, for a minimum of 10,000 counts. Modern standard activities and backgrounds are monitored at least weekly. Mass spectrometric analyses for fractionation correction have been performed at the National Physical Laboratory, Middlesex.

Calculations are based on the Lamont VIII formulae (Radiocarbon,

1961, v. 3, p. 176-204) and the standard deviations quoted (1σ) describe only the uncertainties associated with the sample, modern, background, and mass-spectrometric determinations.

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SAMPLE DESCRIPTIONS

I. INTERCALIBRATION SAMPLES

Before routine measurement of C-14 activities and ages began a number of samples were requested from various established laboratories for intercalibration purposes.

1908 ± 60

GU-10. Kilphedir hut circles, Sutherland, Scotland A.D. 42

Charcoal (*Birch-Betula*) from hut circle, 1 of 5 in locality just below turf at Kilphedir site, Sutherland, Scotland, 3.5 mi from sea at Helmsdale (58° 9' N Lat, 3° 43' W Long). Sample occurred in large pieces 3 to 4 in. across, on living floor and resulted apparently from collapse of conical roof on smouldering hearth. This site, one of few excavated in Scotland, overlies site of earlier dwelling (to be dated). Site was inhabited shortly after change from Sub-Boreal to Sub-Atlantic periods; sample presumably dates end of occupation.

2064 ± 55

GU-11. Kilphedir hut circles, Sutherland, Scotland 114 B.C.

Charcoal. *Comment*: third sample was forwarded to Dr. D. L. Thurber, Lamont Geol. Observatory, Columbia Univ., and dated 2100 ± 80 (L-1061, unpubl.). Coll. 1965 and subm. by H. Fairhurst, Archaeol. Dept., Univ. of Glasgow.

GU-12. Cardross, Dunbartonshire, Scotland 11,787 ± 122

Marine shells (mainly *Arctica islandica*) from marine clayey silt (~1 ft) at junction of laminated basal part and homogeneous upper part, Cardross, Dunbartonshire (55° 58' N Lat, 4° 40' W Long). Stratigraphic succession represents continuous deposition from subglacial through glaciomarine till and laminated sediments to normal marine clayey silts, produced by thinning of Clyde glacier. Proximal lamination indicated sediments were deposited immediately after ice melted at Cardross. Normal marine deposition followed; adjacent morphology indicates sea level at +25m. Coll. 1967 and subm. 1968 by J. Rose, Dept. of Geog., Univ. of Glasgow. *Comment* (J.G.R.): duplicate sample dated by T. Hamada, Inst. of Phys. and Chem. Research, Bunkyo-Ku, Japan,

at $11,900 \pm 170$, Ref. N. 475. Recent dates obtained by Sissons (1967), from Loch Lomond I-2235, $11,700 \pm 170$ and the upper Forth I-2234, $11,800 \pm 170$ indicate low land in Forth and Clyde basins was submerged $\sim 11,800$ yrs ago. Date agrees with these results.

GU-13. Robert Hill Tree **3702 ± 69**

Wood from Robert Hill Tree previously dated by Birmingham Univ. BIRM-5, 3847 ± 60 (Radiocarbon, 1967, v. 9, p. 36) and BIRM-11, 3911 ± 58 (Radiocarbon, 1968, v. 10, p. 201). *Comment*: results agree fairly well and within expectations since parts of the tree were denatured to such an extent as to prevent id. of rings.

GU-14. Redkirk Point, Dumfriesshire **$11,828 \pm 105$**

Peat from Redkirk Point previously dated by Birmingham Univ. BIRM-41, $11,205 \pm 177$ (Radiocarbon, 1968, v. 10, p. 202).

GU-15. Redkirk Point, Dumfriesshire **$12,158 \pm 218$**

Sample of same peat dated because of slight discrepancy between GU-14 and BIRM-41. Internal agreement between GU-14 and GU-15 is good and discrepancy may be due to sampling difficulties experienced.

II. ATMOSPHERIC CO₂ SAMPLES

Data reported here are derived from atmospheric CO₂ samples coll. at several stations established in both hemispheres in 1967. Sampling points range in lat from 60° N to 75° S and the following table presents data from only 6 of 13 stations in operation. Measurements were made as part of continuing study of the transport of C¹⁴ within the "dynamic" carbon reservoir and complement the work of other laboratories in this field (Nydal, 1968; Young and Fairhall, 1968; Münnich and Roether, 1967; Olsson *et al.*, 1967; Bien and Suess, 1967; and Rafter, 1965).

