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PHYSICAL RESEARCH LABORATORY (CHEMISTRY) RADIOCARBON DATE LIST I

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INTRODUCTION

We present here radiocarbon dates obtained using a liquid scintillation system installed at the Physical Research Laboratory (PRL), which has been in operation for the past three years for ^{14}C measurements of oceanographic and geochemical samples from India.

We follow the procedure of Noakes *et al.* (1965) to synthesize benzene from the samples. This involves four major steps: 1) liberation of CO_2 from the samples by either dry combustion or hydrolysis; 2) conversion of CO_2 to Li_2C_2 at ~700°C; 3) hydrolysis of Li_2C_2 to acetylene; and 4) trimerization of acetylene to C_6H_6 on activated alumina-coated vanadium catalyst. The sample benzene (~1.5–2.5 g) is transferred to a 7-ml low-potassium glass vial, made to 3 ml by weight (2.637 g) by adding scintillation-grade dead benzene. To this we add 0.5 ml of scintillation cocktail [42 g liter^{-1} PPO + 0.7 g liter^{-1} POPOP in benzene]. The benzene samples are counted using a Packard Tri-Carb® 2250CA liquid scintillation spectrometer in low-level mode. To reduce the background further, we use a Pico-XL™ plastic vial holder to surround the glass vial containing the sample benzene (Noakes and Valenta 1989). The samples are generally counted for 30 cycles of 100 min each.

Figure 1 shows the background count rate in the 11–98 keV region as determined by counting benzene synthesized from Makrana marble belonging to the Precambrian Railo formation in Rajasthan, India. Most of the marble blank count rates center around a value of 1.15 cpm. The mean count rate of marble blanks (excluding the four runs that had count rates in the range of 1.37–1.58 cpm, circled in Fig. 1) is 1.154 ± .009 cpm. This count rate is used as background in our calculation. Also given in Figure 1 are count rates for scintillation-grade benzene, anthracite and IAEA ^{14}C quality assurance material C-1. All these samples also yield count rates that are indistinguishable from the marble blank within errors.

The mean count rate of NBS oxalic acid standard batch SRM-4990C (OX-II) during 1991–1993 is 27.911 ± .070 cpm for 3 ml benzene. This yields a counting efficiency of 63% in the 11–98 keV region. We calculated $\Delta^{14}C$ values following Stuiver and Polach (1977). The $\delta^{13}C$ of some of the CO_2 samples was measured in our laboratory. For corals and tree rings the $\Delta^{14}C$ values are corrected for decay to the year of growth. Age calculations are based on ^{14}C half-life of 5730 ± 40 yr.

As an intercalibration exercise, we measured ^{14}C in IAEA quality assurance materials C-1, C-2, C-3, C-4 and C-5 (Table 1) and in NBS oxalic acid standard SRM-4990 (OX I). The mean $\delta^{13}C$ normalized count rate of OX II/OX I, based on three repeat measurements, is 1.268 ± .004, consistent with count rates published in the literature (Mann 1983). The $\delta^{13}C$ of OX II and OX I were taken as −17.3‰ and −19‰, respectively. The OX II was normalized to a $\delta^{13}C$ value of −25‰ and OX I to −19‰ (Stuiver and Polach 1977). In addition, we carried out repeat measurements of several samples, the results of which agree well.

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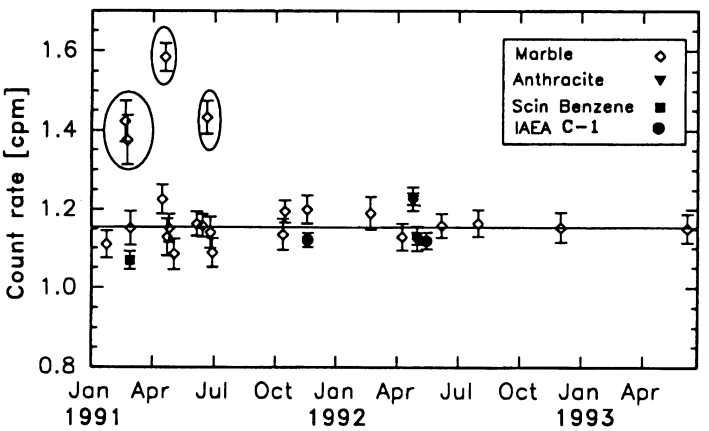

Fig. 1. Marble and other blank sample count rate (in 11–98 keV region). The mean blank count rate (excluding the four circled ones) is 1.154 ± 0.0088 cpm (horizontal line).

