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UNIVERSITY OF CAMBRIDGE NATURAL RADIOCARBON MEASUREMENTS IX

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The University of Cambridge Radiocarbon Dating Laboratory has been completely rebuilt and modernized, incorporating new techniques developed here for the various stages of measurements. Sample radioactivity is measured in gas proportional counters after conversion to highly purified CO_2. Four counters are mounted within a single anticoincidence shield consisting of plastic scintillation material. This is surrounded by a graded cosmic ray shield of low radioactive steel, boron loaded wax, and finally, about 16 tons of ancient low radioactive lead blocks. The electronics are all solid state devices except for the stabilized high voltage supplies.

A large plastic anticoincidence shield, in which it is possible to place several proportional counters of differing sizes, has been developed and functions well. It is 105 cm long and 40 cm in diameter with minimum wall thickness of 7.5 cm at any point; it completely encloses the sample counters with scintillation material so that even axial radiation is detected. Cosmic-ray produced charged particles are detected with 100% efficiency and the shield has high efficiencies for γ-rays and neutrons. It gives better shielding than the normal Geiger or multiple anode anticoincidence shields since their detection efficiencies for uncharged particles are relatively low. Scintillations are detected by two 25 cm diameter photomultiplier tubes operating in coincidence, to reduce noise, and the resultant pulses are used in anticoincidence with the pulses from the sample counters.

Pure copper is used for the proportional counter bodies; two have tin oxide coated quartz inner liners to which the E.H.T. is applied. They are normally operated at 2 atm pressure of CO_2. Plateaux at least 1200 volts long with slopes of 0.4% per 100 volts are routinely typical of the 2 counters that are at present used for dating purposes.

All samples are subjected to pretreatment, unless otherwise stated, to attempt to remove contamination due to carbon non-contemporary with the sample. Pretreatment consists of boiling the shredded sample with 1% hydrochloric acid solution for at least 1 hr and a similar treatment with 1% solium hydroxide solution. Following each of these reagents, the sample is boiled with distilled water, finally filtered and dried, either at 110°C or in the vacuum oven.

Oxidation of the samples is carried out very rapidly and efficiently with high pressure oxygen in a specially developed combustion bomb. This consists of a 5L stainless steel cylinder with a gas-tight lid carrying inlet and outlet tubes for the gases and held in position with a spin ring. Our experiments have shown that small volume, higher pressure bombs are not as effective, as the combustion flame is quenched and material remains unburned. Samples of 20 g are easily combusted with 8 atm pressure of oxygen when an electric current is passed through a thin wire covered by the sample held in a quartz or nickel crucible. The reaction is over within a few seconds as shown by the pressure gauge returning to its original reading. The great heat dissipated is removed rapidly by an external jacket with a flow of cooling water.

Boiled water placed in the combustion bomb removes most of the sulphur and nitrogen oxides from the reaction products and the CO_2 may easily be purified to the stringent requirements for proportional counting. The purification line contains all dry reagents operating under reduced pressure; it is semi-automatic and requires little attention during the hour or so taken from the initial firing of the combustion bomb to the production of a fairly pure sample of solid CO_2. A final purification line consisting of several *in vacuo* distillations through furnaces containing finely divided copper catalyst on a silica/alumina support and silver metal yield the pure counting gas.

The pulses from the anticoincidence shield and each counter are amplified and passed through pulse-height analyzers prior to being counted on fast scalers. Separate scalers also record the selected anticoincidence, *i.e.*, radiocarbon, pulses for each channel. Accumulated counts and the time required in minutes are printed out at pre-set intervals on a teletypewriter which can also produce punched paper tape for computer use. Experiments are normally conducted overnight for 1000 min and throughout the weekend. Usually sufficient runs are made on each sample to accumulate at least 10,000 disintegrations above background so that the statistical uncertaintly is reduced to $<1\%$. The laboratory modern standard is the activity of the 1850 growth ring of oak tree grown in the Cambridgeshire Fens and this is compared with 95.0% of the activity of the N.B.S. oxalic acid. The background is that given by a sample of Welsh Anthracite. The ages of samples are calculated using the conventional half life of 5568 ± 30 years and the uncertainty is stated in terms of one standard deviation of the counting statistics.