CO₂ is coll. through exposure of carbonate-free 8N KOH solution supplied to each station by ourselves. Monthly samples are obtained and returned to our laboratories in sealed polythene bottles.

Lerwick series, 1967

Samples coll. by Meteorological Office in their ventilated East hut, Lerwick (60° 08' N Lat, 01° 11' W Long).

	$\delta C^{14}\%$	$\delta C^{13}\%$	$\Delta\%$
GU-16. Lerwick, Scotland CO ₂ coll. Jan. 1967.	63.7 ± 0.8	(-23.0)	$63.1 \pm 0.8^*$
GU-17. Lerwick, Scotland CO ₂ coll. Feb. 1967.	66.6 ± 0.8	(-23.0)	$66.0 \pm 0.9^*$
GU-18. Lerwick, Scotland CO ₂ coll. March 1967.	66.2 ± 0.8	(-23.0)	$65.6 \pm 0.9^*$
GU-19. Lerwick, Scotland CO ₂ coll. April 1967.	69.4 ± 0.9	(-23.0)	$68.7 \pm 1.0^*$

GU-20. Lerwick, Scotland	67.7 ± 0.9	-22.4	$66.9 \pm 0.9^{**}$
CO ₂ coll. July 1967.			
GU-21. Lerwick, Scotland	80.4 ± 1.1	-21.5	$79.2 \pm 1.1^{**}$
CO ₂ coll. Oct. 1967.			

Comment: in this and some other series mass spectrometric measurements were not available for all samples. A single asterisk indicates that no mass spectrometric measurement was available for the sample; a value of $-23.0 \pm 1\%$ was assumed. A double asterisk indicates that a mass spectrometric measurement on N.B.S. Oxalic Acid sample was unavailable; a value of -19.0% was assumed.

Gibraltar series, 1967

Samples coll. by Meteorological Office, R.A.F. Gibraltar, in well-ventilated room, adjacent to open window ($36^{\circ} 09' N$ Lat, $05^{\circ} 21' W$ Long).

	$\delta C^{14}\%$	$\delta C^{13}\%$	$\Delta\%$
GU-22. Gibraltar	67.1 ± 0.8	(-23.0)	$66.4 \pm 0.9^*$
CO ₂ coll. Jan. 1967.			
GU-23. Gibraltar	67.2 ± 0.9	(-23.0)	$66.5 \pm 0.9^*$
CO ₂ coll. April 1967.			
GU-24. Gibraltar	68.8 ± 1.2	(-23.0)	$68.1 \pm 1.3^*$
CO ₂ coll. July 1967.			
GU-25. Gibraltar	99.1 ± 1.1	-20.4	97.2 ± 1.2
CO ₂ coll. Oct. 1967.			

Comment: high value for Oct. 1967 is being investigated further with samples from preceding and following months.

Singapore series, 1967

Samples coll. by Meteorological Office, R.A.F. Changi, Singapore, at airport ($01^{\circ} 22' N$ Lat, $103^{\circ} 59' E$ Long).

	$\delta C^{14}\%$	$\delta C^{13}\%$	$\Delta\%$
GU-26. Singapore	64.1 ± 0.8	-21.9	$63.1 \pm 0.9^{**}$
CO ₂ coll. April 1967.			
GU-27. Singapore	62.5 ± 0.9	-22.6	$61.7 \pm 1.0^{**}$
CO ₂ coll. July 1967.			
GU-28. Singapore	66.4 ± 0.9	-25.0	66.4 ± 0.9
CO ₂ coll. Oct. 1967.			

Pretoria series, 1967

Samples coll. by Atomic Energy Board, Pelindaba, Pretoria, in a Stephenson Screen housing a variety of meteorological instruments ($25^{\circ} 45' S$ Lat, $28^{\circ} 16' E$ Long).

	$\delta C^{14}\%$	$\delta C^{13}\%$	$\Delta\%$
GU-29. Pretoria	64.5 ± 0.9	-22.8	$63.8 \pm 1.0^{**}$
CO ₂ coll. Jan. 1967.			

