

isotopes have maximum beta energies of 0.155, 0.542, 0.608, and 1.70 Mev, respectively. The volumes of aqueous solution employed were in the range of 25 to 100  $\mu$ l. The active filter papers were dried and then wetted with a liquid scintillator solution containing *p*-terphenyl (4.0 gm/liter) and 1,4-di-(2-(5-phenyloxazolyl))-benzene (POPOP) (0.1 gm/liter) in monoisopropylbiphenyl. The solvent was purified by washing with concentrated  $H_2SO_4$ , followed by 10-percent NaOH solution, and successive washings with pure water. It was then dried over  $CaSO_4$ , treated with chromatographic alumina, and vacuum distilled at 4 mm at 135° to 136°C.

The impregnated filter paper was placed on the surface of a Dumont 6292 photomultiplier tube, covered with aluminum foil, and counted on a scintillation counting assembly, without phototube refrigeration or anticoincidence circuitry. A linear amplifier and an integral pulse height selector, set at the lowest level commensurate with tolerable photomultiplier noise, were employed.

The data are succinctly illustrated in Fig. 1, where it can be seen that a linear dependence of counting rate on the activity of the sample is obtained. The absolute activity of the stock solution was checked and calibrated by internal liquid scintillation counting. This permitted the determination of counting efficiencies for the various isotopes under the conditions of measurement. The background counting rates were consistently in the region of 0.7 to 0.8 count per second, and the counting efficiencies, in percentage, were as follows:  $I^{131}$ , 83;  $P^{32}$ , 78;  $Na^{22}$ , 76; and  $C^{14}$ , 31.5.

The lower efficiency for  $P^{32}$  was believed due to incomplete capture of the energy in the thin layer of scintillator employed. In order to investigate the effect of thickness of scintillator solution, a series of experiments was conducted in which a petri dish was placed on the photomultiplier tube and the filter paper was suspended horizontally parallel to the tube face between a series of narrow metal rings of 1/4 inch wall thickness. With rings of varying depth the thickness of the layer of liquid scintillator above and below the filter paper could be varied. The detection efficiency for  $P^{32}$  increased with added depth of scintillator solution to a maximum of 96-percent with a volume of 3.5 ml.

This method of filter paper counting has the additional advantage of preventing possible contamination of the photomultiplier face.

The results indicate that direct filter

paper counting can be employed as a technique for rapid and reproducible measurement of small quantities of low-energy beta emitters, with good detection efficiency and minimum sample preparation, and is particularly valuable for the measurement of inorganic compounds which are not readily soluble in organic solvents.

B. LIONEL FUNT

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### Late Glacial and Postglacial Hudson Bay Sea Episode

**Abstract.** Geological investigations, archaeological studies, and radiocarbon dates indicate a similarity of events around Hudson Bay, commencing at the time Hudson Bay Basin was freed of glacier ice. The sea that then spread around Hudson Bay 7000 to 8000 years ago is here named "Tyrrell Sea." The subsequent rate of land emergence decreased exponentially.

Recent studies of Pleistocene deposits around Hudson Bay, including ice recession and marine overlap studies by Bird (1), archaeological studies by Rainey and Ralph (2), and ice recession and stratigraphic studies by Fyles (3) and by me (4, 5), suggest a correlation of events.

This region is within the central zone of the maximum Wisconsin ice sheet. It was greatly downwarped during occupation by the ice, was flooded during ice recession, and later partly emerged as upwarping progressed. The dominant marker in these events is the marine

submergence, to which the name "Tyrrell Sea" is here given.

The Tyrrell Sea reached its maximum extent 7000 to 8000 years ago, as indicated by radiocarbon ages obtained on shells collected from near the highest strand lines west and south of the bay. The age of  $6975 \pm 250$  years was obtained on shells from west of Hudson Bay (4) (site 1 in Fig. 1), and south of the bay ages of  $7875 \pm 200$  and  $7280 \pm 50$  years were obtained on shells collected by O. L. Hughes from sites 2 and 3 in Fig. 1 (the various laboratories engaged in this work are listed in the figure legend). Dates are not yet available for the east coast of Hudson Bay. Comparative ages on other Pleistocene seas outside of the central zone of the maximum Wisconsin glaciation are: about 10,000 to 11,000 years before the present (B.P.) for the Champlain Sea episode (6) and 13,325 years for the marine overlap along the Atlantic Coast, near Saint John, New Brunswick [dating index I (GSC) 7]. The latter date is on shells I collected from beds of marine clay which were overlain by deltaic gravels.