TABLE 1. IAEA Intercalibration Samples

		$\delta^{13}C$ (‰)		^{14}C pMC (%)	
Code	Source	IAEA	CH	IAEA	CH
CH-129	IAEA C-1	2.42 ± 0.38	2.76 ± 0.1	0.00 ± 0.02	–0.32 ± 0.20
CH-150	IAEA C-4	–23.96 ± 0.62	–25.77 ± 0.1	0.20–0.44	–0.17 ± 0.11
CH-151	IAEA C-5	–25.49 ± 0.72	–26.50 ± 0.1	23.05 ± 0.02	22.22 ± 0.20
CH-154	IAEA C-5	–25.49 ± 0.72	–25.40 ± 0.1	123.05 ± 0.02	23.06 ± 0.18
CH-122	IAEA C-2	– 8.25 ± 0.31	– 7.00 ± 0.1	41.14 ± 0.03	39.05 ± 0.33
CH-152	IAEA C-3	–24.91 ± 0.49	–26.10 ± 0.1	129.41 ± 0.06	128.56 ± 0.50
CH-153	IAEA C-3	–24.91 ± 0.49	–24.60 ± 0.1	129.41 ± 0.06	128.18 ± 0.50

RESULTS OF REPEAT MEASUREMENTS

Seawater from Pirotan Island, Gulf of Kutch. Surface seawater from Pirotan Island (22°36'N, 70°E) collected in 1993, located within a few kilometers of coral (Gulf of Kutch) site, for study of surface seawater ^{14}C activity.

CH-174. Surface Seawater # 1 **Δ = 49 ± 8‰**

CH-175. Surface Seawater # 2 **Δ = 43 ± 6‰**

$\delta^{13}C$ = –0.18‰

Charcoal (PRL # 1382). Collected from Mahidpur, Ujjain District in Madhya Pradesh (23°17′N, 75°28′E) from Trench MDP.TR.I at a depth of 221 cm by Rahmat Ali of Vikram University, Ujjain. Provided by S. Kusumgar. Est. $\delta^{13}C = -25‰$.

CH-145. Charcoal PRL # 1382 $\Delta = -341 \pm 7‰$
CH-148. Charcoal PRL # 1382 $\Delta = -364 \pm 4‰$

Groundwater Sample. Collected from the laboratory campus, Ahmedabad (23°N, 72°40′E). Well depth = 200 m. Est. $\delta^{13}C = 0‰$.

CH-188. Groundwater from PRL Campus $\Delta = -631 \pm 3‰$
CH-189. Groundwater from PRL Campus $\Delta = -630 \pm 3‰$

Amini Coral. Coral sample collected in 1988 from Amini Island, Lakshadweep Archipelago (10°N, 73°E) by R. Ramesh and S. Chakraborty for stable isotopic measurement to calibrate coral $\delta^{18}O$ against sea-surface temperature. Est. $\delta^{13}C = 0‰$.

CH-75. Amini Coral $\Delta = 56 \pm 7‰$
CH-89. Amini Coral $\Delta = 62 \pm 7‰$
CH-140. Amini Coral $\Delta = 36 \pm 7‰$
CH-141. Amini Coral $\Delta = 47 \pm 5‰$

Tree Ring. Sample collected by R. Ramesh from Gulmarg Forest compartment 63 near Tangmarh (34°04′N, 74°25′E) from a silver fir tree *(Abies pindrow)*.