GU-30. Pretoria	60.5 ± 0.8	-24.3	60.3 ± 0.9**
CO ₂ coll. April 1967.			
GU-31. Pretoria	58.4 ± 1.0	-24.1	58.1 ± 1.1
CO ₂ coll. July 1967.			
GU-32. Pretoria	65.8 ± 0.9	-23.5	65.3 ± 0.9
CO ₂ coll. Oct. 1967.			

Stanley, Falkland Islands series, 1967

Samples coll. outdoors by Meteorological Office, Stanley, Falkland Is., in meteorological thermometer screen (51° 42' S Lat, 57° 52' W Long).

	$\delta C^{14}\%$	$\delta C^{13}\%$	$\Delta\%$
GU-33. Stanley	59.4 ± 0.8	-24.1	59.1 ± 0.9
CO ₂ coll. April 1967.			
GU-34. Stanley	57.5 ± 0.8	-24.0	57.1 ± 0.9
CO ₂ coll. July 1967.			
GU-35. Stanley	56.1 ± 0.8	-23.0	55.5 ± 0.9
CO ₂ coll. Oct. 1967.			

Halley Bay series, 1967

Samples coll. by British Antarctic Survey in one of their instrument huts (75° 31' S Lat, 26° 45' W Long).

	$\delta C^{14}\%$	$\delta C^{13}\%$	$\Delta\%$
GU-36. Halley Bay	60.2 ± 1.2	-18.4	58.1 ± 1.2
CO ₂ coll. April 1967.			
GU-37. Halley Bay	58.9 ± 0.9	-19.3	57.0 ± 1.0
CO ₂ coll. July 1967.			
GU-38. Halley Bay	58.4 ± 0.8	-19.5	56.6 ± 0.9
CO ₂ coll. Oct. 1967.			

III. SPIRIT SAMPLES

An attempt has been made to establish atmospheric C¹⁴ concentrations in Scotland in past yrs. A series of malt whisky samples have been analyzed for the period 1933-1966. A good correlation exists between atmospheric C¹⁴ concentrations and those in the spirit samples for recent times and thus we have considerable confidence in the application of this material to studies of past atmospheric C¹⁴ fluctuations in this region.

	$\delta C^{14}\%$	$\delta C^{13}\%$	$\Delta\%$
GU-39. Malt whisky, Scotland, 1933	-0.3 ± 0.6	-19.9	-1.4 ± 0.7**
Barley coll. 1933, distilled 1934.			

GU-40.	Malt whisky, Scotland, 1937	-1.5 ± 0.6	(-26.5)	-1.2 ± 0.6**
	Barley coll. 1937, distilled 1938.			
GU-41.	Malt whisky, Scotland, 1941	-3.0 ± 0.7	-26.6	-2.7 ± 0.7
	Barley coll. 1941, distilled 1942.			
GU-42.	Malt whisky, Scotland, 1945	-4.6 ± 0.7	-22.8	-4.8 ± 0.7**
	Barley coll. 1945, distilled 1946.			
GU-43.	Malt whisky, Scotland, 1949	-3.2 ± 0.7	-24.0	-3.4 ± 0.7**
	Barley coll. 1949, distilled 1950.			
GU-44.	Malt whisky, Scotland, 1951	-3.0 ± 0.6	-29.5	-2.1 ± 0.6
	Barley coll. 1951, distilled 1952.			
GU-45.	Malt whisky, Scotland, 1957	6.5 ± 0.7	-25.1	6.5 ± 0.7**
	Barley coll. 1957, distilled 1958.			
GU-46.	Malt whisky, Scotland, 1958	12.3 ± 0.7	-28.2	12.9 ± 0.7
	Barley coll. 1958, distilled 1959.			
GU-47.	Malt whisky, Scotland, 1960	20.1 ± 0.7	-27.9	20.8 ± 0.8
	Barley coll. 1960, distilled 1961.			
GU-48.	Malt whisky, Scotland, 1962	39.1 ± 0.8	-24.9	39.1 ± 0.8**
	Barley coll. 1962, distilled 1963.			
GU-49.	Malt whisky, Scotland, 1963	86.1 ± 1.1	(-26.5)	86.6 ± 1.1
	Barley coll. 1963, distilled 1964.			
GU-50.	Malt whisky, Scotland, 1964	87.7 ± 1.0	-30.0	89.5 ± 1.0
	Barley coll. 1964, distilled 1965.			
GU-51.	Malt whisky, Scotland, 1965	76.0 ± 1.2	-29.0	77.4 ± 1.3
	Barley coll. 1965, distilled 1966.			