A full description of the laboratory and processes used is in preparation for publication elsewhere.

The dating program of the new laboratory is maintaining the policy of directing assays largely toward projects under investigation in the University Sub-Department of Quaternary Research. In 1969 these projects included dating of pollen zone boundaries, of Scottish tree stump horizons, and of archaeologic sequences in the Somerset levels.

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SAMPLE DESCRIPTIONS

I. GEOLOGIC SAMPLES

British Isles

Pollen Zone Boundary Determinations (Red Moss) series

The vertical sequence through a raised bog, Red Moss near Horwich, Lancashire (53° 35′ N Lat, 2° 35′ W Long, Nat. Grid. Ref. SJ 631103) has been subjected to careful pollen analysis. A monolith of peat was transferred to the laboratory and each major zone boundary was identified and marked. Two or three peat samples were taken as thin slices at each boundary and at intermediate points corresponding to significant changes in the pollen diagram. These were carefully pretreated to remove contaminants and combusted in pure oxygen. They extend from Zone III of the Late-Weichselian period to Zone VIIb of the Flandrian. The results are discussed in detail by Hibbert and Switsur (ms. in preparation). Collection and pollen analysis are by F. A. Hibbert and radiocarbon measurements by V. R. Switsur. The pollen zones are those currently in use in England and Wales.

The results from the site, apart from the lowest sample, are internally consistent and comparable with those obtained at Scaleby Moss (Godwin, Walker, and Willis, 1957).

The separate samples are identified by depth in the pollen diagram.

4370 ± 80
Q-910. Red Moss, 114 to 116 cm **2420 B.C.**

2 cm slice of *Sphagnum-Eriophorum-Calluna* peat. Pollen curves at this level show recovery in *Ulmus* and *Tilia* with a fall in weeds and grass pollen, possibly indicating the end of a Landnam occupation phase.

4715 ± 80
Q-911. Red Moss, 124 to 126 cm **2765 B.C.**

2 cm slice of *Sphagnum-Eriophorum-Calluna* peat. Pollen diagrams show *Ulmus* at very low frequency but the weed pollen is high, possibly indicating a Landnam occupation.

5010 ± 80
Q-912. Red Moss, 132 to 134 cm **3060 B.C.**

2 cm slice of moderately humified *Sphagnum-Eriophorum-Calluna* peat. The pollen diagram here indicates boundary of Zone VIIa/VIIb; *Ulmus* pollen falls to very low frequencies here.

5060 ± 80
Q-913. Red Moss, 139 to 140 cm **3115 B.C.**

2 cm slice of *Sphagnum-Eriophorum-Calluna* peat. Pollen diagram indicates close of Zone VIIa by beginning of decline of *Ulmus* pollen frequencies.

5399 ± 100
Q-914. Red Moss, 158 to 160 cm **3449 B.C.**

2 cm slice of *Sphagnum-Eriophorum-Calluna* peat. Pollen curves for *Fraxinus* and *Tilia* exhibit maxima here.

6880 ± 100
Q-915. Red Moss, 225 to 227 cm **4930 B.C.**

2 cm slice of *Sphagnum-Eriophorum-Calluna* peat. Pollen curves for *Fraxinus* and *Tilia* begin here and rapid expansion of *Alnus* ends.

7107 ± 120
Q-916. Red Moss, 230 to 232 cm **5157 B.C.**

2 cm slice of *Sphagnum-Eriophorum-Calluna* peat. There is a very rapid rise of *Alnus* pollen frequencies in the diagram here indicating boundary of Zones VI/VIIa, generally recognized as Boreal/Atlantic transition.

7460 ± 150
Q-917. Red Moss, 237 to 239 cm **5510 B.C.**

2 cm slice of *Sphagnum-Eriophorum-Calluna* peat. The pollen diagram shows the beginning of the rise in *Alnus* pollen marking the end of Zone VI.

8196 ± 150
Q-918. Red Moss, 259 to 261 cm **6246 B.C.**

2 cm slice of fen peat. Pollen frequencies of *Pinus* exceed those of *Betula*. This increase is before the *Alnus* rise.