CH-158. Silver Fir Tree $\Delta = -38 \pm 5‰$
$\delta^{13}C = -24.6‰$

CH-159. Silver Fir Tree $\Delta = -31 \pm 5‰$
$\delta^{13}C = -25.2‰$

Oceanographic and Geochemical Samples

Coral

We report ^{14}C time series data on a coral, *Favia speciosa* (GK), collected in June 1990 from Pirotan Island, Gulf of Kutch (22°36′N, 70°E), by S. Chakraborty and R. Ramesh. The coral was subsampled for ^{14}C assay based on X-radiography banding. We measured $\delta^{13}C$ on the coral $CaCO_3$ and used the values averaged over each set of sampled bands for $\Delta^{14}C$ calculation. $\Delta^{14}C$ values reported are decay-corrected to the average year of growth. The ^{14}C measurements were made to determine the air-sea CO_2 exchange rate in this area (Chakraborty 1993; Chakraborty *et al.* 1994). These measurements are part of our study on isotopic and trace element records in corals from the Indian coast (Chakraborty 1993).

CH-66. Pirotan Island Coral GK-Bl6 $\Delta = 55 \pm 7‰$
Coral bands 40–42; growth years 1988–1990. $\delta^{13}C = 0.66‰$

CH-67. Pirotan Island Coral GK-B15 $\Delta = 71 \pm 6‰$
Coral bands 36–39; growth years 1984–1987. $\delta^{13}C = 0.56‰$

CH-68. Pirotan Island Coral GK-Bl4 $\Delta = 96 \pm 7‰$
Coral bands 35; growth year 1983. $\delta^{13}C = -0.12‰$

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CH-69. Pirotan Island Coral GK-B13 — **Δ = 99 ± 7‰**
Coral bands 33–34; growth years 1981–1982. — $\delta^{13}C$ = –0.26‰

CH-76. Pirotan Island Coral GK-B12 — **Δ = 102 ± 7‰**
Coral bands 30–32; growth years 1978–1980. — $\delta^{13}C$ = –0.15‰

CH-77. Pirotan Island Coral GK-B11 — **Δ = 122 ± 6‰**
Coral bands 28–29; growth years 1976–1977. — $\delta^{13}C$ = 0.26‰

CH-78. Pirotan Island Coral GK-B10 — **Δ = 146 ± 7‰**
Coral bands 25–27; growth years 1973–1975. — $\delta^{13}C$ = 0.11‰

CH-80. Pirotan Island Coral GK-B9 — **Δ = 131 ± 7‰**
Coral bands 23–24; growth years 1971–1972. — $\delta^{13}C$ = –0.35‰

CH-81. Pirotan Island Coral GK-B8 — **Δ = 156 ± 7‰**
Coral bands 21–22; growth years 1969–1970. — $\delta^{13}C$ = 0.19‰

CH-82. Pirotan Island Coral GK-B7 — **Δ = 170 ± 6‰**
Coral bands 20; growth year 1968. — $\delta^{13}C$ = –0.06‰

CH-83. Pirotan Island Coral GK-B6 — **Δ = 147 ± 8‰**
Coral bands 18–19; growth years 1966–1967. — $\delta^{13}C$ = –0.39‰

CH-84. Pirotan Island Coral GK-BS — **Δ = 120 ± 7‰**
Coral bands 16–17; growth years 1964–1965. — $\delta^{13}C$ = –0.06‰

CH-85. Pirotan Island Coral GK-B4 — **Δ = 57 ± 7‰**
Coral bands 13–15; growth years 1961–1963. — $\delta^{13}C$ = –0.34‰

CH-86. Pirotan Island Coral GK-B3 — **Δ = 1 ± 6‰**
Coral bands 7–12; growth years 1955–1960. — $\delta^{13}C$ = –0.25‰

CH-87. Pirotan Island Coral GK-B2 — **Δ = –53 ± 6‰**
Coral bands 4–6; growth years 1952–1954. — $\delta^{13}C$ = –0.65‰

CH-88. Pirotan Island Coral GK-B1 — **Δ = –60 ± 5‰**
Coral bands 1–3; growth years 1949–1951. — $\delta^{13}C$ = –0.79‰