The advance of the Tyrrell Sea into the Hudson basin shaped the direction of the last ice recession. These shifts of glacier flow are recorded both west and east of Hudson Bay in the distribution of erratics and the orientations of drumlins and striations (4, 5). The former positions of the ice-sea contacts are recorded in distinctive drift ridges, termed by me straight-ridged minor moraines for the region west of the bay (4) and washboard moraines for the region east of the bay (5). I have since studied the classical area of washboard moraines in the Chibougamau region of Quebec (7), and they all appear to have had a similar origin. These shifts of flow and washboard moraines indicate similar ice-sea conditions both west and east of the bay.

Upwarping of the land began upon removal of the load of the ice sheet, and caused a regression of the Tyrrell Sea. Radiocarbon dates on shells, wood, and bones collected from the marine deposits at known elevations around Hudson Bay give information on the rates of this land emergence. The highest shore lines, about 800 to 900 feet above present sea level, are recorded east of Hudson Bay (5), in contrast to about 400- to 600-foot elevations west of the bay (3, 4). This difference in elevation is due either to greater rebound east of Hudson Bay, where the ice sheet had been thicker, or to greater, unrecorded uplift having taken place west of Hudson Bay before the highest shore lines were formed. The information on emergence is summar-

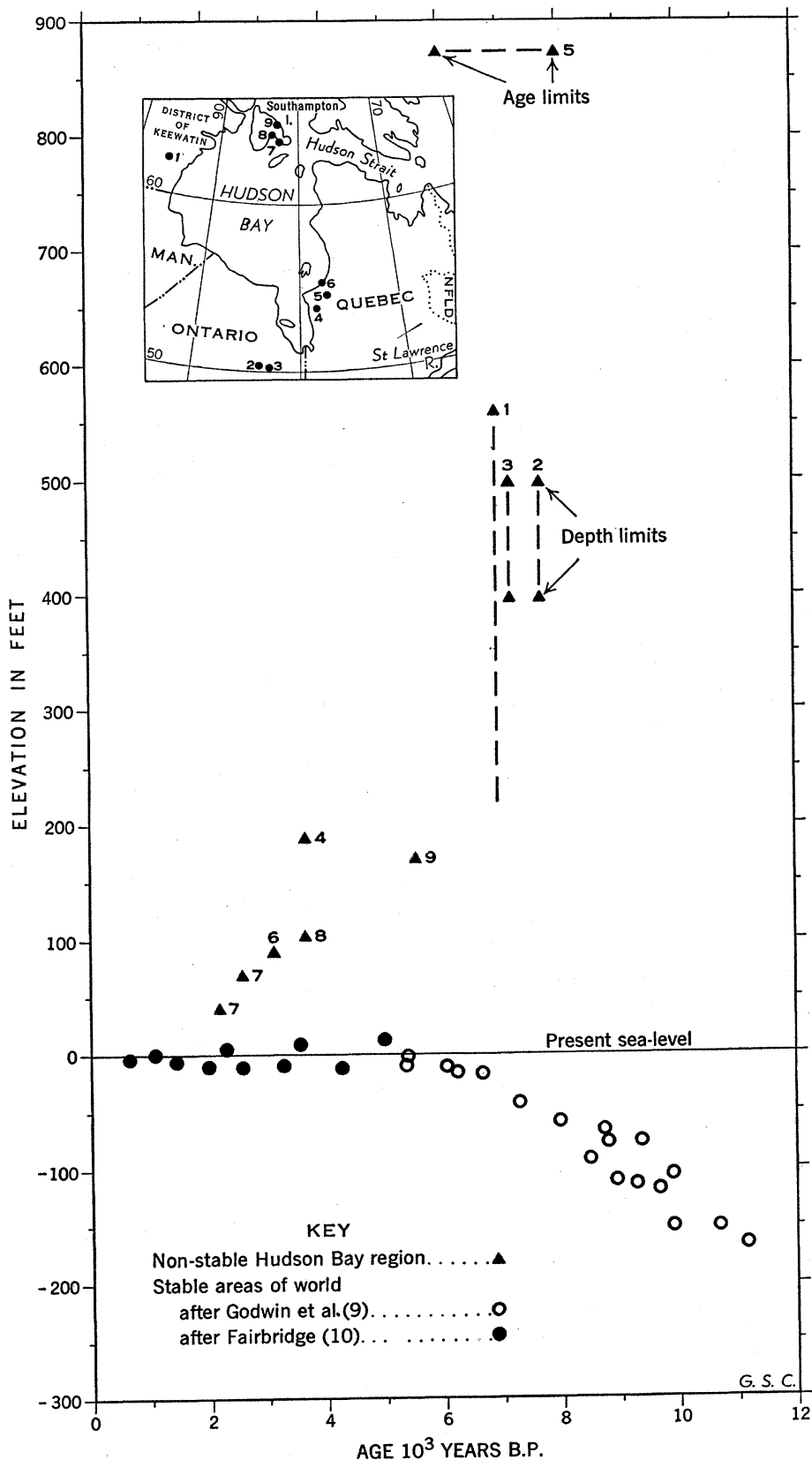


Fig. 1. Radiocarbon ages relative to elevations above and below present sea level (index map inset). Site 1, carbon dating index I (GSC) 8, shells (4). Site 2, I (GSC) 14, shells. Site 3, Gro. 1698, shells. Site 4, L433A, wood (5). Site 5, estimated age 6000 to 8000 yr. Site 6, L441A, wood (5). Site 7, P76, P77, burned bone (2). Site 8, S12, shells (8). Site 9, S13, shells (8). [Dating stations referred to above: I (GSC), Isotopes (Geological Survey of Canada); Gro., Groningen; L, Lamont; S, University of Saskatchewan; P, University of Pennsylvania.]

ized in Fig. 1, and a comparative curve is shown for changes of sea level through postglacial time in the stable areas of the world. The rate of emergence around Hudson Bay follows an exponential curve with an initial rapid uplift of the order of 20 feet per century, and later a much decreased rate of the order of 1 to 3 feet per century. The samples dated are not all equally reliable, for they are of different materials from many regions, and correlation of material to a stand of the sea cannot be precise. Hence, the graph gives only the relative rates of emergence.