8742 ± 170
Q-919. Red Moss, 269 to 271 cm **6793 B.C.**

2 cm slice of wood peat. At a level of falling pollen frequencies of *Corylus* and rising frequencies of *Ulmus* and *Quercus*.

8790 ± 170
Q-920. Red Moss, 290 to 293 cm **6840 B.C.**

2 cm slice of wood peat. At level where rapid rise of *Corylus* pollen frequencies in a very short depth denotes Zone V/VI boundary.

8880 ± 170
Q-921. Red Moss, 296 to 298 cm **6930 B.C.**

2 cm slice of wood peat. Pollen diagram indicates the beginning of the rise of *Corylus* at this level, denoting the end of Zone V.

9456 ± 200
Q-922. Red Moss, 305 to 307 cm **7506 B.C.**

2 cm slice of fen peat. *Betula* pollen frequencies increase at Zone IV/V boundary.

9586 ± 200
Q-923. Red Moss, 310 to 312 cm **7636 B.C.**

2 cm slice of fen peat. At this point the curve of *Juniperus* is falling, indicating end of Zone IV.

9798 ± 200
Q-924. Red Moss, 320 to 322 cm **7848 B.C.**

2 cm slice of fen peat. Pollen diagram shows maximum frequencies of *Juniperus* pollen in Zone IV.

9508 ± 200
Q-925. Red Moss, 325 to 330 cm **7558 B.C.**

5 cm slice of organic lake mud, immediately above clay deposits of Zone III and marks the beginning of organic deposition at Zone III/IV boundary. Age of this sample does not fit the excellent consistency of the remainder of the series. An identical sample from a duplicate core yielded the same results for age. The sample is at the contact of clay and mud. Perhaps the lateral movement of ground water along such a contact has introduced younger carbon into the mud. Further investigations are required for this point.

Scottish Tree Stump series

Part of an investigation of the stratigraphy of horizons of tree stumps commonly found in Scottish peats (Birks, 1969). Samples were gathered from 2 main areas, the Eastern Highlands and the Galloway Hills in SW Scotland. Three sites were studied by Lewis (1905-7, 1911) who described forest and arctic plant beds in the Merrick-Kells dist. and the Eastern Highlands. Samuelson (1910) correlated Scandinavian tree layers with those in Scotland and applied the climatic sequence of Blytt and Sernander to the British Isles. Samples for pollen analysis and radiocarbon assay were coll. 1965 and 1966 by H. H. Birks and radiocarbon assays were made by V. R. Switsur.

Eastern Highland area

4425 ± 100
Q-886. Allt na Feithe Sheilich **2475 B.C.**

Birch and heather twigs form indistinct horizon at 150 cm, probably indicating a dry period on peat surface. Pine wood from an horizon 180 cm below surface was previously dated (K-1419, 6960 ± 130 B.P.). This is one of original Lewis sites of blanket peat on the Spey-Findhorn watershed at 1950 ft alt (57° 19′ N Lat, 3° 54′ W Long, Nat. Grid Ref. 28/8526).

5880 ± 100
Q-881. Loch Einich, 120 cm **3930 B.C.**

Fossil mor humus 'soil' at 120 cm forming a stratigraphic horizon between the pine stumps at this site. Alt 1650 ft (57° 05′ N Lat, 3° 48′ W Long, Nat. Grid Ref. 28/919001). Pine stump from this layer was previously dated (K-1418, 5970 ± 120 B.P.).

4150 ± 100
Q-883. Loch Einich, 80 cm **2200 B.C.**

Birch twigs from 80 cm layer.

6980 ± 100
Q-887. Coire Bog, 255 cm **5030 B.C.**

Bark from pine stump at 255 cm assoc. with ill-defined charcoal layer above *Sphagnum* peat at 215 cm. Alt 1400 ft (57° 51′ N Lat, 4° 25′ W Long, Nat. Grid. Ref. 28/582857).

6731 ± 100
Q-888. Coire Bog, 190 cm **4781 B.C.**

Birch wood from 190 cm depth contained in humified peat.

5005 ± 100
Q-889. Coire Bog, 160 cm **3055 B.C.**

Birch wood from 160 cm depth, a separate layer from that at 190 cm.