GU-52. Malt whisky, Scotland, 1966 68.3 ± 1.2 -29.5 69.8 ± 1.3

Barley coll. 1966, distilled 1967.

Comment: several other samples of malt and blended whisky have been analyzed at the National Physical Laboratory, Teddington and discussed by Walton *et al.* (1967). As shown in fig. 1, results of this series agree well with data on Danish cereals reported by Tauber (1967). Small discrepancies may be attributable to slightly different growth periods of the Copenhagen and Glasgow samples. The former were coll. on July 1st of each yr whereas barley for whisky manufacture is harvested during August/September. Results indicate materials of plant origin reflect accurately the atmospheric C^{14} concentrations prevalent during growth.

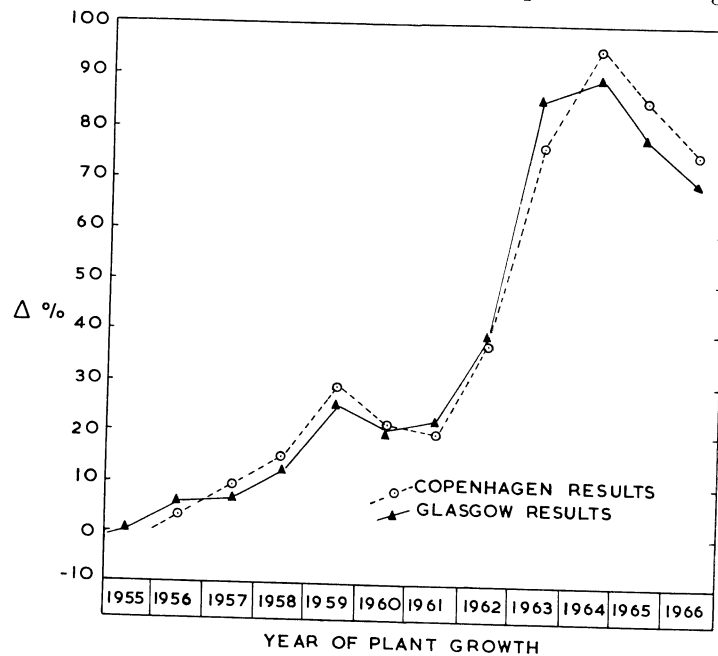


FIG. 1 COMPARISON OF C^{14} CONCENTRATIONS IN SCOTTISH MALT WHISKIES AND DANISH CEREALS [AS REPORTED BY TAUBER (1967)]

IV. TREE SEED SAMPLES

In a study of the possible latitudinal variation of atmospheric C^{14} concentrations a number of tree seeds (subm. and id. by U. K. Forestry Commission) have been analyzed. The seeds, stored in vacuum since collection, represent a variety of species.

$\delta C^{14}\text{‰}$ $\delta C^{13}\text{‰}$ $\Delta\text{‰}$
 72.8 ± 1.0 -26.8 $73.5 \pm 1.0^{}$**

Seeds (*pinus sylvestris*) coll. 1965 from Moray ($57^{\circ} 30' N$ Lat, $3^{\circ} 30' W$ Long).

