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The 2009 recipient of the Brady Medal: Dr Thomas M. Cronin

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Fig. 1. Tom Cronin.

Dr Thomas Cronin is a worthy recipient of the Brady Medal, not simply for his outstanding achievements in the application of micropalaeontology to palaeoceanography, palaeoclimatology and evolutionary studies but because, like the Brady brothers, he has worked on both ostracods and foraminifera, fossil and living.

Tom Cronin was born in 1950 in the Bronx, New York City, USA and first became interested in geology when attending a freshman general course at Colgate University taught by Bob Linsley and Jim McClelland – in Tom's words: 'two great educators'. He graduated with a BA in Geology from Colgate in 1972 and then carried out postgraduate work at Harvard University leading to a MA (1974) and PhD (1977) in Geology. After graduation he joined the US Geological Survey and is currently a senior scientist with the Eastern Geology and Climate Science Center, US Geological Survey in Reston, Virginia. There his present role is Project Chief for the 'Abrupt Climate Change: Eastern US' project and he also contributes to the 'South Florida Ecosystem Project'.

Tom's doctoral work concerned both foraminifera and ostracods of the Pleistocene of the north-eastern seaboard of North America, but it is as an ostracod worker that he is best known, especially for deep sea fossil and living faunas. His publications portray a developing pattern of research interest and achievement from a relatively classical doctoral treatment of shallow marine Pleistocene ostracods and foraminifera and their environmental significance, via early marine palaeoclimate reconstruction work in the Neogene-Quaternary of the US eastern seaboard, to the innovative interpretation of deep sea palaeoceanographic parameters using ostracods and other proxies. The following brief and selective review should serve to give a flavour of Tom's outstanding scientific contributions over the past three and half decades as witnessed by a record of more than 160 publications.

At the end of the last glaciation, as the Laurentide Ice Sheet retreated, marine waters from the Atlantic inundated the isostatically depressed region of the St Lawrence lowlands to form the Champlain Sea. Tom Cronin's PhD research used ostracods and foraminifera to elucidate the complex salinity and temperature history of this inland sea, reflecting the interplay of post-glacial climatic warming, eustatic sea-level rise and isostatic uplift, which he expounded in a series of publications (Cronin, 1976a, 1976b, 1977a, 1977b, 1979a, 1979b, 1981). Subsequently, increasing attention to freshwater forcing by meltwater pulses as a cause of abrupt changes in North Atlantic thermohaline circulation and climate led to a renewed interest in the salinity record of the Champlain Sea. Using benthonic foraminifera and ostracods as palaeosalinity proxies, Cronin *et al.* (2008a) determined that a sharp decrease in Champlain Sea salinity around 11.4 – 11.2 ka could best be explained as the result of a rapid influx of freshwater from glacial Lake Algonquin, coincident with the Preboreal Oscillation, a climatic cooling episode.

Tom's contributions to the documentation of Cenozoic to Recent marine ostracod faunas from many parts of the world have advanced our knowledge and understanding of the distribution of ostracod taxa in the oceans and paved the way for applications in palaeoceanography, palaeoclimatology and evolutionary studies. Examples include descriptions and applications of ostracod faunas from the Eocene of Egypt (Cronin & Khalifa, 1979) and Atlantic DSDP sites (Cronin & Compton-Gooding, 1987), the Neogene of Enewetak Atoll (Cronin *et al.*, 1991) and Iceland (Cronin, 1991), the Plio-Pleistocene of Japan (Cronin & Ikeya, 1987; Ikeya & Cronin, 1993), the Quaternary of the Arctic (Cronin *et al.*, 1994; Jones *et al.*, 1999; Cronin *et al.*, 2008b) and the Holocene of the Black Sea (Ivanova *et al.*, 2007). In the Arctic, Cronin *et al.* (1994) showed the species composition of ostracod assemblages to be related to the characteristics of water masses such as Arctic Ocean Deep Water and Greenland Sea Deep Water, and demonstrated their utility as proxies for circulation changes in the Late Pleistocene and Holocene. A recent investigation of deep North Atlantic ostracod faunas over the past 20,000 years revealed major collapses of benthonic communities coincident with abrupt changes in deep-water circulation, probably linked to changes in surface productivity and demonstrating the sensitivity of deep-sea ecosystems to benthonic habitat disturbance driven by climate change (Yasuhara *et al*., 2008)