Galloway area

7471 ± 120
Q-871. Cooran Lane, 110 cm **5521 B.C.**

Pine stump from decayed, highly humified, blanket-bog peat at depth 110 cm. Alt 850 ft (55° 7′ N Lat, 4° 23′ W Long, Nat. Grid. Ref. 25/480843).

6805 ± 200
Q-873. Cooran Lane, 120 cm **4855 B.C.**

Blanket-bog peat from 120 cm corresponding to peak of *Pinus* pollen in pollen diagram.

7541 ± 120
Q-874. Cooran Lane, 140 cm **5591 B.C.**

Blanket-bog peat from 140 cm. Fluctuations in pollen curves and presence of charcoal fragments in peat suggest occurrence of a fire at this level.

7165 ± 180
Q-876. Loch Dungeon Peat, 125 cm **5215 B.C.**

Pine stump from 125 cm just beneath highly humified amorphous black layer which may be a fossil soil. Alt 1250 ft (55° 7′ N Lat, 4° 19′ W Long, Nat. Grid. Ref. 25/5284).

6787 ± 200
Q-877. Loch Dungeon Peat **4837 B.C.**

Pure organic fossil mor humus soil assoc. with Q-876 pine wood.

5080 ± 100
Q-878. Clatteringshaws Loch, 87 cm **3130 B.C.**

Pine stump at 87 cm depth in layer of wood peat. Alt 800 ft (55° 4′ N Lat, 4° 17′ W Long, Nat. Grid. Ref. 25/5477).

General Comment (H.H.B.): the dates show that the pine stumps are of different ages in the Eastern Highlands and the Galloway Hills and are of different ages within each of these areas. The relationship of the stumps to the pollen stratigraphy from each site is consistent with these results. From the available dates, and studies of local vegetational events by pollen analysis and peat stratigraphy, no climatic conclusions may be drawn from the occurrence of these pine stumps to support the Blytt-Sernander scheme of climatic periods.

II. ARCHAEOLOGIC SAMPLES

Somerset Levels series, SW England

Excavations of the prehistoric trackways of the Somerset Levels (Godwin, 1960) has been continued by J. M. Coles and his students from the Dept. of Archaeol. and Anthropol., University of Cambridge (Coles and Hibbert, 1968). The Sub-Dept. of Quaternary Research is also assoc. with the work through the participation of F. A. Hibbert who checked the peat stratigraphy and carried out pollen analyses, and through V. R. Switsur who made the radiocarbon analyses. The number of trackways discovered continues to grow and forms a veritable arterial road system between Westhay and Catcott Burtle, the oldest such system in Europe. Samples were coll. between August 1967 and September 1968 by Coles and Hibbert to obtain precise correlation between tracks in this area.

3964 ± 60
Q-908. Abbot's Track Peat **2014 B.C.**

Sphagnum-Eriophorum-Calluna peat underlying the Abbot's track, overlying layers of wood and fen peat (51° 7′ Lat, 2° 50′ W Long, Nat. Grid Ref. ST 417427). This agrees very well with wood from the track itself (Q-926).

4018 ± 80
Q-926. Abbot's Track Peg **2068 B.C.**

Wooden peg used to stabilize the track which lies in ombrogenous peat ca. 40 m W of Honeygore track (Q-909), and in a stratigraphically younger position in the peat (51° 11′ N Lat, 2° 50′ W Long, Nat. Grid Ref. ST 417427). Date agrees well with peat underlying the track (Q-908), and with other determinations of age of track (LU-298, 3940 ± 65; Gak-1950, 4040 ± 90). It does not agree, however, with our previous determination, Q-674, and we now disregard this date for technical reasons assoc. with its dating.

4570 ± 80
Q-927. Bell Track 'A' **2620 B.C.**

Birch stump rooted beneath Trackway 'A', severed during construction of the track, which should date the surface upon which it was lain (51° 11′ N Lat, 2° 50′ W Long, Nat. Grid Ref. ST 428422). Date falls between those of the Abbot's and Honeygore, and agrees with its stratigraphic position.

Q-909. Honeygore Trackway Peg **4773 ± 80**
2823 B.C.