- GU-54. Alaska, U.S.A.** 73.7 ± 1.2 -28.4 74.9 ± 1.3
 Seeds (*pinus contorta*) coll. 1965 from Alaska (56° 50' N Lat, 155° W Long).
- GU-55. NW England** 77.3 ± 0.9 -31.6 $79.6 \pm 1.0^{**}$
 Seeds (*pinus sylvestris*) coll. 1965 from NW England (54° N Lat, 2° 30' W Long).
- GU-56. Campine, Belgium** 79.2 ± 1.3 (-28.0) $80.3 \pm 1.4^{**}$
 Seeds (*alnus glutinosa*) coll. 1965 from Campaine, Belgium (51° N Lat, 5° E Long).
- GU-57. SE England** 76.8 ± 1.0 -26.8 $77.5 \pm 1.0^{**}$
 Seeds (*pinus sylvestris*) coll. 1965 from SE England (51° N Lat, 0° 30' W Long).
- GU-58. Homburg, Germany** 75.6 ± 1.2 -28.1 76.9 ± 1.3
 Seeds (*larix decidua*) coll. 1965 from Homburg, Germany (50° N Lat, 8° 30' E Long).
- GU-59. British Columbia, Canada** 73.6 ± 0.9 -26.8 74.3 ± 1.0
 Seeds (*pinus contorta*) coll. 1965 from British Columbia (50° N Lat, 125° W Long).
- GU-60. Styria, Austria** 73.9 ± 1.3 (-28.0) $74.9 \pm 1.3^{**}$
 Seeds (*larix decidua*) coll. 1965 from Styria (47° 30' N Lat, 15° E Long).
- GU-61. Washington, U.S.A.** 76.7 ± 0.9 (-28.0) $77.7 \pm 1.0^{**}$
 Seeds (*picea sitchensis*) coll. 1965 from Washington (46° 40' N Lat, 120° W Long).
- GU-62. Oregon, U.S.A.** 77.5 ± 1.0 (-28.0) $78.6 \pm 1.0^{**}$
 Seeds (*abies amabilis*) coll. 1965 from Oregon (45° N Lat, 120° W Long).
- GU-63. Nagano, Japan** 75.9 ± 1.2 (-28.0) $76.9 \pm 1.2^{**}$
 Seeds (*larix leptopolis*) coll. 1965 from Nagano (36° N Lat, 138° E Long).
- General Comment:* C¹⁴ activities scatter outside the statistical error and indicate disequilibrium in N lats. These fluctuations may reflect injections of stratospheric C¹⁴ into troposphere at preferred lats although local Suess effects cannot be ignored in industrial areas.

V. GEOLOGIC AND ARCHAEOLOGIC SAMPLES

- GU-64. Newbie Cottages, Solway Firth** 7254 ± 101
 Peat at base of low cliff on N shore of Solway Firth, 50m W of W angle of Newbie Cottages, Dumfriesshire, Scotland, Nat. Grid. Ref. NY

167 649 (54° 58' N Lat, 3° 18' W Long). Sample is top 5 cm of peat bed 12.5 cm thick underlain by fluvio-glacial sands and gravels, overlain by Carse Deposits. Top of peat bed is at 5.79m above Ordnance Datum (Newlyn). Coll. 1965 and subm. by W. G. Jardine, Dept. of Geol., Univ. of Glasgow. *Comment* (W.G.J.): date is younger than that of (Q-637) 8135 ± 150 yrs B.P. (Godwin and Willis, 1952) for wood from tree stump *in situ* in peat bed at Redkirk Point, 11 km E of Newbie Cottages. Both sites are on present shore of Solway Firth, but older peat, at Redkirk Point, occurs ca. 3m lower than peat in Newbie Cottages.

GU-65. Sandyknowe Bridge, Lochar Water **7426 ± 136**

Wood fragments from borehole on W bank, Lochar Water, S side Dumfries/Lockerbie Rd., A 709, Dumfriesshire, Scotland, Nat. Grid. Ref. NY 017 776 (55° 5' N Lat, 3° 32' W Long). Sample immediately above junction of silty fine sand (local representative of Carse Deposits) and underlay fluvio-glacial sands and gravels, at 0.58m above Ordnance Datum (Newlyn). Locality is 11 km inland from present N shore of Solway Firth. Coll. 1965 by Geotechnical and Concrete Services Ltd; subm. by W. G. Jardine. *Comment* (W.G.J.): date indicates beginning of Flandrian marine transgression at site; it agrees closely with previous date GU-64 and suggests marine transgression was approx. contemporaneous along present N shoreline of Solway Firth and within large elongate embayment, to SE of Dumfries, now covered by Lochar Moss.

GU-66. Carlisle Castle mortar **2002 ± 58**
52 B.C.

Mortar from "De Ireby's Tower" Carlisle Castle (54° 47' N Lat, 2° 55' W Long). Sample taken from ground floor W room, Garderobe Entrance, 9.5 ft from ground level, 2 ft from interior wall face and 1.5 ft above lower side of stone lintel. Coll. and subm. 1967 by Ministry of Public Buildings and Works, Ancient Monuments Branch. *Comment*: true age is 580 and thus contamination by considerable quantity of old carbon is evident.

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