TREE-RING SAMPLES

We list below ^{14}C measurements from the annual rings of a teak tree (*Tectona grandis)* from Thane (19°14′N, 73°24′E) near Bombay, India. G. B. Pant (Pant and Borgaonkar 1983) provided the samples and their chronology. The individual rings were pulverized using a Wiley mill and pretreated following the method of Cain and Suess (1976). Briefly, the wood powder was soaked first in acetone for ~3 h (with intermittent ultrasonic agitation), then in 5% NaOH for 6–8 h, and finally in 1% HCl for ~6 h to remove resinous and oily substances. The sample was thoroughly washed with distilled water, dried and used for ^{14}C measurements. The $\delta^{13}C$ of the samples was not measured; however, it was measured in the cellulose of an adjacent teak tree (Ramesh, Bhattacharya and Pant 1989). The values ranged between –25 and –26‰. We used a value of –25‰ in all samples for calculating $\Delta^{14}C$. As with coral, ^{14}C data on tree rings are used to determine the air-sea exchange rate of CO_2 in the Gulf of Kutch (Chakraborty 1993; Chakraborty *et al.* 1994).

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CH-171. Tree Ring Th-1 **Δ = 260 ± 7‰**
Growth years 1979–1980.

CH-172. Tree Ring Th-2 **Δ = 299 ± 6‰**
Growth year 1978.

CH-173. Tree Ring Th-3 **Δ = 311 ± 6‰**
Growth year 1977.

CH-176. Tree Ring Th-4 **Δ = 341 ± 7‰**
Growth year 1976.

CH-177. Tree Ring Th-5 **Δ = 354 ± 6‰**
Growth year 1975.

CH-178. Tree Ring Th-6 **Δ = 420 ± 7‰**
Growth year 1974.

CH-179. Tree Ring Th-7 **Δ = 400 ± 7‰**
Growth year 1973.

CH-180. Tree Ring Th-8 **Δ = 434 ± 7‰**
Growth years 1971–1972.

CH-181. Tree Ring Th-9 **Δ = 476 ± 7‰**
Growth years 1969–1970.

CH-182. Tree Ring Th-10 **Δ = 534 ± 7‰**
Growth year 1968.

CH-183. Tree Ring Th-11 **Δ = 560 ± 7‰**
Growth year 1967.

CH-184. Tree Ring Th-12 **Δ = 587 ± 8‰**
Growth year 1966.

CH-185. Tree Ring Th-13 **Δ = 630 ± 8‰**
Growth years 1964–1965.

CH-186. Tree Ring Th-14 **Δ = 565 ± 8‰**
Growth year 1963.

CH-187. Tree Ring Th-15 **Δ = 338 ± 6‰**
Growth year 1962.

CH-190. Tree Ring Th-16 **Δ = 260 ± 6‰**
Growth year 1961.

CH-191. Tree Ring Th-17 **Δ = 238 ± 6‰**
Growth year 1960.

GEOLOGICAL SAMPLES

R. K. Pant and Navin Juyal collected oyster samples from the Saurashtra coastline to study sea-level changes (Juyal *et al.* 1994). The samples were cleaned mechanically to remove adhering impurities

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and soaked in 30% H_2O_2 for 2 days to remove organic matter. We report ^{14}C ages of the samples below.

CH-96. Chikasa Gosa Reef Oyster **>30,000**
Collected from Chikasa, Saurashtra (21°45′N, 70°30′E) at 1 m asl.

CH-97. Chikasa Gosa Reef Oyster **>30,000**
Collected from Chikasa at 1 m asl.

CH-98. Chikhli Oyster **>30,000**
Collected from Chikhli (20°48′N, 70°52′E) at 4 m asl.

CH-99. Patan Bridge Oyster **>30,000**
Collected from Patan Bridge over the Hiren River (20°55′N, 70°30′E) at 12 m asl.

CH-101. Babarkot Oyster **710 ± 40**
Collected from Babarkot (20°52′N, 71°25′E) at 8 m asl.

CH-102. Diu Oyster **3450 ± 45**
Collected from Diu (20°44′N, 70°55′E) at 2 m asl.

CH-103. Jafarabad Oyster **5460 ± 50**
Collected from Jafarabad (20°52′N, 71°25′E) at 3 m asl.

CH-108. Rohisa Oyster **4170 ± 50**
Collected from Rohisa (20°50′N, 71°15′E) at 2 m asl.

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