Wooden peg from track in *Sphagnum-Eriophorum-Calluna* peat (51° 10′ N Lat, 2° 50′ W Long, Nat. Grid Ref. ST 417428), parallel to the Abbot's track but lower stratigraphically. Lund radiocarbon date for this track is 4760 ± 65 (LU-297) and our previous determination Q-431 was 4750 ± 130; they agree well but disagree with the Gakushuin date 5640 ± 120 (Gak-1939) by ca. 1600 yr.

Q-948. Morton, Fife **6735 ± 180**
4785 B.C.

Small sample of charcoal from Morton near Tayport, Fife, Scotland (56° 25′ N Lat, 2° 52′ W Long, Nat. Grid Ref. NO 467257), assoc. with hearths of Mesolithic occupation levels, in sands at depth 16 to 19 in. below grass, 8 to 11 in. below plough-disturbed soil. Sands rest on volcanic bluff overlooking Tentsmuir Sands at ca. 39′ O.D. Archaeologic program concerns investigations of earliest traces of man in Scotland. This is earliest date for Mesolithic in Scotland. Morton contains the largest known stone industry and will probably serve as a type site. Coll. 1969 by J. M. Coles, Dept. of Archaeol. and Anthropol., Univ. of Cambridge.

Q-950. Myrtos 1, Crete **3805 ± 85**
1855 B.C.

Wood charcoal (35° 00′ N Lat, 25° 36′ E Long) from 0.5 m below surface in black burnt earth in a small room with stone walls on 3 sides and filled with large pottery store jars. Myrtos settlement belongs to Early Minoan II and is on the SW coast of Crete. Date is related to destruction of the settlement. Coll. 1968 by P. Warren, Dept. of Archaeol., Univ. of Durham.

Q-953. Myrtos 2, Crete **4142 ± 80**
2192 B.C.

Wood charcoal from a further room of settlement at Myrtos lying on the natural bedrock in clayey, heavily burnt, black earth 1 m below surface. Expected archaeol. date. Coll. by P. Warren.

III. CHECK SAMPLES

Q-970. Scaleby Moss, 176.5 to 178.5 cm B **7401 ± 120**
5451 B.C.

A re-determination of Q-165 (7432 ± 350) of peat from Zone VI/VIIa boundary.

Q-971. Scaleby Moss, 178.5 to 180.5 cm B **7451 ± 120**
5501 B.C.

A re-determination of Q-167 (7361 ± 146) of a 2 cm slice of peat just below previous sample.

Q-972. Scaleby Moss, 69.5 to 71.5 cm C **10,200 ± 200**
8250 B.C.

A re-determination of Q-152 (10,160 ± 193) of a 2 cm slice of coarse detritus mud just above Zone III/IV boundary. Above samples were measured before unknown samples were undertaken to compare performance of the new apparatus with known data.

REFERENCES

Birks, H. H., 1969, Studies in the vegetational history of Scotland: Ph.D. dissert., Univ. of Cambridge.

Coles, J. M. and Hibbert, F. A., 1968, Prehistoric roads and tracks in Somerset, England: 1, Neolithic: Prehist. Soc. Proc., v. 34, p. 238-258.

Godwin, Harry, 1960, Prehistoric wooden trackways in the Somerset Levels: their construction, age, and relation to climatic change: Prehist. Soc. Proc., v. 26, p. 1-36.

Godwin, Harry and Willis, E. H., 1959, Cambridge University natural radiocarbon measurements I: Am. Jour. Sci. Radiocarbon Supp., v. 1, p. 63-75.

——— 1960, Cambridge University natural radiocarbon measurements II: Am. Jour. Sci. Radiocarbon Supp., v. 2, p. 62-72.

Godwin, Harry, Walker, Donald, and Willis, E. H., 1957, Radiocarbon dating and postglacial vegetational history: Scaleby Moss: Royal Soc. [London] Proc., ser. B, v. 147, p. 352-366.

Lewis, F. J., 1905-7, 1911, The plant remains in the Scottish peat mosses: Royal Soc. Edinburgh Trans., v. 41, p. 699-723; v. 45, p. 335-360; v. 46, p. 33-70; v. 47, p. 793-833.

Samuelson, G., 1910, Scottish peat mosses, a contribution to the knowledge of the late Quaternary vegetation and climate of the North-west Europe: Geol. Inst. Uppsala Bull., v. 10, p. 197-260.