OLD WATER IN THE OCEAN:

THE ANTARCTIC RADIOCARBON RESERVOIR

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Radiocarbon in the Southern Ocean is dominated by the upwelling of "old" deep water from the northern hemisphere and, to a lesser extent, by "new" surface water which interacts with the atmosphere south of the Antarctic Convergence (Pickard and Emery 1982, Broecker 1987). This upwelling at the Antarctic Divergence enhances organic productivity and creates the oldest surface waters in the ocean, producing marine species with apparent radiocarbon ages that exceed a thousand years (Gordon and Harkness 1992).

During the 20th century, however, the transfer of radiocarbon in this highly productive marine ecosystem has been altered by the atmospheric input of radiocarbon from fossil fuel combustion (Suess 1955) and nuclear explosions (Broecker and Walton 1959). To determine the magnitude of these anthropogenic impacts, calcareous marine species which were collected alive prior to 1945 were obtained from museum collections and compared to modern samples. Analyses of these calcareous marine species were used to produce the first pre-bomb radiocarbon reservoir correction from the Southern Ocean based on biogenic structures that precipitate in isotopic equilibrium with seawater, as indicated by $\delta^{13}C$ values around zero. These data indicate that radiocarbon age of surface seawater around Antarctica decreased nearly 500 years because of nuclear explosions in the atmosphere and that the pre-bomb radiocarbon reservoir correction in the Southern Ocean is around 1300 years (Berkman and Forman 1996).

However, because of the scarcity of pre-bomb shells which were radiocarbon dated, there are limitations to applying the 1300-year reservoir correction in the circumpolar Southern Ocean. To address this limitation with the Antarctic marine radiocarbon reservoir correction from Berkman and Forman (1996), we have begun identifying additional pre-bomb biogenic carbonates which were collected alive from around Antarctica. Samples from an Antarctic scallop (*Adamussium colbecki*) and clam (*Laternula elliptica*), collected alive during Robert Falcon Scott's *'Terra Nova'* expedition to McMurdo Sound from 1910-12, were obtained from the British Museum (Table 1). Radiocarbon age of the *Laternula* sample, which still had tissue remaining and was definitely living near the time of collection, complements earlier measurements. However, without additional data it is inappropriate to even speculate on the discrepancy with the *Adamussium* sample, which was more than 600 years older than any of the previous pre-bomb biogenic carbonates which were radiocarbon

dated from around Antarctica. These measurements reinforce the need for canvasing the museums of the world to identify and radiocarbon-date biogenic carbonates which were collected alive, from around the continent before 1945 - during the 'historic age' of Antarctic exploration.

Calcareous marine fossils (which are widespread, abundant and well-preserved from the circum-Antarctica region) are critical for assessing the timing of climate, ice-sheet and sea-level impacts during the Late Quaternary and Holocene (Berkman 1992, Berkman et al. 1998). Further work is required to evaluate regional variations in the Antarctic marine radiocarbon reservoir to accurately constrain the ages of these fossils and accurately linking phenomena in the Antarctic coastal zone to global changes which have been observed from Marine Isotope Stage 3 (Hays et al. 1976) to the present.

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REFERENCES

Berkman, P.A. 1992. Circumpolar distribution of Holocene marine fossils in Antarctic beaches. *Quatern. Res.* 37:256-260.

Berkman, P.A. and Forman, S.L. 1996. Pre-bomb radiocarbon and the reservoir correction for calcareous marine species in the Southern Ocean. *Geophys. Res. Lett.* 23:633-636.

Berkman, P.A., Andrews, J.T., Björck, S., Colhoun, E.A., Emslie, S.D. Goodwin, I., Hall, B.L., Hart, C.P., Hirakawa, K., Igarashi, A., Ingólfsson, O., López-Martínez, J., Lyons, W.B., Mabin, M.C.G., Quilty, P.G., Taviani, M. and Yoshida, Y. 1998. Circum-Antarctic coastal environmental variability during the Late Quaternary recorded in emerged marine deposits. *Antarc. Sci.* 10:345-362.

Broecker, W.S. 1987. The biggest chill. *Nat. Hist.* (October):74-81.

Broecker, W.S. and Walton, A.A. 1959. Radiocarbon from nuclear tests. *Science* 130:309-314.

Gordon, J.E. and Harkness, D.D. 1992. Magnitude and geographic variation of the radiocarbon content in Antarctic marine life: implications for reservoir corrections in radiocarbon dating. *Quatern. Sci. Rev.* 11:697-708.

Hays, J.D., Imbrie, J. and Shackleton, N.J. 1976. Variations in the Earth's orbit: pacemaker of the ice ages. *Science* 194:1121-1132.

Pickard, G.L. and Emery, W.J. 1982. *Descriptive Physical Oceanography: An Introduction.* Pergamon Press, New York.

TABLE 1

PRE-BOMB RADIOCARBON CONTENT OF LIVING CALCAREOUS MARINE SPECIES FROM MCMURDO SOUND, ANTARCTICA, WHICH WERE COLLECTED DURING THE 1910-12 *'TERRA NOVA'* EXPEDITION LED BY ROBERT FALCON SCOTT**

LAB NUMBER	SUESS	SPECIES#	LATITUDE	LONGITUDE YEAR	COLLECTION (yr BP)	^{14}C-AGE& (‰)	Δ^{13}C (‰)	Δ^{14}C** EFFECT** (‰)
AA 28855-O	Le	78°30'S	165°00'W	1911	1565 ± 45	-23.40	-177.0 ± 5.6	-2.7
AA 28855-S	Le	78°30'S	165°00'W	1911	1375 ± 40	+1.61	-157.3 ± 5.0	-2.7
AA 28856	Ac	78°30'S	165°00'W	1911	2155 ± 45	+1.15	-235.3 ± 5.6	-2.7

** Comparisons to four pre-bomb biogenic carbonates which were previously analyzed based on methods in Berkman and Forman (1996).

Ac *Adamussium colbecki*, **Le** *Laternula elliptica* (O-tissue and S-shell materials).

& Conventional laboratory-reported ^{14}C-age ± 1 σ based on the Libby half-life of 5568 years, with reference to 1950 and corrected to δ^{13}C of -25‰