The similarity of events around Hudson Bay is also recorded in a section through the soil strata. The composite section valid for either side of the bay has bedrock at the base, overlain by glacial till and sand, then by marine—usually fossiliferous—clay, silt, and sand, and then by beds of organic, alluvial, or dune deposits of peat and sand. Lake beds can be expected below the marine or glacial deposits south of Hudson Bay. In the Fort George—Great Whale region the many sections I examined (5) show thick beds of dark, odoriferous clay with shells, overlain by thick beds of stony silt with shells and wood, and with beds of alluvial sand overlying the silt. A bore hole at Fort George traversed 15 feet of alluvial sand, then 185 feet of the dark, odoriferous clay before encountering bedrock.

The marine submergence has been shown to mark a series of events around Hudson Bay. It is here proposed that the name "Tyrrell Sea" be given to that late glacial and postglacial sea in the Hudson Bay region, after the explorer and geologist Joseph Burr Tyrrell (1858–1957), who was one of the first, if not the first, to describe and map shore lines related to this submergence. This sea would include Hudson Bay and all the surrounding land that was submerged at the maximum extent of the postglacial marine submergence, in Quebec, Ontario, Manitoba, and Keewatin northward to and including Wager Bay and the islands of Southampton, Coats, and Mansel. The Tyrrell Sea reached its maximum expanse 7000 to 8000 years ago, and Hudson Bay is its modern remnant.

The features and events described for this region are remarkably similar to those described for the central zone of the maximum Scandinavian ice sheet, including rates of upwarping calculated by Niskanen (11) and washboard moraines reported by Hoppe (12) (13).

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## Colloidal Silica as a Standard for Measuring Absolute Fluorescence Yield

**Abstract.** The use of colloidal silica as a standard for fluorescence efficiency measurements is proposed. Its advantages over glycogen as a standard are availability, purity, and stability. Absolute fluorescence yields are reported for a number of substances and compared with values in the literature.

Most methods for determining the absolute quantum yield of fluorescence involve either evaluation of the absolute geometry of the apparatus or compensation for it by comparison with a standard scatterer. The latter is usually accomplished by comparing emission from fluorescent solutions with radiation scattered by a magnesium oxide plate, under conditions of identical geometry. Both relative-scattering methods and absolute-geometry methods are tedious and suffer from poor reproducibility (generally 20 percent relative).