A significant proportion of Tom's work, in collaboration with Harry Dowsett, Gary Dwyer and others, has addressed Neogene to Recent climate change, one focus being the reconstruction of the globally warm mid-Pliocene ocean in order to furnish data for climate modelling of the causes of Pliocene and future warmth. A benchmark paper in *Science* (Dwyer *et al*., 1995) established the utility of Mg/Ca ratios of ostracod shells as a proxy for deep-ocean bottom-water temperatures (adapting a method originally developed in the context of nonmarine ostracods) and paved the way for innovative investigations and interpretations of Pliocene, Pleistocene and Holocene marine faunas (e.g., Cronin *et al*., 2000, 2003, 2005, 2010a). A *Nature* paper (Cronin & Raymo, 1997) showed for the first time that the diversity of deep-ocean benthos has varied on geological timescales related to glacial-interglacial cycles and ultimately linked to the 41,000 year obliquity cycle. Investigating Late Pliocene records from North Atlantic DSDP cores, they compared ostracod species diversity with ostracod Mg/Ca ratios and foraminiferal oxygen stable isotope ratios, respectively proxies for bottom-water temperature and global ice-volume. They showed that high deep-ocean biodiversity, far from indicating long-term environmental stability as some had thought, is relatively unstable and varies dynamically with orbitally induced changes in food supply and temperature; they found the diversity of abyssal benthonic ostracods to be markedly lower in glacials than in interglacials. Ostracod taxa (e.g., *Henryhowella*, *Bradleya* and some *Krithe* species) inhabiting the abyssal North Atlantic during interglacials may survive glacial intervals by shifting to bathyal environments, similar to the way in which shallow marine species shift their ranges poleward or equatorward in interglacials and glacials respectively.

In the last decade concerns about the rapid melting and disappearance of Arctic sea-ice have stimulated research on past variations in ice cover in relation to climate change. The marine ostracod *Acetabulastoma arcticum* is unusual in living not on the sea floor but commensally on pelagic amphipods associated with sea-ice, although its shells ultimately become part of benthonic assemblages; Cronin *et al*. (2010b) recognised and developed its potential as a proxy for sea-ice cover, finding support for the idea that much of the Arctic was seasonally ice-free only 6,000 years ago during an early Holocene thermal maximum.

Ostracods, having the most complete and abundant fossil record of any arthropods, are an ideal group with which to study the operation of evolutionary processes on geological timescales, particularly speciation in relation to tectonic and climatic changes. Studying the Miocene to Holocene marine ostracod *Hermanites transoceanica* from the Pacific and Caribbean sites, Tom found morphological stability among widely separated populations on oceanic islands (possibly indicating frequent passive dispersal events), leading to the conclusion that allopatric speciation should not be assumed in cases of geographical isolation of populations (Cronin, 1988). The rather extreme isolation of populations by the formation of the Panama Isthmus in the Pliocene, separating the Caribbean from the eastern Pacific, was found to have resulted in high speciation rates for some taxa, while for others (e.g., *Orionina*, *Puriana*) the isolation of small founder populations on islands seemed to a more significant factor (Cronin, 1987; Cronin & Schmidt, 1988; Cronin & Ikeya, 1990).

In summary, Tom Cronin has made major contributions to micropalaeontology and to the application of microfossils to environmental interpretation from the shelf to the deep sea, to our understanding of changing oceanographical and climatic patterns and to the linkages between them. Perhaps one of the clearest indications of Tom's reputation is that he was seconded to the White House Science Office during the Clinton Administration to help with US preparation for the Kyoto Climate Treaty. The most recent benchmark in his continuing career is the 2010 publication of the excellent book: *Paleoclimates: A Context for Climate Change*.

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