Recently, Weber and Teale (1) published a novel method for determining

absolute quantum yields of fluorescence. Their method was based on a comparison of the radiation emitted by fluorescent solutions with that scattered by a solution of macromolecules, attenuating the incident radiation to the same extent. The macromolecules behave as pure dipolar scatterers of the incident radiation, and after correction for polarization of the scattered radiation, are equivalent to a material of unit quantum efficiency. By comparison of fluorescent solutions with solutions of the standard scatterer, under identical conditions, the following equation can be derived for the quantum efficiency:

$$q = \frac{[dF/dE]_{\lambda_0} [3 + P_r] f(\lambda_0)}{[dS/dE]_{\lambda_0} [3 + P_s] f(\Delta\lambda)} \quad (1)$$

where  $dF/dE$  is the slope of a plot of fluorescent intensity against absorbance for the compound under investigation,  $dS/dE$  is the slope of a plot of intensity of scattered radiation against apparent absorbance for the standard scatterer,  $P_r$  is the polarization of fluorescence,  $P_s$  is the polarization of the scattered radiation, and  $f(\lambda_0)/f(\Delta\lambda)$  is a correction factor for the difference in detector response to the wavelengths of the scattered radiation and the fluorescent radiation. Thus, the only experimental data necessary to determine fluorescence efficiency are plots of emission versus absorbance for the compound under investigation and the standard scattering material. By using an experimental apparatus not much different from a simple fluorometer, it was possible for Weber and Teale to obtain quantum yields reproducible to about 7 percent.

The standard scattering material used by Weber and Teale was an aqueous solution of glycogen. Although this material gave reproducible quantum yields, we felt that it was not generally desirable as a standard scatterer because of three inherent disadvantages: (i) the material is not readily available in pure form; (ii) since glycogen is naturally occurring, contamination by small amounts of impurities is possible; (iii)

the solutions are not stable over a long period of time. The purpose of the present investigation was to find an acceptable substitute for glycogen that is readily available, free from possible contamination, and stable. After a survey of several possible materials, we chose a suspension of colloidal silica in water, sold under the trade name of Ludox (2). This material is completely satisfactory in terms of the above criteria, and it gives quantum yields reproducible to about 7 percent relative, agreeing with the values reported by Weber and Teale to within 0.02 quantum yield, on the average.

The apparatus used was essentially that of Weber and Teale with the following minor modifications. The source of radiation was an AH-6 mercury arc. The 3650 and 3130 line groups were isolated with filters as described by Kasha (3). The detector in all instances was an RCA 6217 photomultiplier tube, with an integrating screen of  $10^{-3}$  M rhodamine B in ethylene glycol. A Heathkit "Multimeter" was used to measure the photocurrent.

Ludox, the radiation-scattering medium used for this work, is colloidal silica (light-scattering grade GC-3414-.85). The molecular weight of this material compared favorably with the molecular weight of the glycogen used by Weber and Teale ( $1$  to  $2 \times 10^6$  and  $2$  to  $9 \times 10^6$ , respectively). It had a uniform spherical particle size of  $10$  to  $15$  m $\mu$  (diameter). A plot of apparent absorbance against reciprocal fourth power of the wavelength gave a straight line.

Baker reagent-grade benzene and U.S.P. ethanol were used throughout. Phillips Petroleum research-grade hexane was used. The integrating screen used Allied Chemical and Dye XH-P grade ethylene glycol (synthetic and non-fluorescent).

Anthracene (Eastman Special Grade) gave a violet fluorescence and was used without further purification. Naphthalene (Eastman White-Label) was purified by distillation and subsequent recrystallization from alcohol. Fluorescein (Eastman Tech.) was acetylated and recrystallized from alcohol until it was colorless. Pure fluorescein was produced by saponification of the purified acetate. Eosin (Eastman Tech.) was purified in a manner similar to fluorescein except that the acetate was recrystallized from benzene. Acriflavin (National Aniline High-grade) was dissolved in bicarbonate solution and precipitated as the hydrobromide. DuPont technical Koch acid (1-naphthol-3,6,8-trisulfonic acid), sodium salt, was recrystallized four times from 10-percent sodium chloride solution.

Table 1. Comparison of quantum yield values.

| Compound               | Solvent    | Quantum yield |                 |                              |
|------------------------|------------|---------------|-----------------|------------------------------|
|                        |            | This report   | Weber and Teale | Other works                  |
| Acriflavin             | Water      | 0.56          | 0.54            | 0.40 (5)                     |
| Anthracene             | Benzene    | 0.31          | 0.29            | 0.24 (6)                     |
| Anthracene             | Ethanol    | 0.30          | 0.30            |                              |
| Naphthalene            | Hexane     | 0.13          | 0.10            |                              |
| Naphthalene            | Ethanol    | 0.13          | 0.12            |                              |
| Fluorescein            | 0.1 N NaOH | 0.93          | 0.93            | 0.72 (5), 0.80 (7), 0.79 (8) |
| Eosin                  | 0.1 N NaOH | 0.20          | 0.19            | 0.15 (7)                     |
| Koch acid, sodium salt | Water      | 0.14          | 0.15            |                              |